PHOTOELECTRIC OBSERVATIONS OF THE SYMBIOTIC STARS CH CYG, AG DRA AND PECULIAR OBJECT PU VUL DURING THE MAXIMUM OF THEIR ACTIVITY IN THE YEARS 1981 - 1982

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ABSTRACT. The photoelectric U, B, V observations of symbiotic stars CH Cyg, AG Dra and peculiar object PU Vul, performed during maximum of activity of all three object in the years 1981 - 1982 are published. Our observations show different kinds of short and long-term photometric variations.

ФОТОЭЛЕКТРИЧЕСКИЕ НАБЛЮДЕНИЯ СИМБИОТИЧЕСКИХ ЗВЕЗД CH ЛЕБЕДЯ, AG ДРАКОНА И ПЕКУЛИАРНОГО ОБЪЕКТА PU ЛИСИЧКИ ВО ВРЕМЯ ИХ МАКСИМАЛЬНОЙ АКТИВНОСТИ В 1981 - 1982 ГГ. В роботе опубликованы фотоэлектрические U, B, V наблюдения симбиотических звезд CH Лебедя, AG Дракона и пекулиарного объекта PU Лисички выполненые во время максимальной активности всех трех объектов в 1981 - 1982 гг. Наши наблюдения показывают разные роды коротко- и долгопериодических фотометрических изменений.

FOTOELEKTRICKÉ POZOROVANIA SYMBIOTICKÝCH HVIEZD CH CYG, AG DRA A PEKULIÁRNEHO OBJEKTU PU VUL POČAS MAXIMA ICH AKTIVITY V ROKOCH 1981 - 1982. V práci sú publikované fotoelektrické U, B, V, pozorovania symbiotických hviezd CH Cyg, AG Dra a pekuliárneho objektu PU Vul, prevedené počas maxima aktivity všetkých troch objektov v rokoch 1981 - 1982. Naše pozorovania

ukazujú rôzne druhy krátko- a dlho-periodických fotometrických zmien.

1. INTRODUCTION

In the optical region, symbiotic stars are characterized by the superposition of the cool absorption spectrum (usually M-type) and by blue continuum with strong emission lines. Symbiotic stars show irregular photometric variability on time scales of months or years (with amplitudes of up to 1^m) which can be described as a complex of small simultaneous flares. Occasionally larger increases of brightness - outbursts (with amplitudes of 2^m - 5^m) are present. In some cases, e.g. CH Cyg (Slovak and Africano, 1978), CI Cyg (Burchi et al., 1983), rapid variability on time scales of minutes and tenths of minutes is present, which can be destinguish as flickerings and small flares. A number of explanations have been proposed to explain the bizzare behaviour of symbiotic stars. The most promising is the binary star hypothesis, when mass flows from a large, cool giant towards the main sequence star or white dwarf. This star has accreted matter via the accretion disk or by wind. The main sources of the observed photometric variability is the variable mass transfer rate and (or) shell flashes onto the surface of the white dwarf (see Bath, 1977; Paczynski and Rudak, 1980).

The aim of this paper is to report on the photoelectric photometry of the symbiotic stars CH Cyg, AG Dra and peculiar object PU Vul, which characteristics resemble those of symbiotic stars and very slow novae. In the years 1981-82, when the measurements were performed, all these objects were at the maximum of their activity. In spite of different photometric behaviour, the mass transfer process between the components of the close binary system took place in all three objects

2. OBSERVATIONAL PHOTOMETRIC HISTORY

a./ CH Cygni

The behaviour of the light curve of the star CH Cyg was described by Cester (1969) and Duschl (1983). After the outburst in 1967, the V light curve showed nearly periodic variations between $6^m.5$ and $8^m.5$ on a typical time scale of about 700 days during the period 1968 - 1976. Since 1977, the brightness increased from $6^m.7$ nearly monotonically and reached $5^m.7$ - $5^m.8$ in the second quarter of 1982. Cester (1969) found that the light curve varied "irregularly" from night to night during the 1967 outburst. At the end of 1977, during the recent outburst, high-speed photometry with a time resolution of 2 - 4 seconds was performed by Slovak and Africano (1978). They found rapid photometric variations, which can be described by rapid flickering activity ($0^m.02$ - $0^m.04$) on time scales of 5 min. and slow large amplitude flares ($0^m.08$ - $0^m.10$) lasting 15 - 20 min. The amplitude of the variations

is largest in U and V filters. The activity increases towards the blue and is caused by the variable nature of the enhanced blue continuum. Rapid variability was also confirmed by Mikolajewska and Mikolajewski (1980) from observations performed in September 1980.

The conclusions about the nature of the system is influenced by the fact that no orbital period has sofar been definitely deduced from observations. From the analysis of the photometric behaviour, Duschl (1983) proposed a binary model with a cool star, filling the Roche lobe, of a few solar masses, which transfers the matter to an accretion disk around a main sequence star of about one solar mass. Slovak and Africano (1978) suggested a binary model including a subluminous hot companion accreting material from the stellar wind of an SRa variable.

b./ AG Dra

AG Dra is a "yellow" symbiotic star, because the spectral type of the cold component was classified as K0 Ib (Huang, 1982). The light curve of AG Dra resembles the light curve of the prototype Z And. Robinson (1969) distinguished several outbursts with long periods of relative quiescence lasting two or three decades. In quiescence, AG Dra exhibits variations in the U-band of about one magnitude with a period of 554 days (Meinunger, 1979; Oliversen and Anderson, 1982). The amplitudes in B and V bands are much weaker. According to Viotti et al. (1983), these variations may be due to eclipses of an extended optically thick region near the hot star by the cool component, or more probably by the reflection effect. New activity started after 25 years of quiescence in November 1980, when an optical brightening from $9^m.8$ to about $1^m.5$ in V was observed.

c./ PU Vul

There are some doubts about the classification of PU Vul, because of its very peculiar photometric and spectroscopic behaviour. The object is in the list of symbiotic stars published by Baratta and Viotti (1983), and Belyakina et al. (1984) classified it as a slow nova of the RT Serpentis type. The spectral type of the cool component is M6. PU Vul burst at the end of 1977, its brightness slowly increased to 9^m in V, which it reached in 1979. At maximum brightness, which lasted about one year, quasiperiodic oscillations with a period of 78 days and amplitude of $0^m.2$ in V were observed. At the beginning of 1980, a rapid decrease of PU Vul occurred. The brightness minimum ($V=13^m.6$) lasted a few month. In July, August and September 1982, three dips of brightness with small amplitudes occurred, as one can see from Fig. 9. Just after the third dip, the brightness increased by about $0^m.1$ in V and $0^m.7$ in U. More details about the photometric behaviour were published in (Chochol et al., 1981; Belyakina et al., 1982; Purgathofer and Schnell, 1982, 1983; Kolotilov, 1983).

