

Photometry of symbiotic stars – an international campaign VI.

Z And, EG And, V1413 Aql (AS 338), R Aqr, UV Aur,
TX CVn, T CrB, BF Cyg, CH Cyg, CI Cyg, V 1016 Cyg,
AG Dra, CQ Dra (4 Dra), YY Her, V 443 Her, SS Lep,
AG Peg, AX Per, PU Vul

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Abstract. We present new observations of 19 symbiotic and symbiotic-like stars. Photoelectric UBV(R) observations cover the 1993.75 to 1994.75 period. The main results can be summarized as follows: Z And: the visual light curve (LC) indicates a quiet stage of the star. EG And: The primary minimum at JD 2449 230 was observed. V 1413 Aql: The recent outburst has probably finished. UV Aur: Historical photographic LC from 1895 December to 1963 March is presented. It suggests changes in the periodicity of the brightness variation being approximately between 395 and 360 days. TX CVn: A slow gradual decrease in the star's brightness is observed. Historical photographic LC from 1906 May to 1992 March is presented. It indicates an increase in the activity approximately at JD 2434 000. T CrB: Observations indicate a decrease of brightness mainly in U. BF Cyg: The star has returned to quiescence. Historical photographic LC from 1896 October to 1992 September is presented.

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CH Cyg: A gradual increase of the blue continuum during the current outburst is observed. CI Cyg: The primary minima and a complex behavior around the orbital phase 0.5 are seen in the recent visual LC. V1016 Cyg: No significant changes in the UBV continuum are observed. AG Dra: The bright outburst which began in 1994 June was discovered. CQ Dra: It was achieved the complete coverage of the orbital cycle within CQ Dra A+B during this observing season. YY Her: The minimum, probably corresponding to the eclipse of the hot by the cool component in the binary, is observed in the visual LC at JD 2 449 511. V443 Her: Visual LC shows the periodic wave-like variation along the orbital cycle ($\Delta m \sim 0.3$) modulated with a variability of the red giant. SS Lep: Two minima separated by ≈ 830 days are seen in the visual LC. AX Per: A major part of the broad primary minimum is observed. PU Vul: The eclipse of the hot by the cool component was indicated best in B and V.

Key words: stars - binaries - symbiotic - photometry

1. Introduction

This is the sixth paper of the series presenting the results compiled as a part of the campaign of long-term photometry of symbiotic stars (Hric & Skopal, 1989). It represents the continuation of the previous campaign's contributions (Skopal *et al.*, 1990 - Paper I, Hric *et al.*, 1991 - Paper II, Skopal *et al.*, 1992 - Paper III, Hric *et al.*, 1993 - Paper IV, Hric *et al.*, 1994 - Paper V).

2. Observations

Photoelectric UBV(R) observations were performed at the Skalnaté Pleso Observatory (hereafter SP in Tables), at the Stará Lesná Observatory (SL), at the Hlohovec Observatory (H), at the Kryonerion Station of the National Observatory of Athens (K) and at the Bucharest Observatory (BU). The observations carried out at the Skalnaté Pleso Observatory, at the Stará Lesná Observatory, at the Kryonerion Station of the National Observatory of Athens were performed in the same way as described in Paper II and III.

The observations at the Hlohovec Observatory were performed with one-channel photoelectric photometer installed in the Cassegrain focus of the 0.6/7.5 m reflector. The photometer is equipped with an EMI 7147/6094B photomultiplier. The signal was recorded using line recorder TZ 4620.

The observations at the Bucharest Observatory were performed with 0.5 m telescope using the standard UBV system.

New photoelectric observations of the current campaign period were made between October 1, 1993 and September 30, 1994.

Photographic data were taken by method of visual estimates on photographic plates from collection of the Sternberg Institute. The 10 cm and 16 cm telescopes were used for observations in a range of JD 14000 to 35000. Later observations

were made with a 40 cm astrograph of the Crimean Observatory of the Sternberg Institute. Unsensitized plates without filters were used. The measurements, taken with the 40 cm astrograph, are more uniform and close to B of the Jonson system. The magnitude of comparison stars and the finding charts were taken from Wachman (1961) and Shaganyan (1979).

Visual observations were collected by the members of Association Francaise des Observateurs d'Etoiles Variables - AFOEV (coordinator E. Schweitzer).

3. Results

The results for all the observed objects have been summarized in tables (UBVR photoelectric) and depicted in figures, if they exhibited an interesting behavior and/or provided a large amount of data (visual photometry). Individual stars are arranged in alphabetic order, and described in subsections.

3.1. Z Andromedae

Only visual observations were available for this star. The data covering the period 1991 September to 1994 September are shown in Figure 1. The LC indicates that the star is still in a quiet stage.

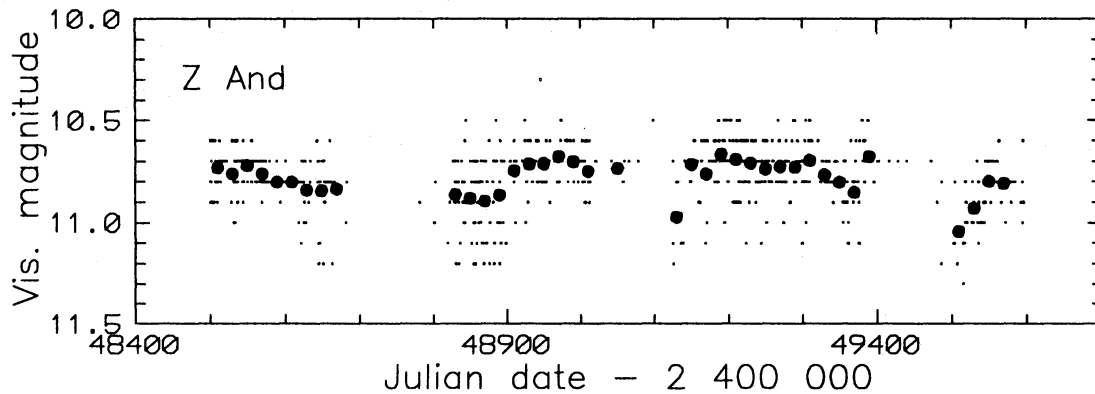


Figure 1. Visual observations of Z And. Full circles: 20-day means of the original data in the intervals containing more than 5 individual observations (20/5). Dots: all individual estimates.

3.2. EG Andromedae

UBV(R) photoelectric observations were carried out during 14 nights. The standard stars S_1, S_2, S_3 are the same as used in the Paper II, and S_4 as in the Paper III. The results are compiled in Table 1, in which differential magnitudes of EG And with respect to the S_1 star are presented. The data cover a part of the ascending branch of the primary minimum at JD 2 449 230. This minimum is

very good seen in the visual LC (Figure 3). Figure 2 displays UBVR observations made between 1992 November and 1994 September.

Table 1. UBVR observations of EG And

JD_{hel}	ΔU	ΔB	ΔV	ΔR	Obs
-2 400 000					
49261.547	-1.543	-1.246	-1.266		SP
49266.532	-1.488	-1.192	-1.262		SP
49272.417		-1.317			K
49273.527		-1.493			K
49274.562		-1.527			K
49275.564		-1.243			K
49276.570		-1.332			K
49278.545		-1.367			K
49279.526		-1.270			K
49285.646	-1.483	-1.355	-1.442		SP
49287.462	-1.573	-1.362	-1.427		SP
49288.507	-1.543	-1.325	-1.407		SP
49311.579		-1.266	-1.330		SP
49563.485		-1.377	-1.444	-1.540	SP