3. OBSERVATIONS AND DISCUSSION

The data were obtained by single-channel photoelectric photometers installed in Cassegrain focus of 0.6 m telescopes at the Skalnaté Pleso (SP) and Brno (B) Observatories in Czechoslovakia and at the Rozhen Observatory in Bulgaria.

a./ CH Cyg

The data for the comparison stars and CH Cyg are in Table 1.

Table 1.

	Star	R.A.$_{1950.0}$	Decl.$_{1950.0}$	V	B - V	U - B	Sp
Comparison	HD 184 786	$19^h32^m18^s.5$	$+49^\circ08'27''$	5.91	+1.62	+1.74	M
Check	HD 183 298	19 25 04.8	+50 53 02.8	8.11	+0.58	+0.09	G0
CH Cyg	HD 182 917	19 23 14	+50 08 27				M6

The magnitude and colours of the check star were adopted from Cester (1969), the magnitude and colours for the comparison star were determined by us. The comparison star is satisfactorily constant. Our U, B, V observations of CH Cyg are in Table 2. Every value represents the average of observations made during one night. The letter "n" designates the number of individual observations included. The results are shown in Fig. 1. Our photometric observations were made in the period of maximum brightness of CH Cyg during the recent outburst. At the end of 1982, the brightness of CH Cyg reached the value $5^m.6$ in V, which had not been observed during the whole known photometric history of this star. The decrease of the B - V index in 1982 in comparison with 1981 shows that the blue continuum brightened. While the slow variability is lower than in the pre-outburst period, the rapid variability is very high. For four nights, when more observations were obtained, individual observations are given in Fig.2. For a more detailed study of rapid variations we observed the star with a higher time resolution (integration time 10 seconds) at the Rozhen Observatory in October and November 1982. The journal of observations is in Table 3. Figures 3. - 6. show the nature of rapid variability. The U light curve is characterized by flickering activity ($0^m.08$ - $0^m.11$) on a time scale of 3 - 5 min. and flares with an amplitude of $0^m.15$ on a time scale of 15 - 20 min. The amplitude of variations found in this work are greater compare to the results published by Slovak and Africano (1978), as one can see from Fig. 6., a slow variability on a time scale of hours and amplitudes of $0^m.3$ in U and of $0^m.2$ in V were observed. Longer observations during night-runs are necessary to established the time scale of these variations.

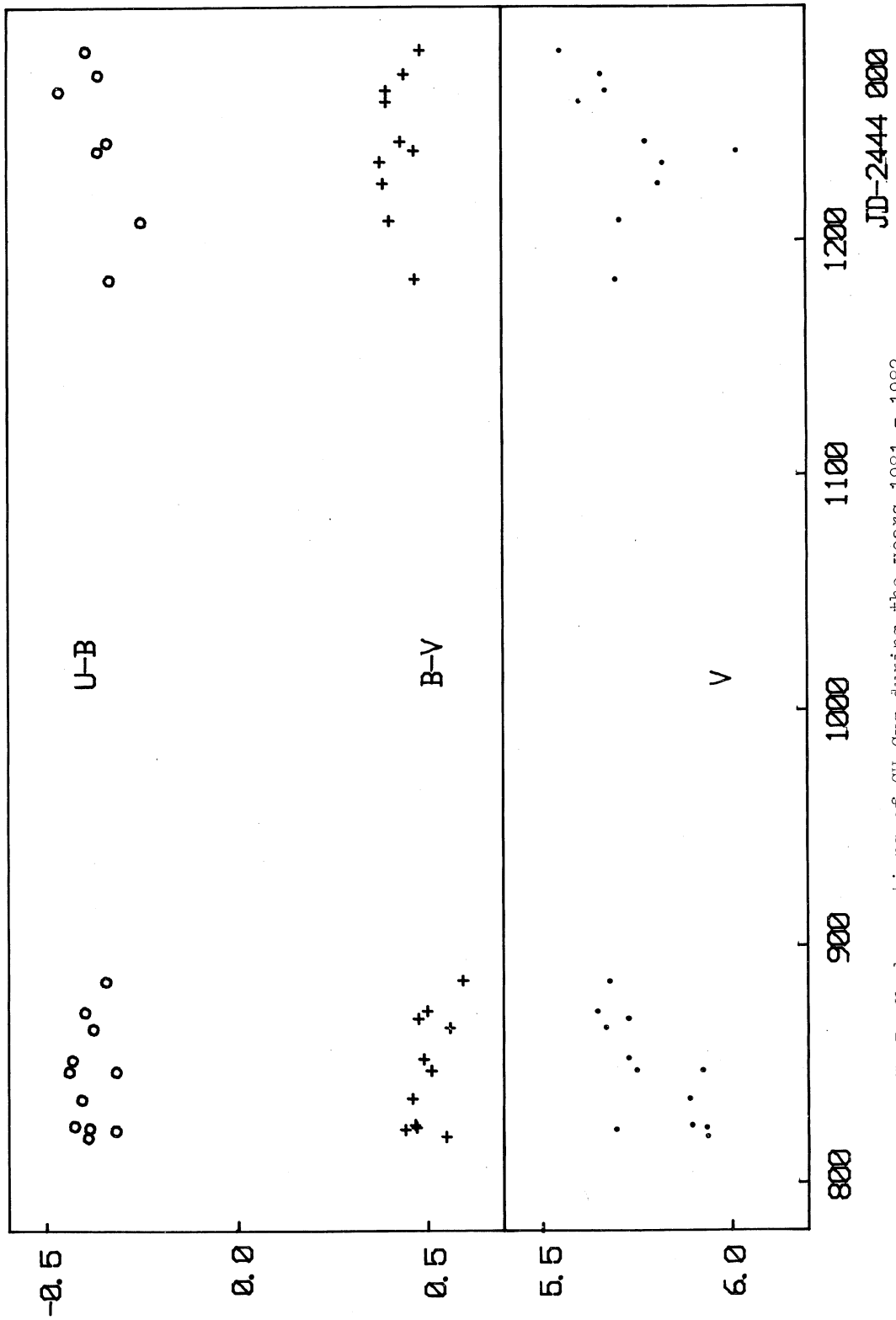

Fig. 1. U, B, V observations of CH Cyg during the years 1981 - 1982.