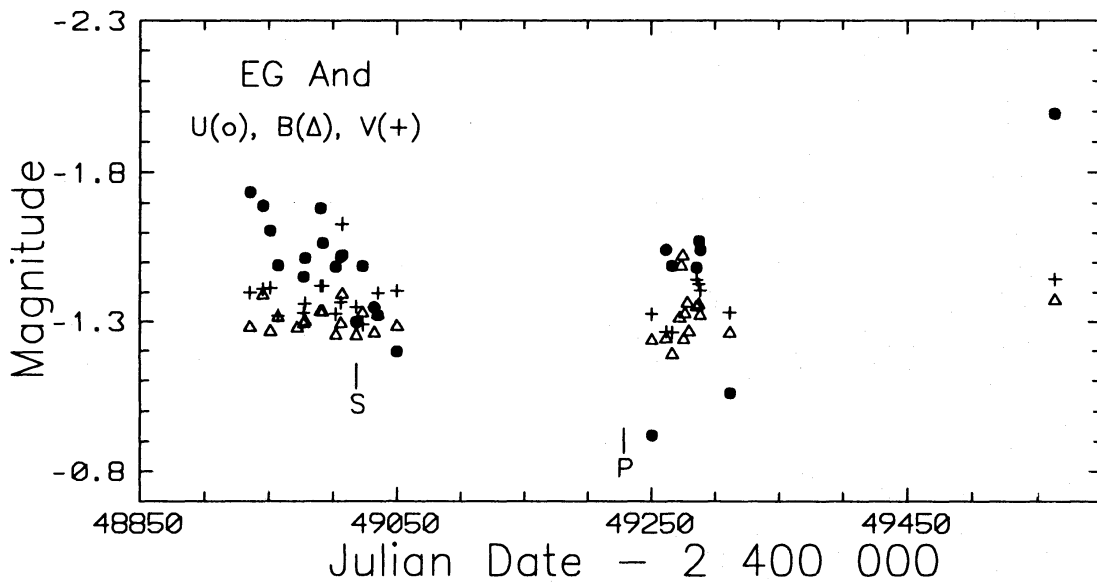


Figure 2. UBVR observations of EG And during the 1992 November to 1994 September period. Position of the primary (P) and the secondary (S) minimum is marked.

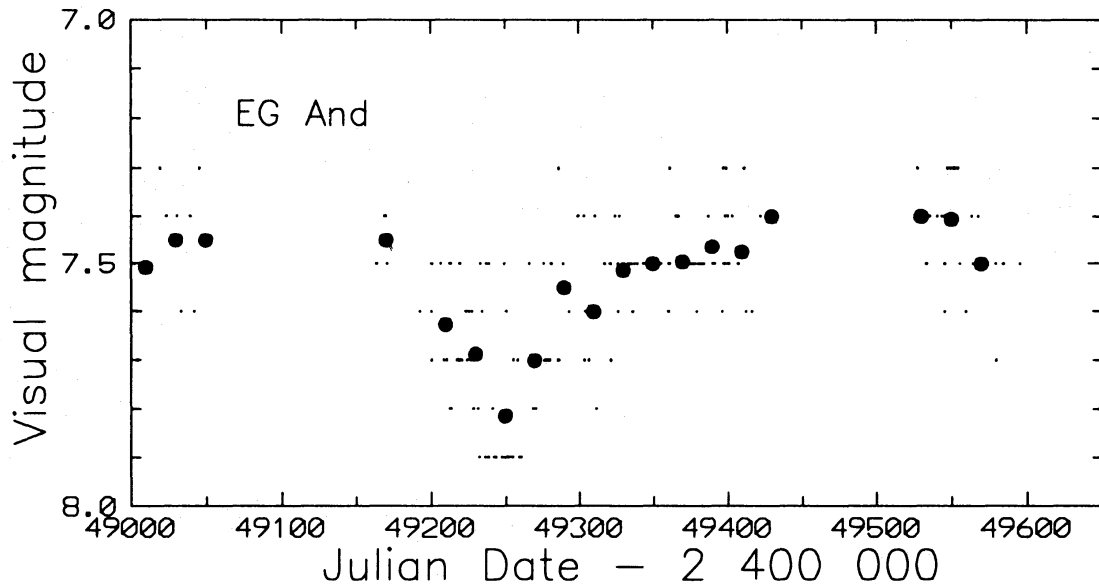


Figure 3. Visual observations of EG And. Denotation as in Fig. 1, but 20/2.

3.3. R Aquarii

Recent visual observations are plotted in Figure 4. The data represent the well known Mira-like behavior of the cool component in this symbiotic system.

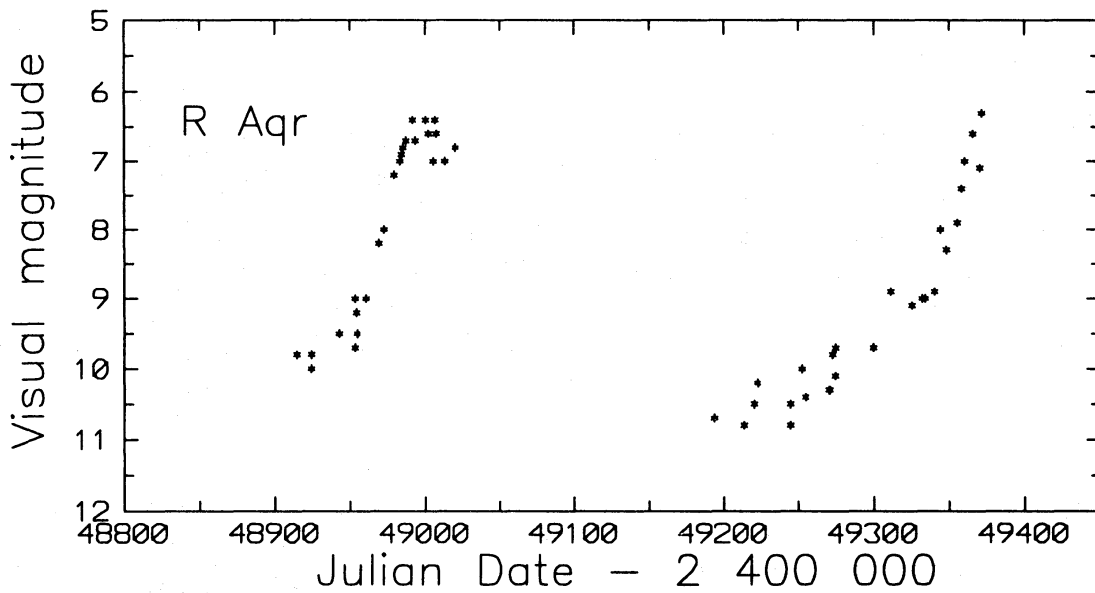


Figure 4. Visual observations of R Aqr

3.4. V 1413 Aquilae (AS 338)

The visual observations of this star are shown in Figure 5. They indicate a small outburst which began about at JD 2449250 and probably finished at \sim JD 2449500. However, new observations are needed to confirm whether this is the end of the outburst or an eclipse-like effect.

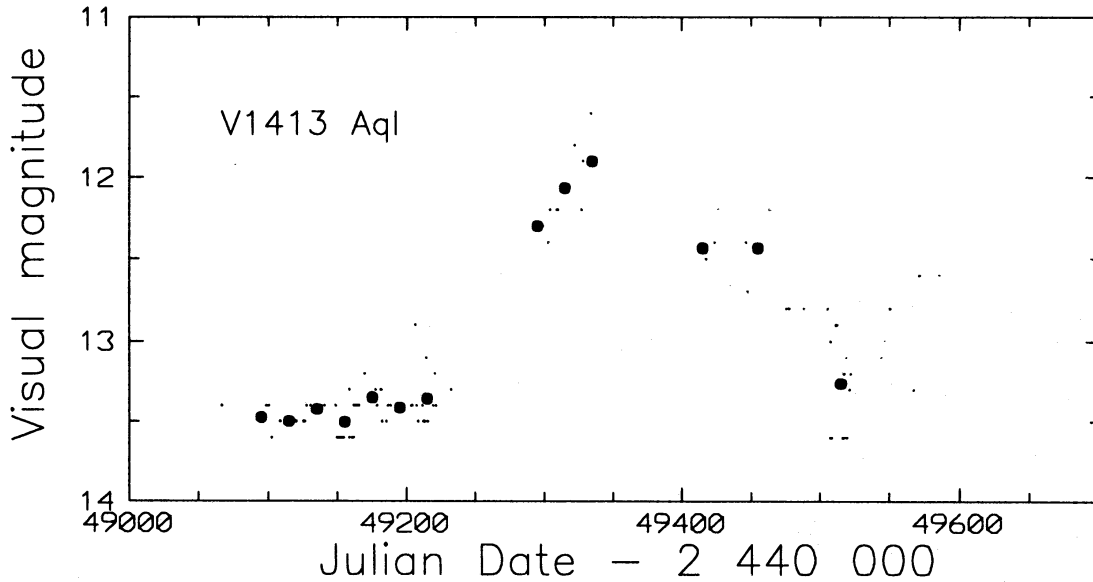


Figure 5. Visual observations of V 1413 Aql. Full circles are 20/2 day means

3.5. UV Aurigae

The photoelectric observations of this star were obtained on 16 nights. The results are compiled in Table 2 and depicted in Figure 6. Observations determine well the maximum of the star's brightness, but the minima are poorly defined.