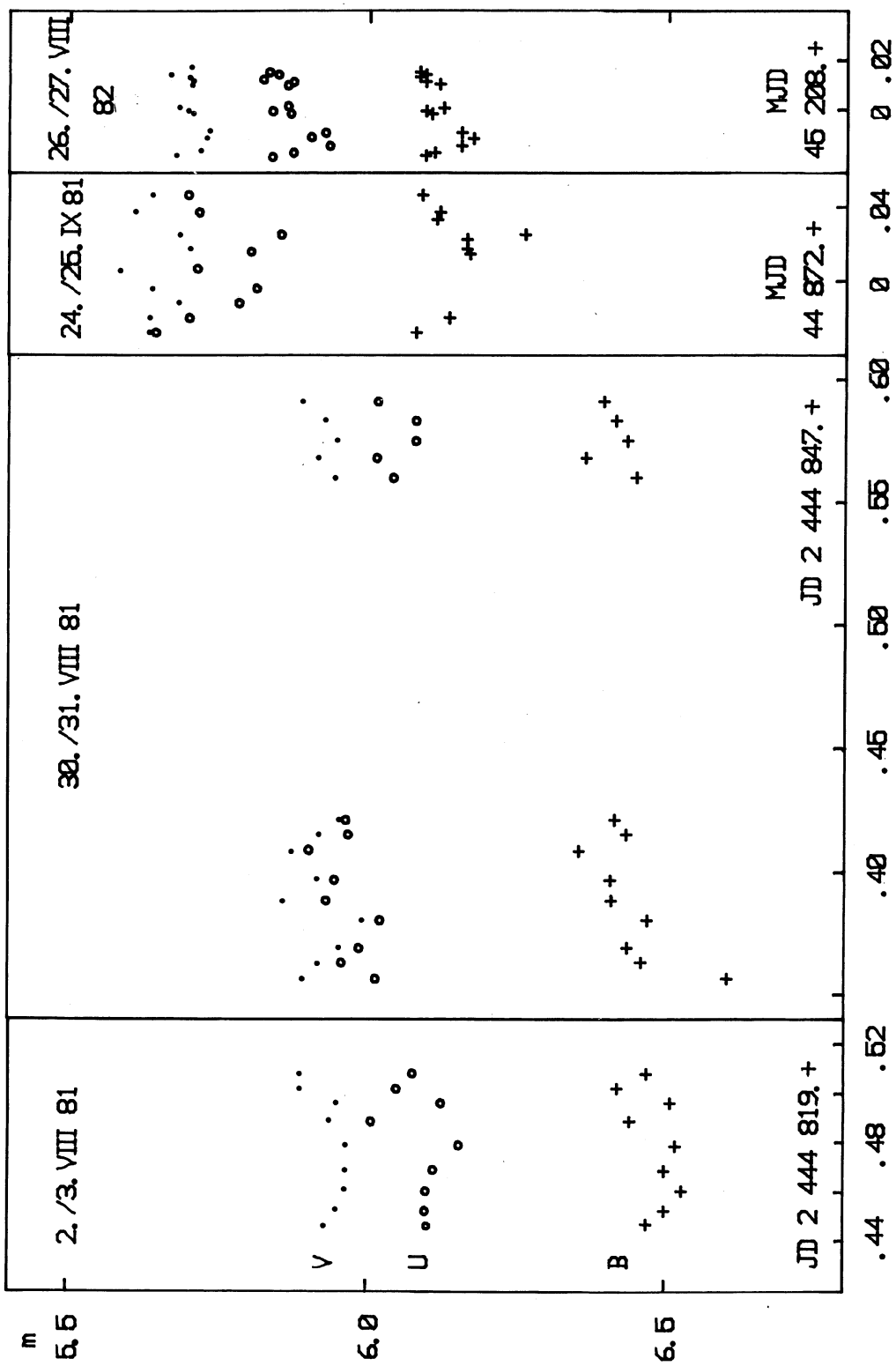

Fig. 2. U, B, V observations of CH Cyg for four nights, when more observations were obtained.

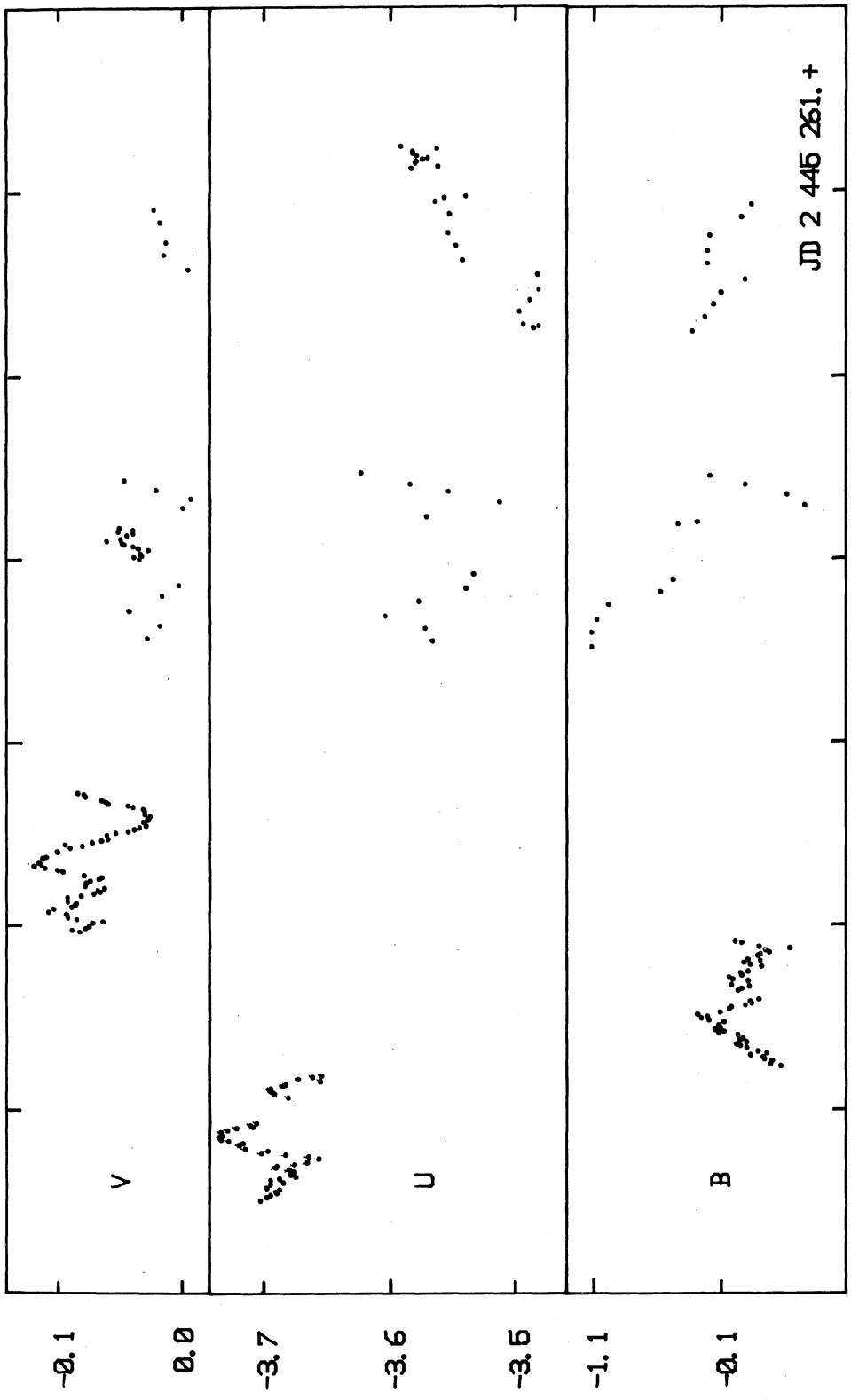

Fig. 3. Rapid variability of CH Cyg in instrumental system.

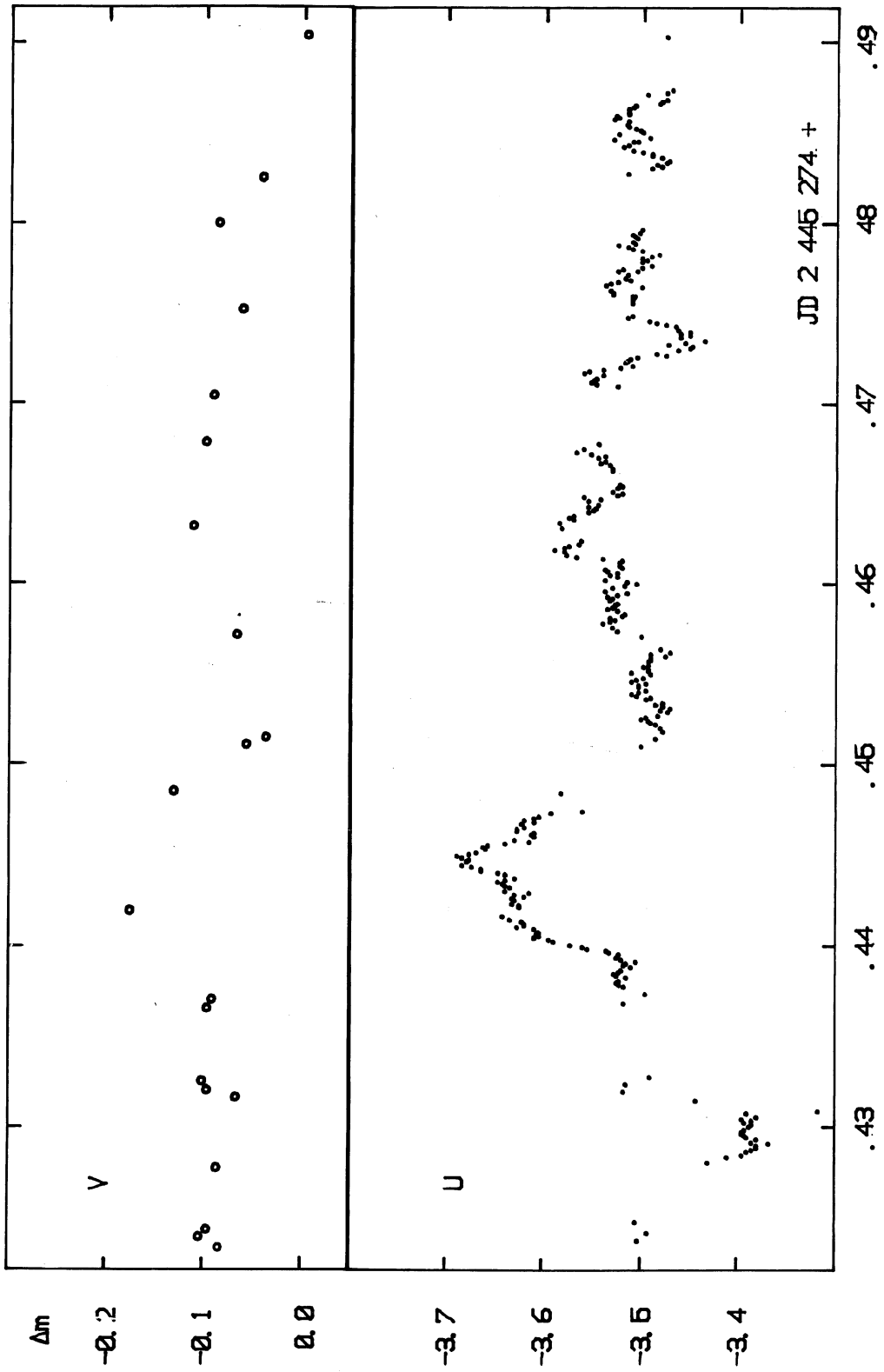

Fig. 4. Rapid variability of CH Cyg in instrumental system.