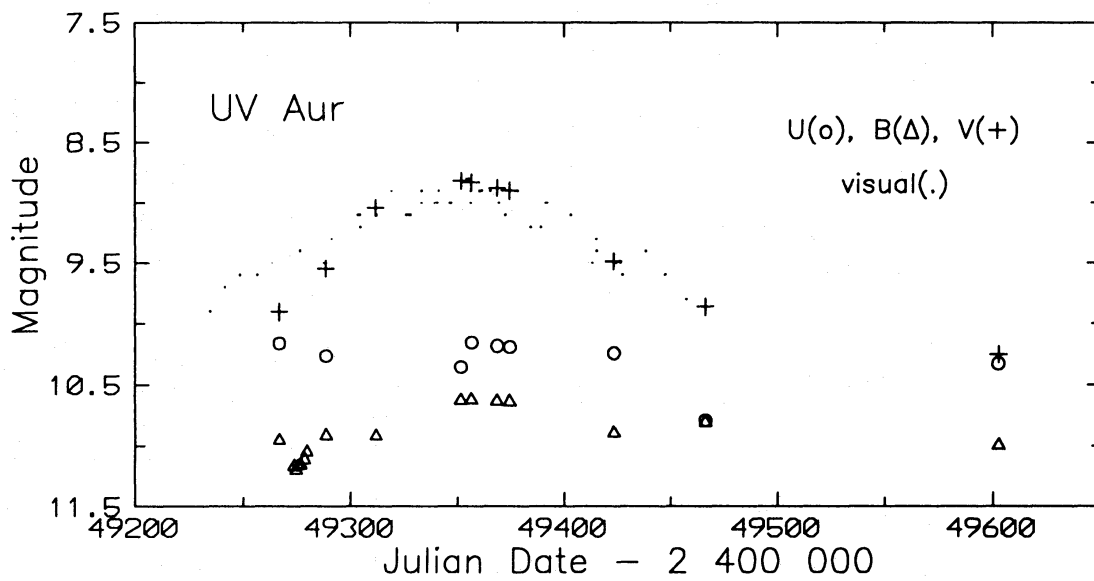
The photographic observations were obtained on 211 nights from JD 2413544 (1895 December) to JD 2438115 (1963 March). The results are summarized in Figure 7. These data are available on request. The period analysis of the data between JD 2428784 and JD 2438115 gave the best period of 394 days. This result suggests changes in the periodicity of the brightness variations (cf. Paper II, III, IV).

3.6. TX Canum Venaticorum

The photoelectric photometry of this star was carried out on 11 nights. The standard stars are the same as used in Paper II. Observations are summarized in Table 3. Figure 8 shows the UBV LCs compiled from the data published in Papers II, III, IV, V and this one, but observations in the V band made at the

Table 2. UBVR observations of UV Aur

JD_{hel}	U	B	V	ΔR	Obs
-2 400 000					
49266.577	10.162	10.939	9.906		SP
49273.605		11.153			K
49274.640		11.184			K
49275.599		11.150			K
49276.611		11.141			K
49278.597		11.098			K
49279.555		11.033			K
49288.464	10.265	10.900	9.550		SP
49311.662		10.902	9.044		SP
49351.565	10.354	10.616	8.822		SP
49356.538	10.157	10.608	8.830		SP
49368.520	10.183	10.618	8.880		SP
49374.480	10.191	10.623	8.900		SP
49423.333	10.242	10.877	9.488	-2.502	SP
49466.305	10.788	10.791	9.864	-1.922	SP
49602.588	10.328	10.979	10.254	-1.790	SP

**Figure 6.** UBVR observations of UV Aur

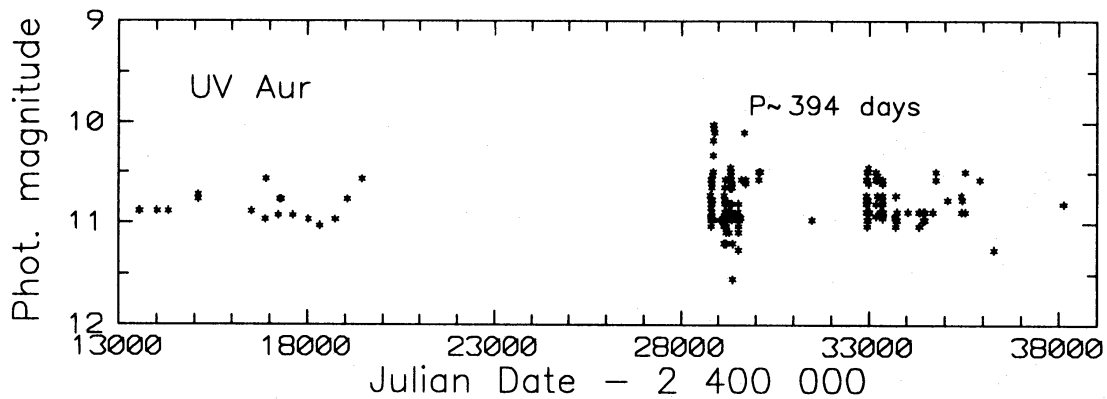


Figure 7. Photographic observations of UV Aur

Kryonerion station were omitted. The visual LC, 20-day means, fits perfectly the photoelectric V data. A gradual decrease in the star's brightness is observed.

The photographic observations were made on 77 nights from JD 2417344 (1906 May) and JD 2448690 (1992 March). The data are available on request. They are depicted in Figure 9. The data indicate an increase in the activity approximately at JD 2434000 continued up to now.

Table 3. UBVR observations of TX CVn

JD_{hel}	U	B	V	ΔR	Obs
-2400000					
49128.350		10.553	9.978		SP
49287.659	10.904	10.532	9.930		SP
49288.646	10.646	10.564	9.938		SP
49351.646	10.849	10.644	9.973		SP
49356.606	10.859	10.700	10.127		SP
49368.586	10.595	10.534	9.888		SP
49421.534	10.770	10.670	10.028	0.268	SP
49428.621		10.720			K
49431.646		10.711			K
49466.371	10.712	10.679	10.275	0.217	SP
49477.328	10.939	10.786	9.982	0.234	SP

3.7. T Coronae Borealis

T CrB was observed photoelectrically on 11 nights. The standard stars are the same as used in Paper II. The observations are given in Table 4. The data indicate a decrease of the star's brightness mainly in the U band. Observed values of the U magnitude around 13.5 have not been observed previously.

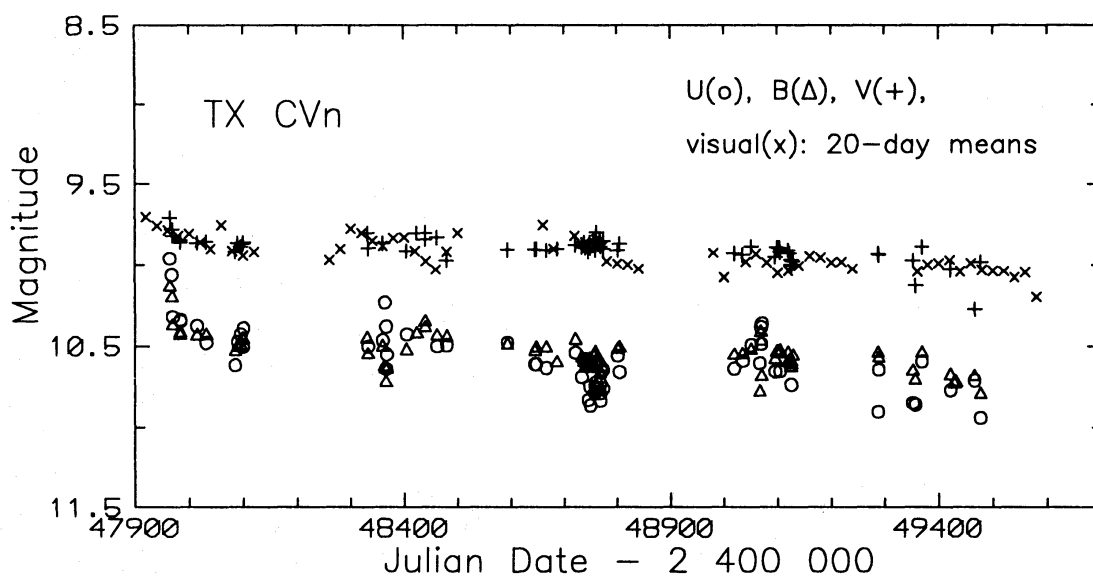


Figure 8. UB and visual observations of TX CVn

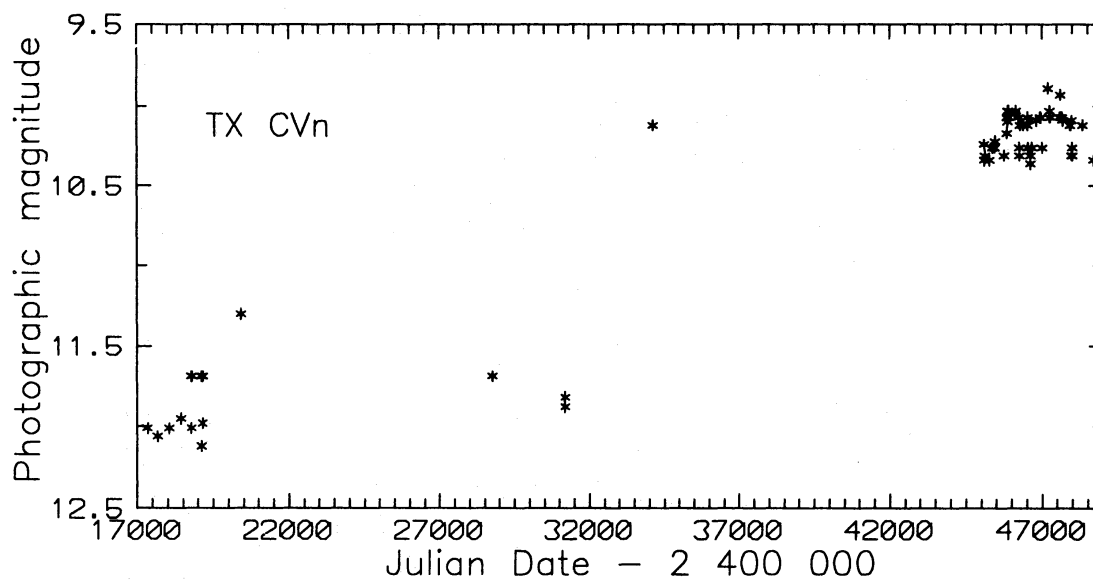


Figure 9. Photographic observations of TX CVn

Visual magnitude estimates together with the V data are plotted in Figure 10. The periodic wave-like variation and a gradual decrease in the star's brightness is indicated.

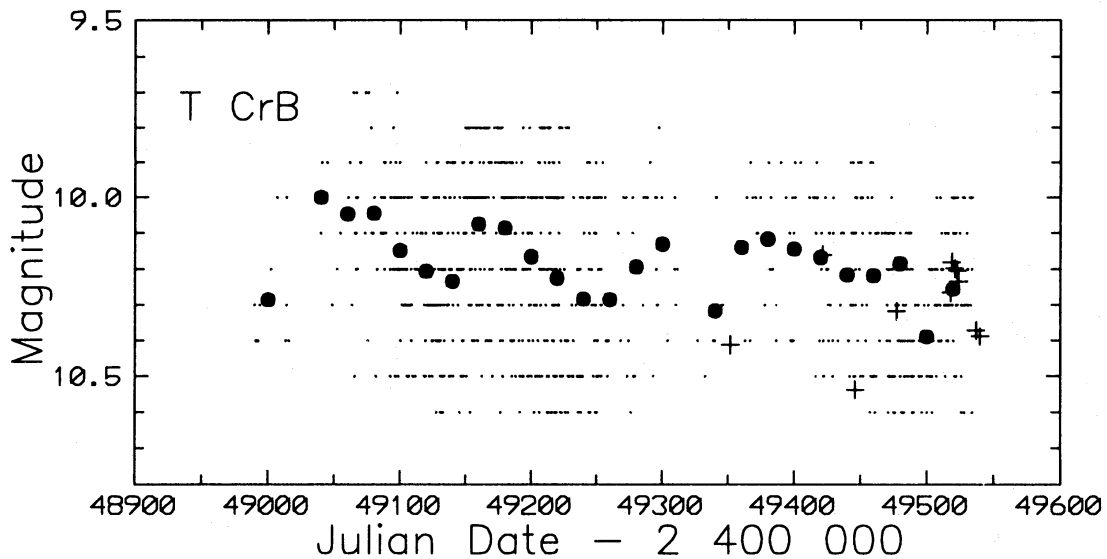


Figure 10. Visual (20/5 day means) and V(+) observations of T CrB

Table 4. UBVR observations of T CrB

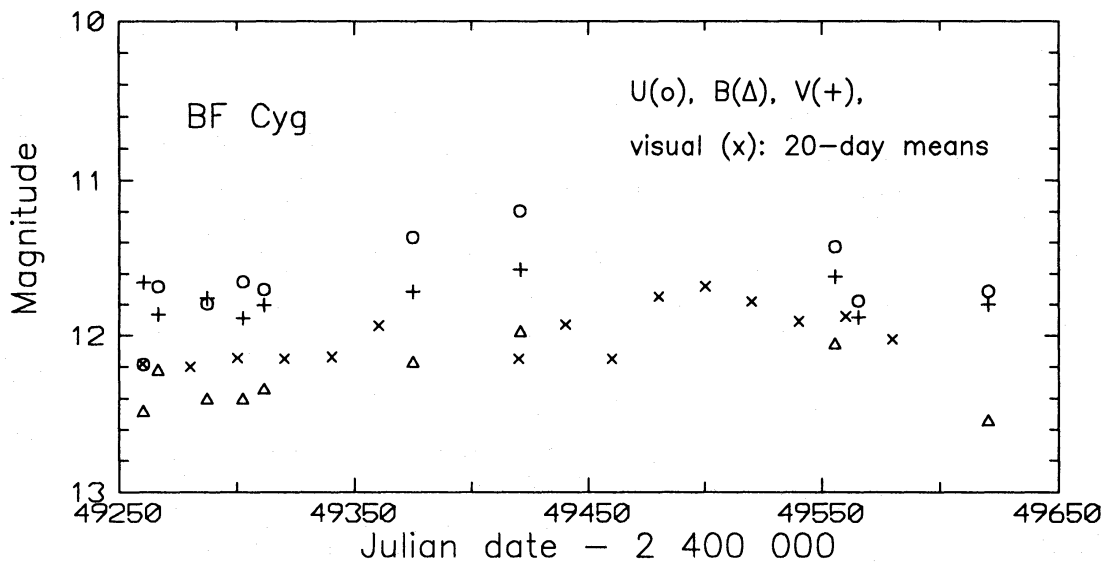
JD_{hel}	U	B	V	ΔR	Obs
-2 400 000					
49351.703	12.043	11.695	10.412		SP
49421.586	13.496	11.722	10.160	0.986	SP
49446.450	13.319	11.949	10.538	1.363	SP
49477.403	13.112	11.878	10.318	1.136	SP
49518.409		11.608	10.265		K
49519.339		11.497	10.181		K
49521.335		11.518	10.198		K
49523.336		11.549	10.203		K
49524.353		11.590	10.234		K
49537.335		11.665	10.372		K
49540.511		11.690	10.388		K