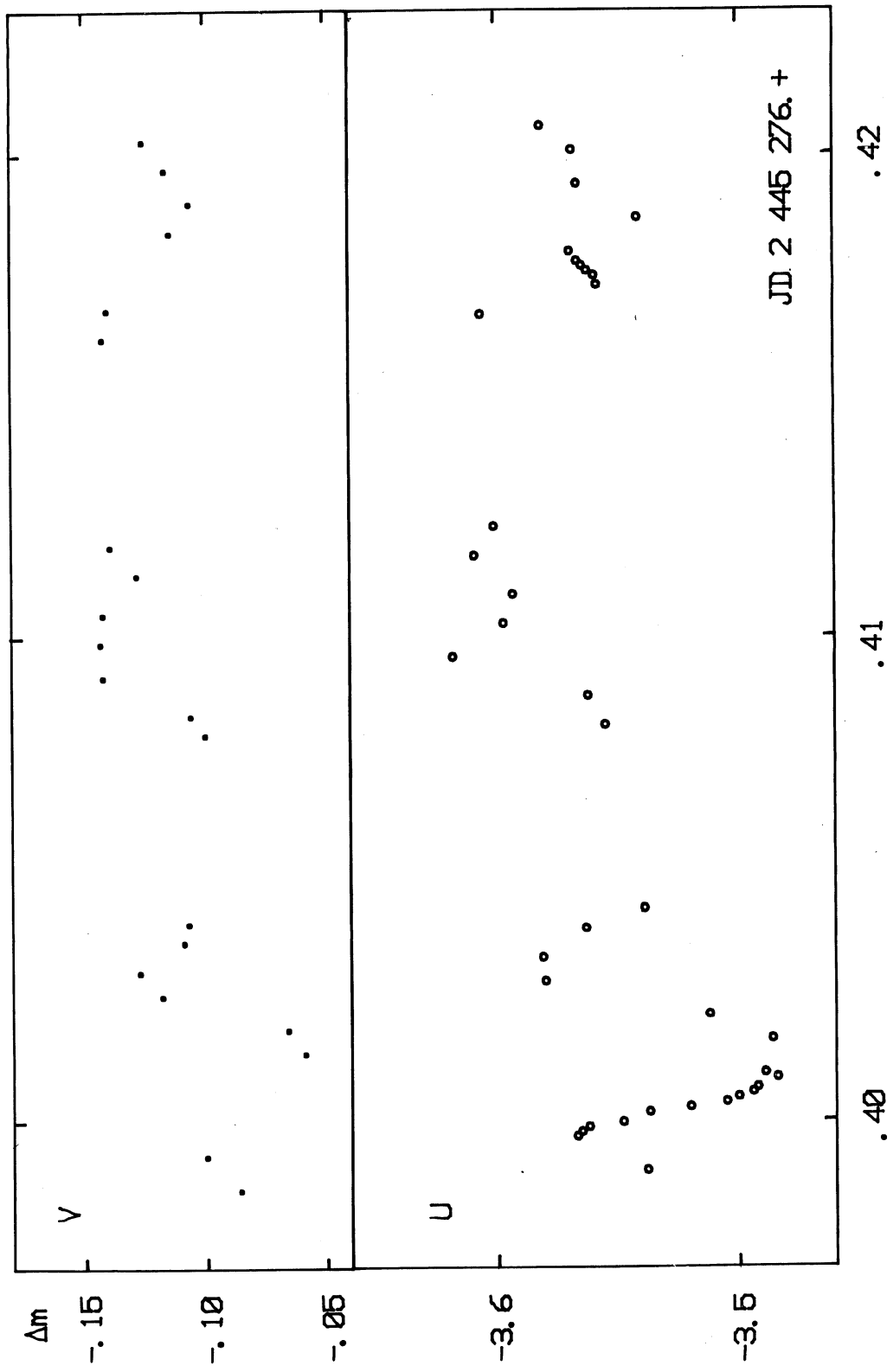

Fig. 5. Rapid variability of CH Cyg in instrumental system.

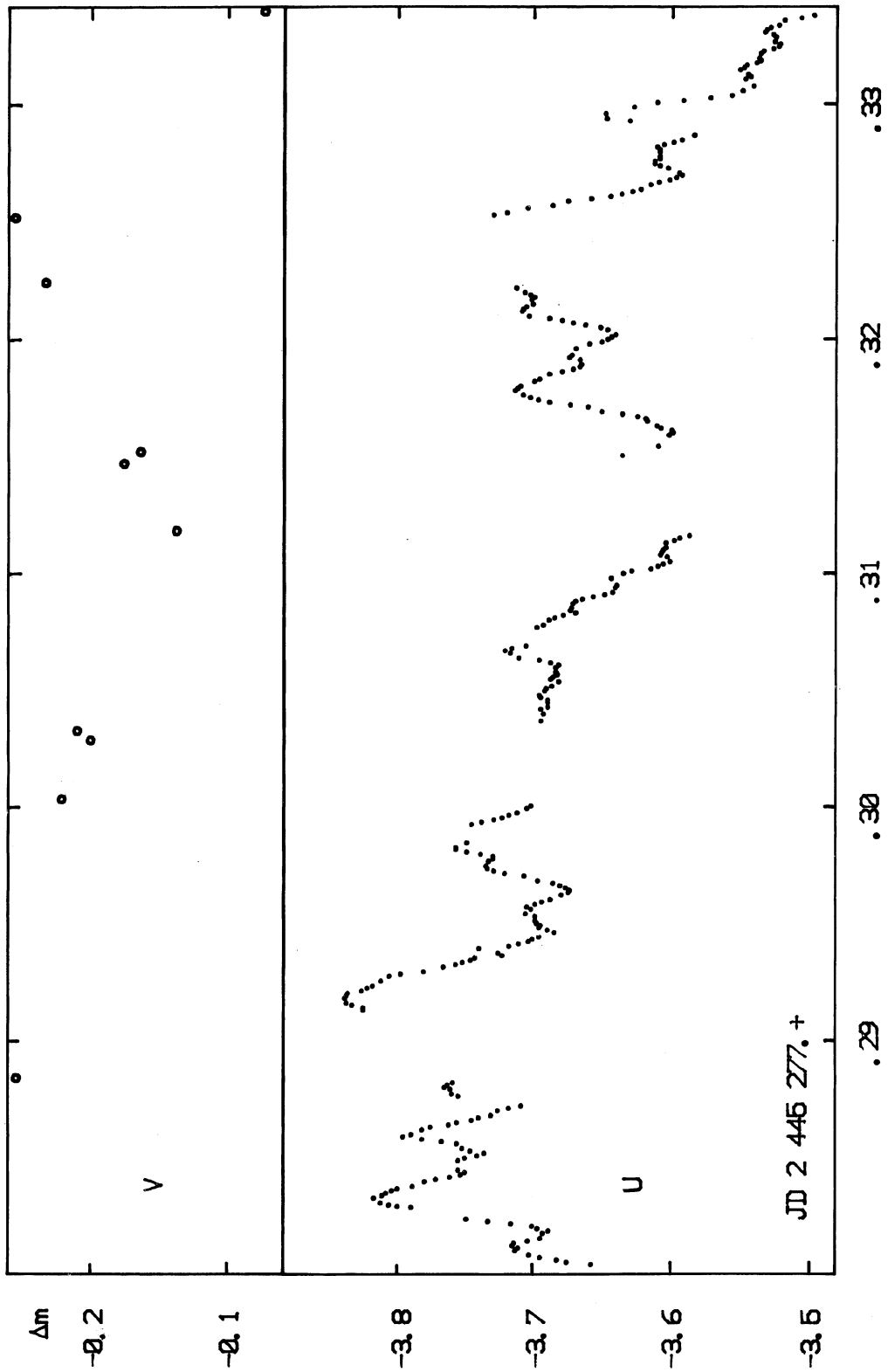

Fig. 6. Rapid variability of CH Cyg in instrumental system.