3.8. BF Cygni

The photoelectric observations were made on 9 nights. We used the same standard stars as in Paper III. The results are given in Table 5 and shown in Figure 11. Observations indicate that BF Cyg definitively returned to quiescence from its 1989 outburst. However, it still remains relatively bright in U ($U - B < 0$). The photographic observations were made on 382 nights from JD 2413836 (1896 October) and JD 2448867 (1992 September). The data are

Table 5. UBVR observations of BF Cyg

JD_{hel}	U	B	V	ΔR	Obs
-2 400 000					
49266.376	11.685	12.219	11.866		SP
49287.239	11.797	12.398	11.762		SP
49302.298	11.654	12.401	11.891		SP
49311.226	11.703	12.337	11.805		SP
49374.686	11.364	12.167	11.718		SP
49420.640	11.193	11.974	11.574	3.845	SP
49555.506	11.426	12.053	11.620	3.790	SP
49565.458	11.779		11.885	3.899	SP
49620.388	11.715	12.537	11.800	3.874	SP

**Figure 11.** UBV and visual observations of BF Cyg

available on request. They are depicted in Figure 12. The historical LC displays frequent outbursting activity. Except of the outburst at the end of the last and the beginning of this century, there are outbursts around JD 2 435 400 and JD 2 440 000. Moreover, the LC displays the minima caused by the orbital motion of the binary with a 756 – 759 day period. Their positions were determined approximately at JD 2 428 000, JD 2 429 500, JD 2 430 600 (a secondary minimum - hereafter S), JD 2 434 100, JD 2 440 500 (S), JD 2 440 850, JD 2 441 520, JD 2 441 950 (S).

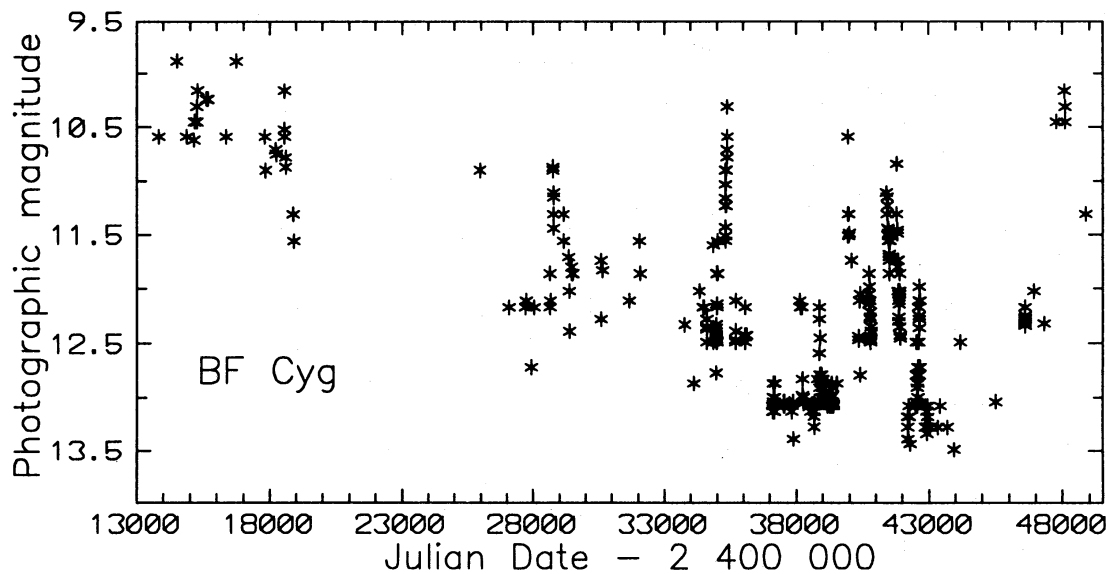


Figure 12. Photographic observations of BF Cyg

3.9. CH Cygni

This star was observed photoelectrically on 27 nights. The star HD 182691 (SAO 31623): $V=6.525$, $B-V=-0.078$, $U-B=-0.24$, $V-R=0.00$, spectrum B9, was used as the basic comparison. The other standard stars are the same as in Papers II and III. The results are compiled in Table 6 and shown in Figure 13. A gradual increase in the star's brightness and irregular variability on a time-scale of days to weeks, more pronounced in U, were observed. Our observations indicate continuation of the current outburst of CH Cyg.

Table 6. UBV observations of CH Cyg

JD_{hel} -2 400 000	U	B	V	R	Obs	JD_{hel} -2 400 000	U	B	V	R	Obs
49266.452	7.921	8.889	8.062		SP	49466.57	7.284	8.340	7.791	6.377	SP
49288.339	7.339	8.381	7.690		SP	49475.53	7.418	8.436	7.865	6.427	SP
49311.316	7.439	8.330	7.582		SP	49486.49	7.119	8.128	7.616	6.302	SP
49351.191	7.451	8.435	7.837		SP	49518.495	6.945	7.969	7.466	6.198	SP
49365.197	7.143	8.228	7.653		SP	49549.503	6.423	7.509	7.175	6.064	SP
49371.215	7.177	8.274	7.697		SL	49556.372	6.973	8.071	7.595	6.303	SP
49374.206	7.364	8.311	7.617		SP	49563.357	6.562	7.620	7.279	6.152	SP
49404.60	7.393	8.406	7.834	6.356	SP	49574.425	6.535	7.626	7.312	6.244	SP
49412.54	7.383	8.382	7.765		SP	49592.600	6.815	7.936	7.583	6.427	SP
49420.57	7.459	8.408	7.756	6.258	SP	49600.551	6.643	7.753	7.406	6.296	SP
49423.57	7.179	8.176	7.599	6.209	SP	49608.355	7.127	8.084	7.638	6.407	SP
49450.51	7.562	8.475	7.795	6.270	SP	49620.499	7.619	8.421	7.817	6.394	SP
49457.42	7.744	8.646	7.938		SP	49621.405	7.527	8.339	7.695	6.323	SP
49464.56	7.192	8.201	7.697	6.325	SP	49626.520	7.605	8.364	7.731	6.343	SP

3.10. CI Cygni

The visual observations of CI Cyg which cover the last two primary minima are plotted in Figure 14. The minima are considerably broader than those observed

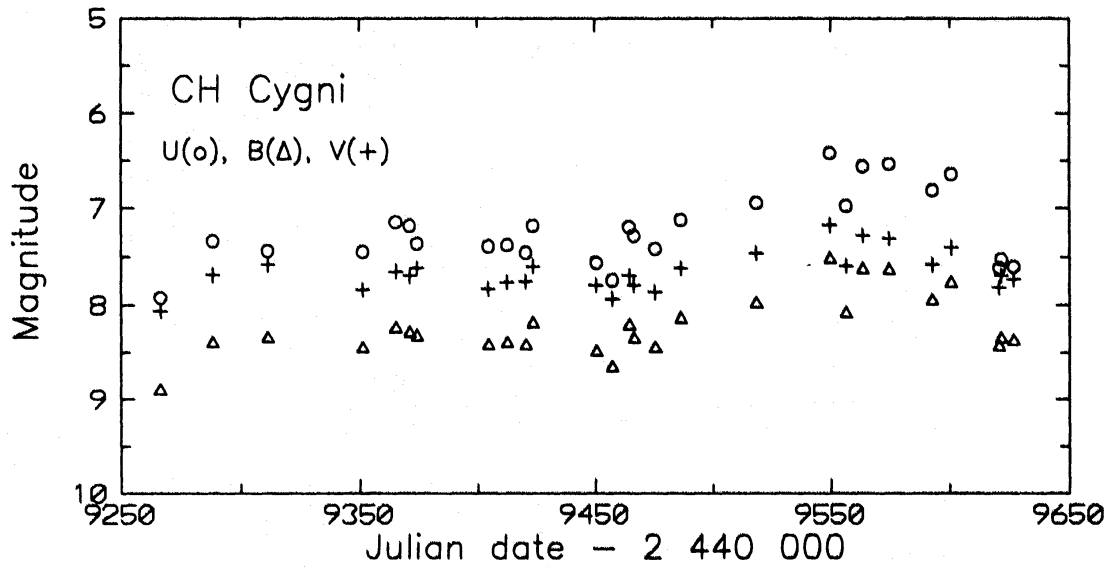


Figure 13. UBV observations of CH Cyg

in outburst (cf. Belyakina 1991). The LC exhibits a complex behavior around the orbital phase 0.5.

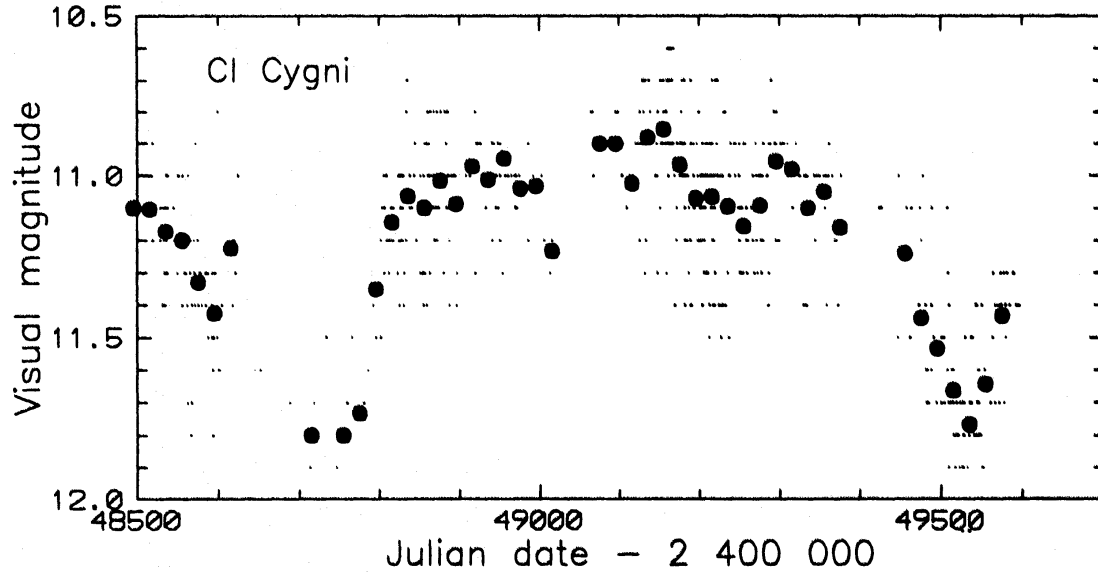


Figure 14. Visual observations of CI Cyg. Full circles are 20/2 day means.

3.11. V 1016 Cygni

The photoelectric measurements of this star were made on 7 nights. The same standard stars were used as in Paper III. The results are compiled in Table 7. No significant changes in the optical continuum were observed.

Table 7. UBVR observations of V1016 Cyg

JD_{hel}	U	B	V	ΔR	Obs
-2 400 000					
49266.415	10.524	11.361	11.057		SP
49287.289	10.475	11.487	11.478		SP
49302.352	10.484	11.346	11.062		SP
49555.382	10.554	11.392	11.151	2.573	SP
49608.468	10.543	11.392	11.149	2.528	SP
49620.447	10.545	11.420	11.203	2.555	SP
49626.476	10.567	11.374	11.160	2.550	SP

3.12. AG Draconis

The photoelectric observations were made on 17 nights. Standard stars are the same as used in Paper II. The results are summarized in Table 8 and shown in Figure 15. Our observations confirmed the new outburst which began in 1994 June (IAU Circ. 6009). The star is brighter than during the 1980 outburst. It is interesting to note that both outbursts began at the same orbital phase (cf. Skopal & Chochol 1994, Skopal 1994b).

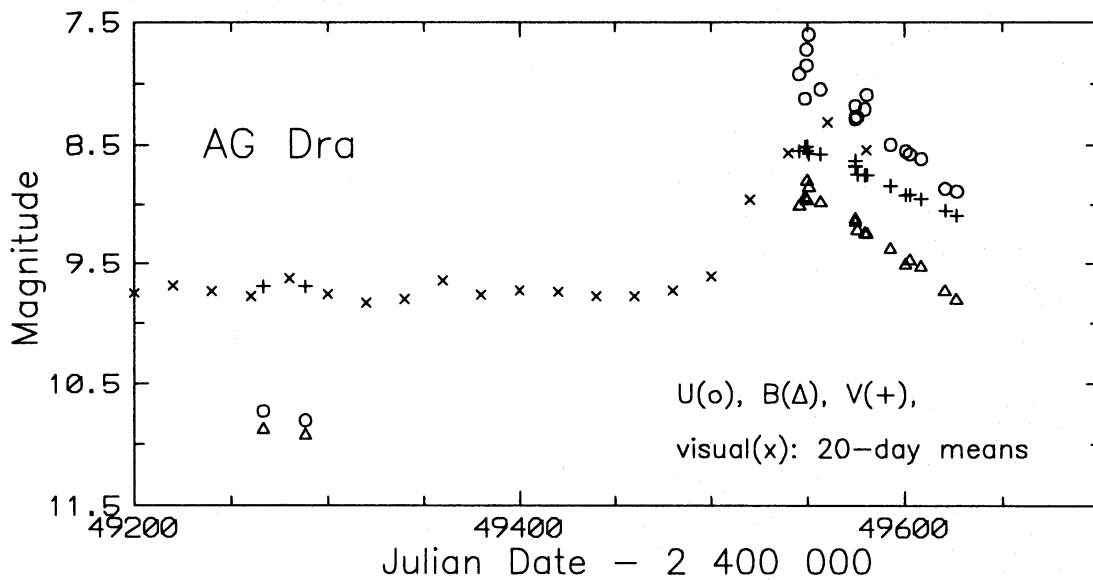


Figure 15. UBVR and visual observations of AG Dra

3.13. CQ Draconis (4 Dra)

We observed this star in 20 nights while using the same comparison stars as described in Paper II. The results are summarized in Table 9. The U colour has

Table 8. UBVR observations of AG Dra

JD_{hel}	U	B	V	ΔR	Obs
-2 400 000					
49266.494	10.727	10.869	9.692		SP
49288.400	10.805	10.915	9.695		SP
49487.407		10.728			K
49545.552	7.92	9.00	8.55		H
49548.466	8.12	8.93	8.52		H
49549.452	7.85	8.79	8.55		H
49549.452	7.72	8.95	8.51		H
49550.471	7.60	8.84	8.57		H
49556.516	8.046	8.969	8.575	-1.504	SP
49574.40	8.29	9.14	8.68		H
49574.43	8.18	9.14	8.63		H
49574.476	8.273	9.116	8.673	-1.436	SP
49575.405	8.270	9.207	8.749	-1.395	SP
49579.428	8.207	9.233	8.754		SL
49580.37	8.09	9.24	8.75		H
49592.53	8.496	9.366	8.842	-1.323	SP
49597.49	8.60	9.52	8.84		H
49600.31	8.50	9.61	8.97		H
49600.49	8.551	9.499	8.919	-1.261	SP
49602.51	8.576	9.463	8.918	-1.258	SP
49608.30	8.616	9.520	8.954	-1.217	SP
49620.61	8.865	9.723	9.051	-1.162	SP
49626.56	8.889	9.793	9.094	-1.126	SP

reached the maximum of the previous steady rise and – after some plateau-like behavior – began to decline. The whole development reflects the orbital motion within the wide binary CQ Dra A+B. As for the B and V colours, the star continued to behave irregularly. We have achieved the complete coverage of the orbital cycle within CQ Dra A+B during this observing season.

3.14. YY Herculis

Only one photoelectric measurement of this star was made at the SP Observatory on 1993 October 5 (JD 2 449 266.328): U = 11.531, B = 12.360, V = 11.724. The standard stars are the same as in Paper II. The visual LC (Figure 16) covers the period from JD 2 449 100 (1993 April) including the recent outburst and the minimum at JD 2 449 511, probably corresponding to the eclipse of the hot by the cool component in the YY Her binary.