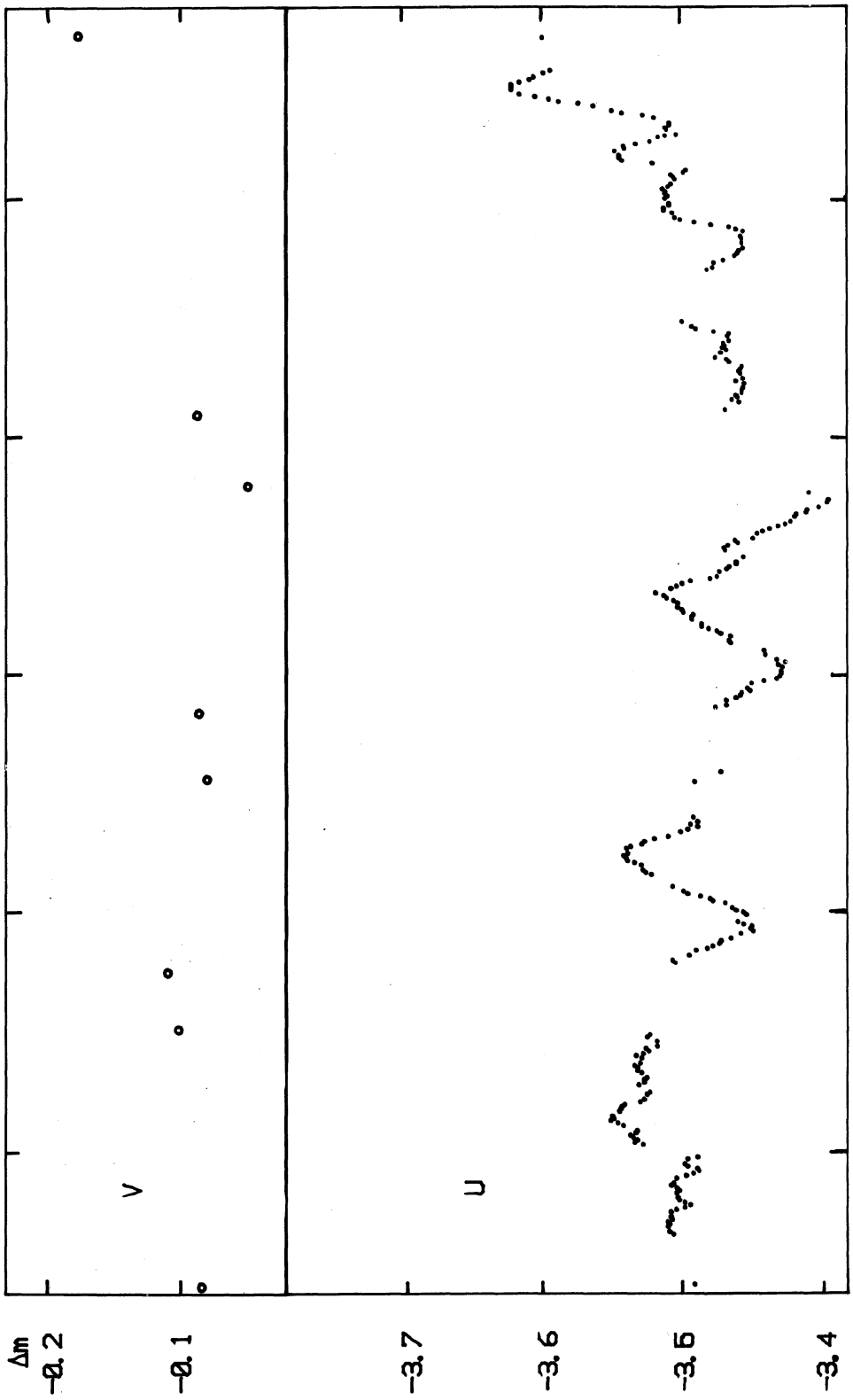

Fig. 6. (continued) Rapid variability of CH Cyg in instrumental system.

Table 2.

J. D. hel	V	B - V	U - B	n	observatory
2 444 819.48	5.939	.547	-.389	9	SP
4 822.42	5.696	.440	-.316	3	B
4 823.44	5.953	.470	-.385	5	SP
4 824.39	5.896	.466	-.425	7	SP
4 835.59	5.891	.459	-.406	2	SP
4 847.39	5.750	.508	-.315	3	B
4 847.47	5.924	.509	-.438	14	SP
4 852.31	5.730	.490	-.430	2	B
4 865.54	5.669	.557	-.375	3	SP
4 869.38	5.730	.475	-	2	B
4 872.51	5.648	.498	-.397	9	SP
4 885.33	5.680	.592	-.342	2	B
5 183.40	5.699	.470	-.329	2	B
5 208.50	5.710	.404	-.245	13	SP
5 224.39	5.812	.388	-	2	B
5 233.34	5.825	.381	-	1	B
5 238.46	6.018	.468	-.359	4	SP
5 242.32	5.777	.433	-.335	2	B
5 259.36	5.603	.397	-	3	B
5 264.22	5.673	.397	-.461	4	SP
5 271.26	5.660	.442	-.358	6	SP
5 281.28	5.551	.484	-.391	5	SP

Table 3.

Date	J. D. hel start	J. D. hel end	Duration (hour)
Oct. 18 / Oct. 19, 1982	2 445 261.	.4850 - .5424	1.377
Oct. 31 / Nov. 1, 1982	2 445 274.	.4232 - .4906	1.617
Nov. 2 / Nov. 3, 1982	2 445 276.	.3986 - .4206	0.526
Nov. 3 / Nov. 4, 1982	2 445 277.	.2567 - .3870	3.126

b./ AG Dra

Our U, B, V observations of AG Dra were performed at the Skalnaté Pleso Observatory. The data for the comparison stars and AG Dra are in Table 4.

Table 4.

	Star	R.A.$_{1950.0}$	Decl.$_{1950.0}$	V	B - V	U - B	Sp
Comparison	BD^{o} +67 925	$16^{h}05^{m}03^{s}$	+66°54'58"	9.88	+0.56	-0.04	
Check	HD 145 454	16 06 07.9	+67 54 02	5.44	-0.02	-0.08	A0
AG Dra	BD^{o} +67 922	16 01 23.5	+66 56 24				K0

Magnitudes and colours of the comparison stars were adopted from Blanco et al. (1968). The photometric observations of AG Dra are in Table 5. and Fig. 7.

Table 5.

J. D. hel	V	B - V	U - B	n	J. D. hel	V	B - V	U - B	n
2 444 660	9.057	.658	-.738	9	2 444 912	8.741	.465	-.829	6
661	9.059	.623	-.722	6	926	8.771	.485	-.866	5
663	9.065	.659	-.777	4	995	8.984	.498	-.903	10
667	9.037	.624	-.771	7	2 445 006	9.107	.650	-.825	10
681	9.138	.693	-.775	5	017	9.074	.598	-.808	15
686	9.153	.671	-.791	5	043	9.171	.687	-.802	6
687	9.159	.737	-.796	5	062	9.167	.761	-.767	5
692	9.201	.667	-.853	5	076	9.281	.770	-.783	5
745	9.399	.843	-.715	3	103	9.392	.831	-.618	5

The letter "n" designates the number of individual observations. Our observations of AG Dra started in February 1981 during the decline of brightness after the outburst in November 1980. As one can see from Fig. 7., the second outburst occurred in the middle of the year 1981. The amplitude of the outburst was the highest in the U region.