Table 9. UBV observations of 4 Dra

JD _{hel}	U	B	V	Obs	JD _{hel}	U	B	V	Obs
49096.300	8.278	6.640	4.958	BU	49375.465	8.167	6.498	5.277	SP
49102.263	8.339	6.682	5.068	BU	49404.493	8.151	6.526	4.964	SP
49134.410	8.227	6.603	5.018	BU	49412.436	8.156	6.554	4.834	SP
49149.315	8.292	6.627	5.014	BU	49420.514	8.162	6.568	5.021	SP
49159.310	8.301	6.681	5.073	BU	49475.463	8.144	6.509	4.957	SP
49266.641	8.249	6.470	4.916	SP	49495.422	8.185	6.548	4.939	SP
49285.578	8.335	6.569	5.012	SP	49554.467	8.183	6.490	5.192	SP
49287.578	8.334	6.557	4.985	SP	49565.351	8.169	6.591	5.046	SP
49288.591	8.330	6.533	4.959	SP	49575.354	8.189	6.547	4.996	SP
49351.493	8.161	6.446	4.877	SP	49626.614	8.284	6.555	4.977	SP

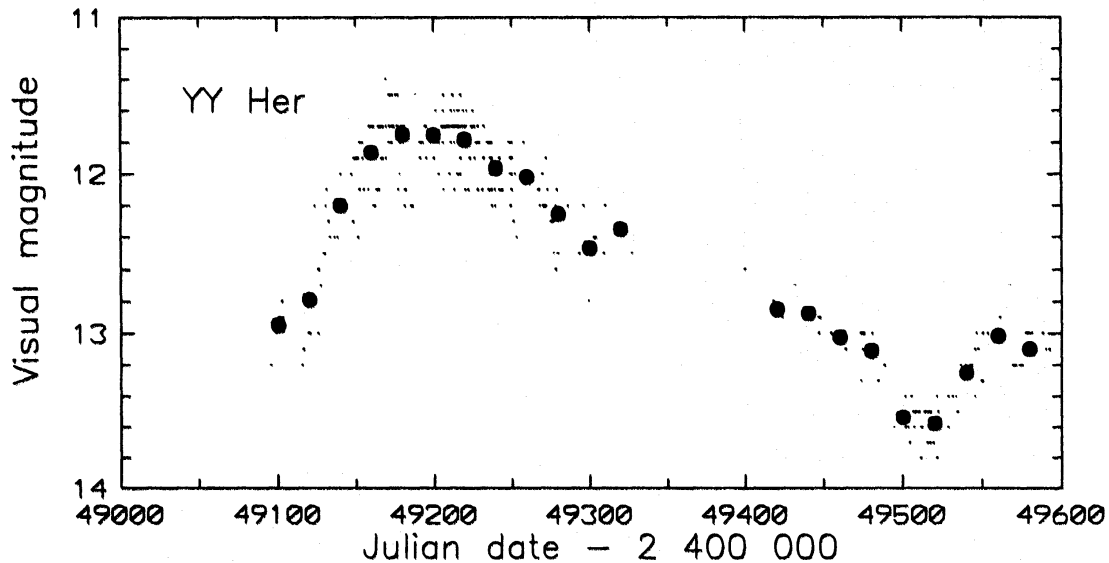


Figure 16. Visual observations of YY Her. Full circles are 20/2 day means.

3.15. V 443 Herculis

The photoelectric observations of this star were carried out on 3 nights. The standard stars are the same as used in Paper II and III. The results are compiled in Table 10.

We collected all available visual estimates of the star's brightness which were obtained between JD 2447018 and JD 2449594 (777 values), and constructed the phase diagram (Figure 17). The data were folded on the period $P = 600$ days and averaged within the $0.05P$ intervals. The uncertainty of such means

is between 0.05 and 0.08 mag. This LC displays the periodic wave-like variation with the amplitude of ~ 0.3 mag. Irregular modulation in the LC is probably caused by the cool component variability.

Table 10. UBVR observations of V443 Her

JD_{hel}	U	B	V	ΔR	Obs
-2400000					
49293.212	11.454	12.118	11.297		SP
49323.184	11.544	12.464	11.405		SP
49556.429	11.955	12.800	11.492	3.324	SP

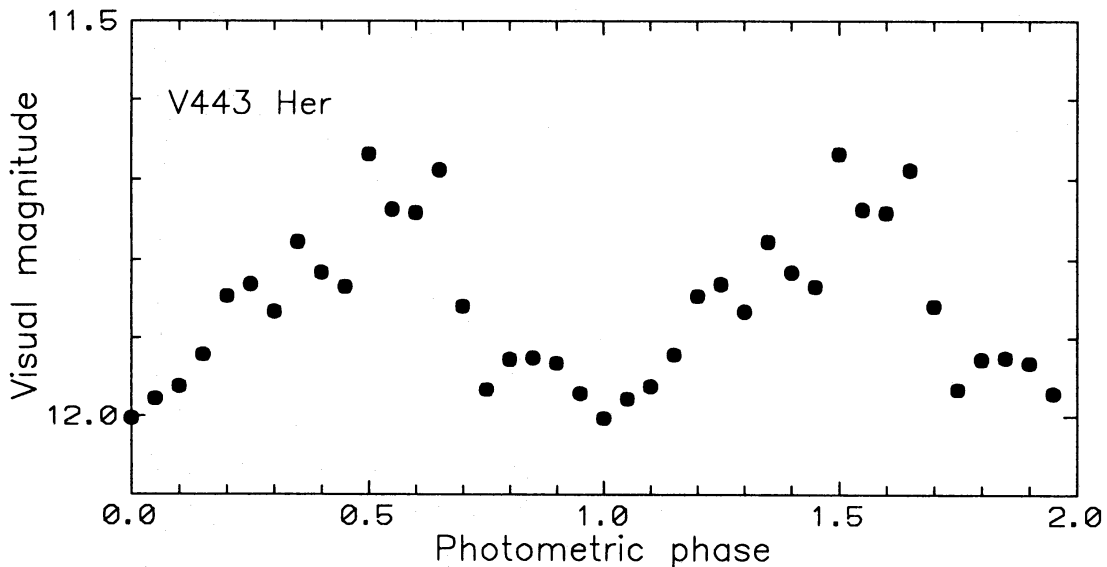


Figure 17. Phase diagram of V 443 Her constructed from all available visual estimates. The points represent means of the individual values within the 0.05 P intervals.

3.16. SS Leporis

The visual observations are shown in Figure 18. Observations are not continuous due to season gaps. In spite of that, someone can recognize two more pronounced minima in the LC separated by ~ 830 days. However, their reality must be supported with further observations.

3.17. AG Pegasi

Only visual observations were available during the current period of this campaign (Figure 19). The data are, more or less, placed around the maximum of the light curve at $\sim JD\ 2449\ 250$.

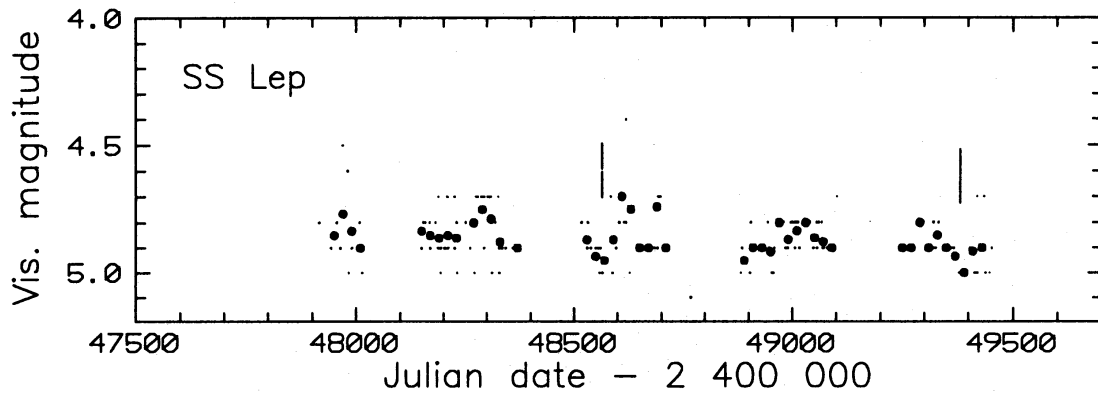


Figure 18. Visual observations of SS Lep. Full circles are 20/2 day means.

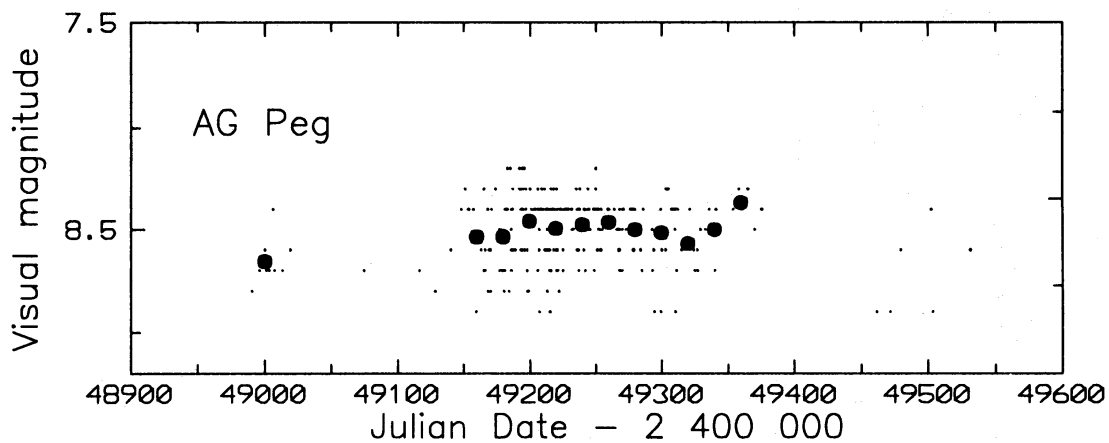


Figure 19. Visual observations of AG Peg. Full circles are 20/5 day means.

3.18. AX Persei

The photoelectric observations of this star were made on 11 nights. The standard stars are the same as those in Paper II and III. The results are summarized in Table 11 and shown in Figure 20. The LC covers in part the primary minimum which is broader than those observed during the outburst in 1988-91 (cf. Skopal 1994a).

3.19. PU Vulpeculae

The photoelectric observations of PU Vul were obtained on 4 nights. The list of standard stars was presented in Paper II. The results are in Table 12 and showed in Figure 21. The observation made at the Kryonerion station on 1993 July 7 was omitted. The eclipse of the hot component by the cool component (cf. IAU Circ. 5960) is seen best in the V band, but practically not indicated

Table 11. UBVR observations of AX Per

JD_{hel}	U	B	V	ΔR	Obs
-2 400 000					
49368.452	11.490	12.072	11.153		SP
49399.5		12.04			H
49477.480	11.695	12.142	11.156	3.018	SP
49554.543	12.569	12.817	11.470	3.349	SP
49563.423	12.587	12.835	11.497	3.384	SP
49570.540	12.689	12.873	11.583	3.400	SP
49574.547	12.712	12.895	11.641	3.434	SP
49593.329	12.744	12.946	11.790	3.515	SP
49600.596	12.733	12.936	11.681	3.460	SP
49608.402	12.742	12.999	11.722	3.496	SP
49620.560	12.715	12.870	11.660	3.495	SP

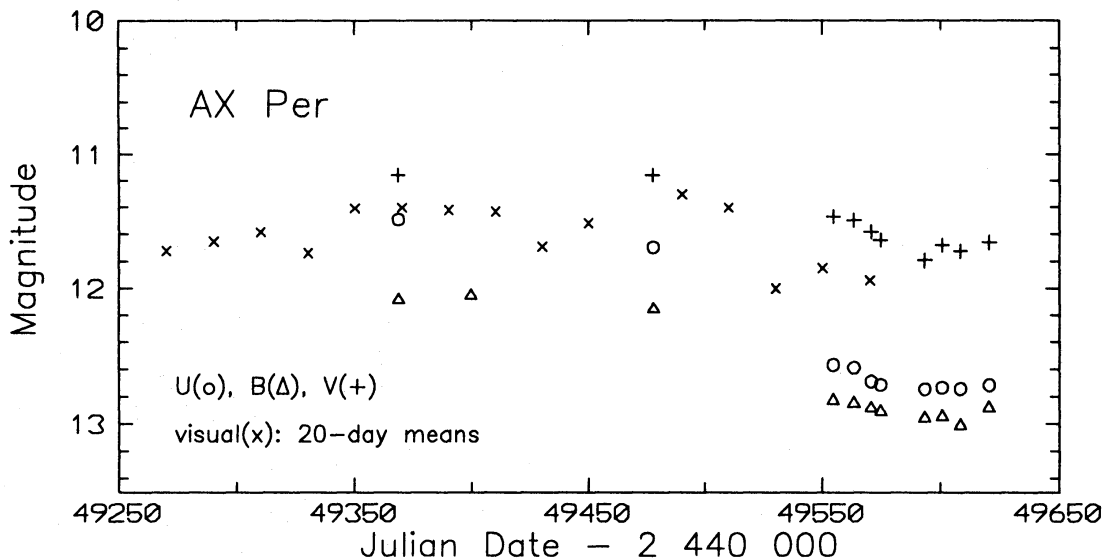


Figure 20. UBV and visual observations of AX Per

in U and B. Compiled V and visual light curve suggests that the eclipse began at $\sim JD\ 2449255$ and finished at $JD\ 2449580 \pm 40$. New observations should determine the end of this eclipse more accurately.

Table 12. UBV observations of PU Vul

JD_{hel}	U	B	V	ΔR	Obs
-2 400 000					
49518.583		11.675			K
49519.512		11.747			K
49521.566		11.743			K
49523.562		11.817			K
49524.565		11.775			K
49540.554		12.051	11.762		K
49556.472	11.105	12.027		3.714	SP
49620.336	10.953	11.544	11.376	3.282	SP
49626.423	10.929	11.597	11.442	3.253	SP

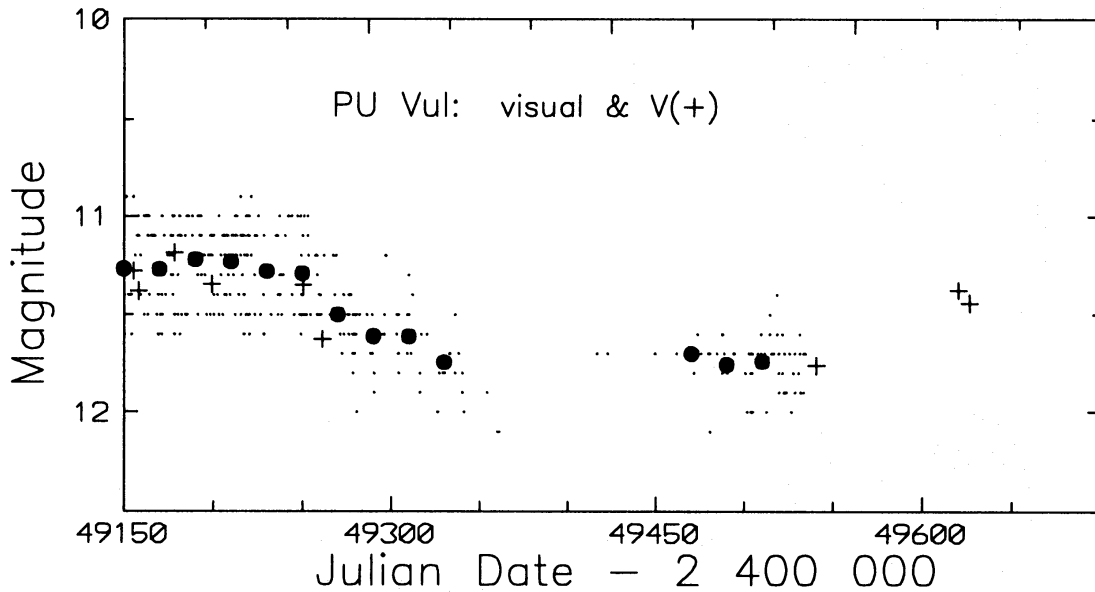


Figure 21. Photoelectric V and visual observations of PU Vulpeculae - full circles are 20/5 day means

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