c./ PU Vul

Our U, B, V observations of PU Vul were performed at the Brno Observatory. The data for the comparison stars are in Table 6. The same stars as in (Chochol et al., 1981) were used. The photometric observations of PU Vul are in Table 7. and Fig. 8. The letter "n" designates the number of individual observations. Our observations confirm the peculiar behaviour of the bright-

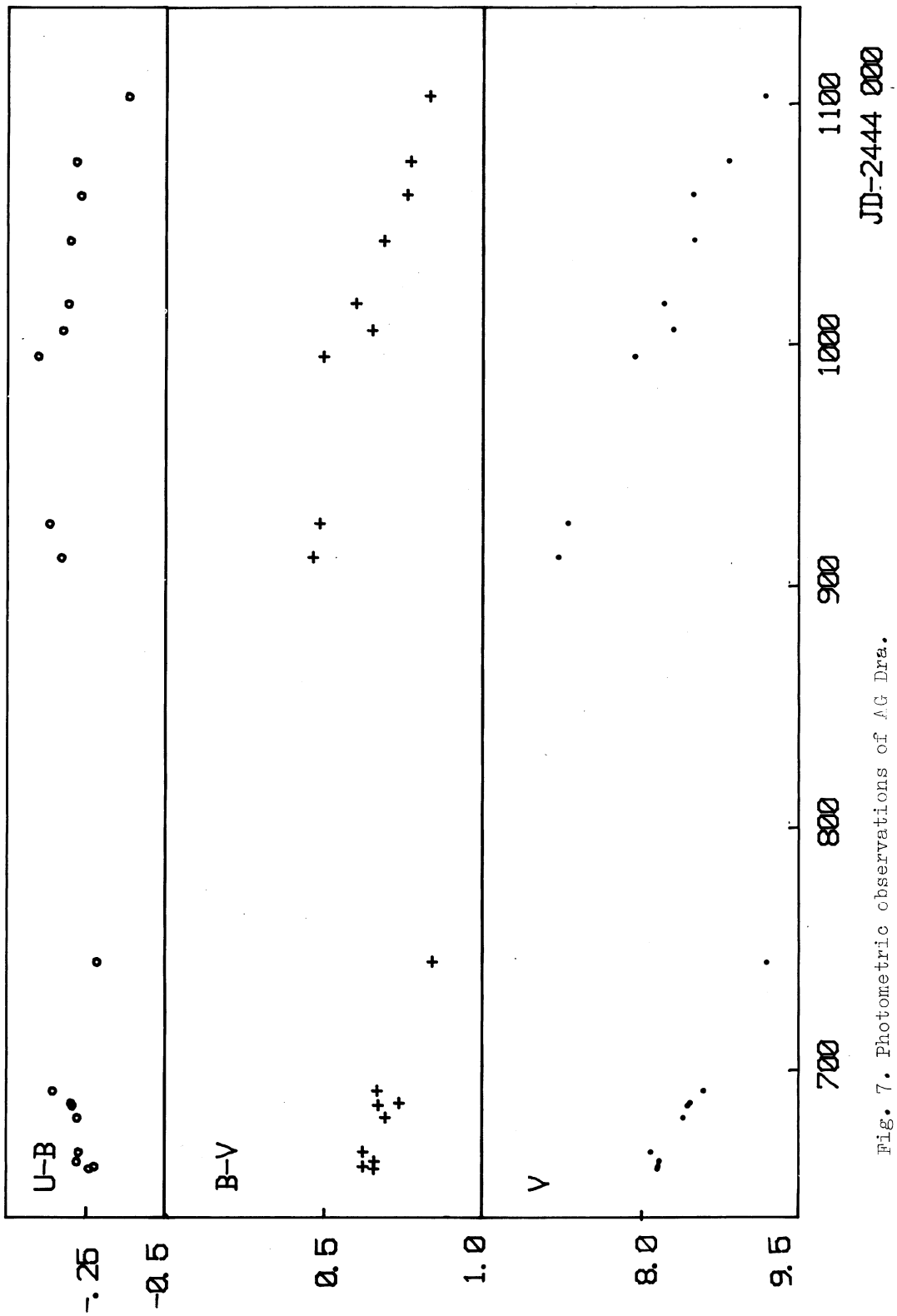

Fig. 7. Photometric observations of AG Dra.

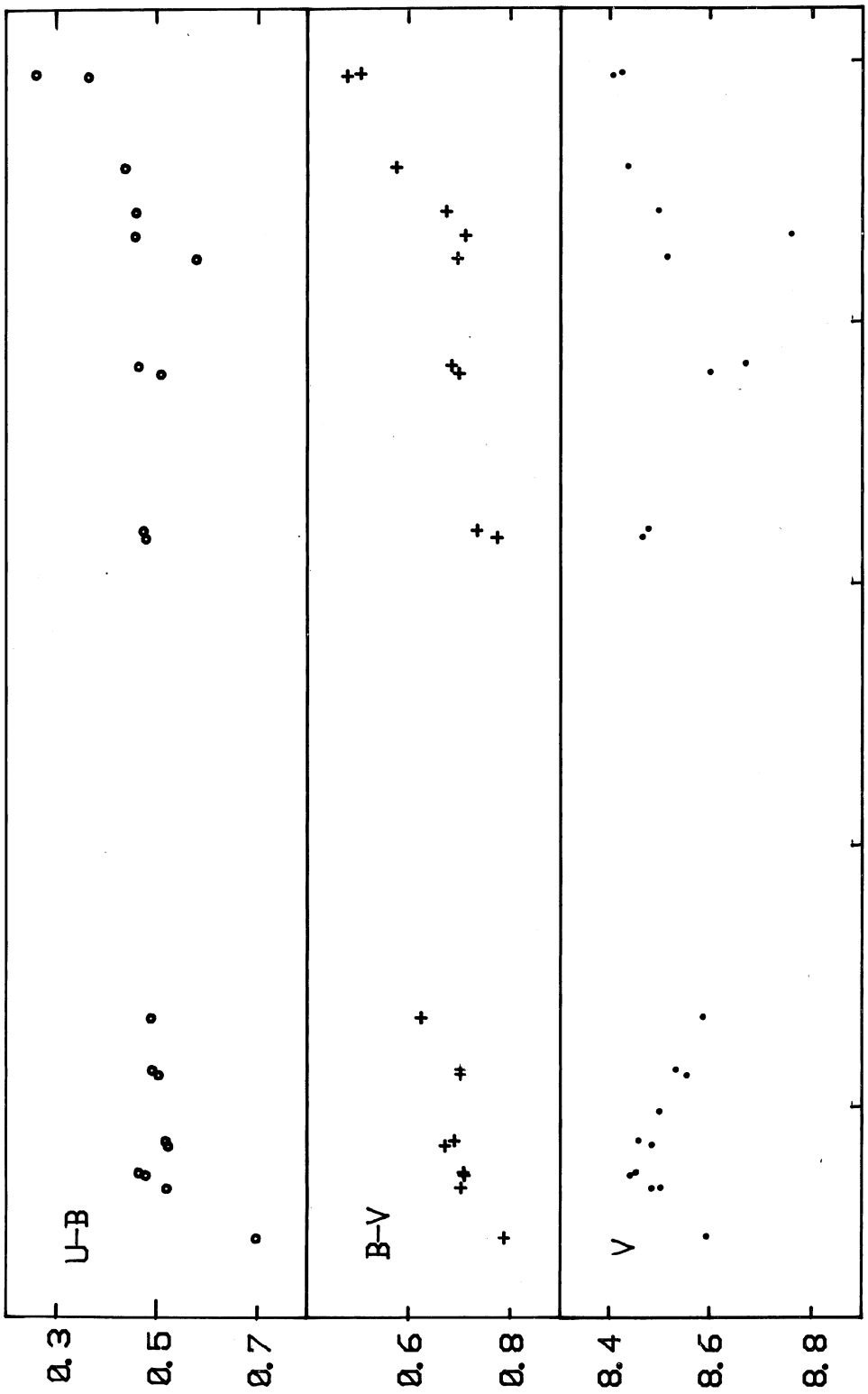

Fig. 8. Photometric observations of PU Vul.

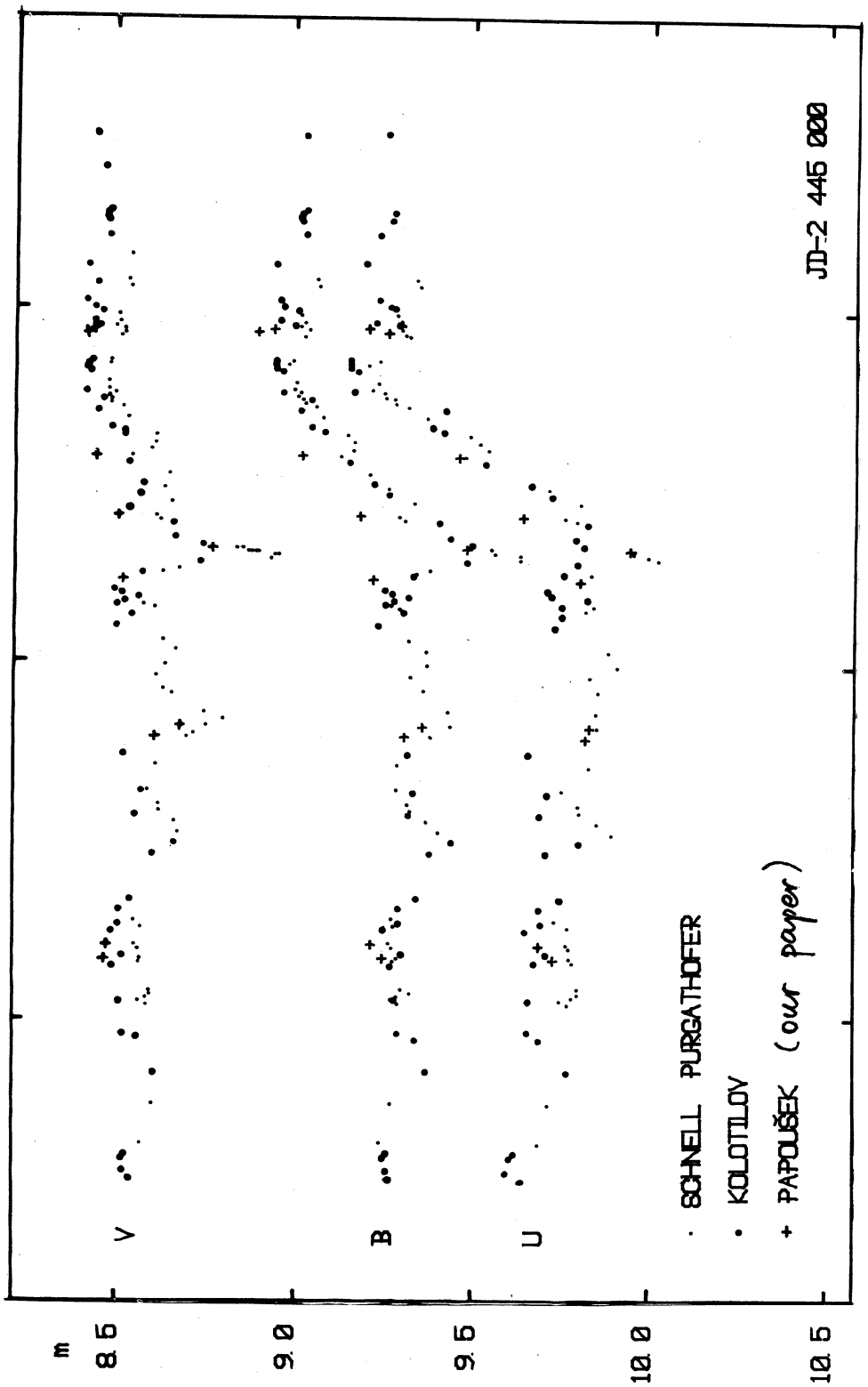

Fig. 9. Photometric observations of PU Vul during the year 1982 from Kolotilov, Papoušek, Schnell and Purgathofer.

ness of PU Vul in the second half of 1982, as described in Section 2.

Table 6.

	Star	R.A.$_{1950.0}$	Decl.$_{1950.0}$	V	B - V	U - B	Sp
Comparison	HD 194 011	$20^h20^m22^s.3$	$+21^\circ38'43''.7$	8.33	+1.24	+1.15	K0
Check	BD $21^\circ4165$	20 18 37.9	+21 23 42.6	9.23	+0.51	-0.01	
PU Vul		20 19 01.1	+21 24 43.1				

Table 7.

J. D. hel	V	B - V	U - B	n	J. D. hel	V	B - V	U - B	n
2 444 869.31	8.486	.703	.521	5	2 445 117.45	8.465	.775	.480	3
869.36	8.500	-	-	17	121.46	8.475	.735	.475	3
874.30	8.440	.710	.480	11	180.42	8.600	.700	.510	6
875.28	8.452	.708	.465	5	183.44	8.670	.685	.465	2
885.31	8.484	.672	.524	6	224.36	8.513	.697	.580	7
887.34	8.455	.691	.519	7	233.31	8.760	.712	.458	7
898.27	8.498	-	-	3	242.30	8.495	.675	.460	6
912.27	8.553	.702	.505	7	259.31	8.435	.577	.438	4
914.27	8.532	.702	.492	4	294.23	8.405	.480	.365	4
934.26	8.585	.625	.490	4	295.25	8.423	.507	.260	5

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