Photometry of symbiotic stars

VIII. EG And, TX CVn, BF Cyg, CH Cyg, AG Dra and AX Per

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Abstract. We present photoelectric U, B, V, R observations of 6 classical symbiotic stars. The main results can be summarized as follows: **EG And** (HD 4174, BD+39 167) : A sinusoidal variation displaying two maxima (minima) during the orbital period was observed also in the R band. **TX CVn** (HD 63173, BD+37 2318): A periodic, ~190-day, variation in the U band was found, corresponding to the orbital period of the binary. The shaping and colour indices of the minima suggest that they are probably caused by eclipses. **BF Cyg** (MWC 315, Hen 1747): A wave-like variation in the light curve (LC) indicates that the system has finally returned to quiescence. A minimum of the light was observed at JD 2 450 684.5. **CH Cyg** (HD 182917, BD+49 2999): This star persisted in a quiescent phase till May 1998. The last observations indicate a brightening of ~1.5 mag in U, showing that CH Cyg just entered a new active phase. **AG Dra** (SAO 16931, BD+67 922): Our measurements cover the recent eruption centred around JD 2 450 670 (1997.6) and the following minimum. **AX Per** (MWC 411, GCRV 896): The recent photometry revealed a deep minimum lasting about 400 days around JD 2 450 280 (1996.5). The timing of two other minima in the historical LC and colour indices during the recent minimum suggests that they can be caused by eclipses of the inner binary (the symbiotic pair, $P_{\rm orb}$=680 days) by a giant star ($R \approx 200 - 300\,R_{\odot}$) orbiting it in a long-period (46.5-yr) orbit.

Key words: stars - binaries - symbiotic - photometry

1. Introduction

Spectrum of symbiotic stars is generally characterized by three different sources of light: the hot ($T_{\star} \sim 10^5$ K) and the cool ($T_{\rm cool}$ ~3000 K) stellar components and a nebular component. Currently they are commonly accepted as long-period interacting binaries. ($P_{\rm orb}$ ~1-3 years) consisting of a red giant and a hot compact object, embedded in a gaseous nebula. Many systems show extended quiescent periods which are often alternated by intensive activity.

A very different geometry of the source of the optical light during different levels of activity can be observed in the profiles of LCs (e.g. Skopal 1998). The main aim of this contribution is to present new photometric observations of selected symbiotic stars, and to illustrate such behaviour.

2. Observations

Our photoelectric U, B, V, R measurements were performed using single-channel photoelectric photometers mounted in the Cassegrain foci of 0.6-m reflectors at the Skalnaté Pleso (hereafter SP in Tables) and Stará Lesná observatories (SL). Our new Observations cover the period from about January 1996 to June 1998.

3. Results

3.1. EG And

Differential photometry, EG And – HD 4143 (SAO 63173, BD+37 2318), is compiled in Table 1. Figure 1 shows the LC in the R band. A modulation displaying a double wave during the orbital period is the most significant feature of the EG And LC. The amplitude, ΔR_{max} ~0.2 mag, is comparable to that observed in V and B (cf. Skopal 1997a). Currently, the nature of the observed sinusoid in LCs of EG And is seen in the ellipsoidal variation due to tidal distortion of the red giant component (Wilson & Vaccaro 1997). However, the same type

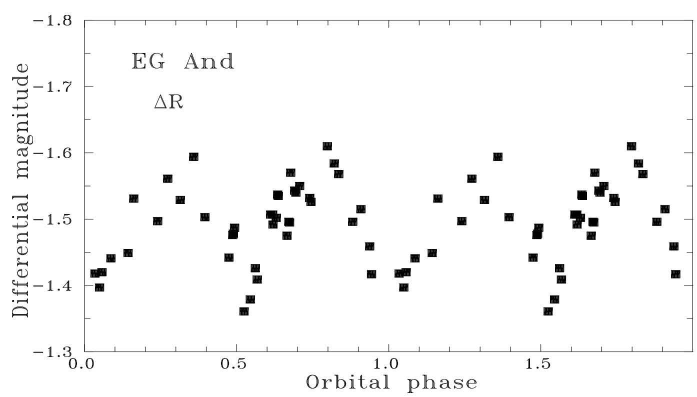

Figure 1. The LC of EG And in R. It consists of the data published by Hric et al. (1996) and those in Table 1. The data were folded with the ephemeris for the primary minima, $Min = JD\,2\,446\,336.7 + 482 \times E$, which corresponds to the times of inferior conjunction of the cool giant (Skopal 1997).

of variability in U, but with ΔU >0.3 mag, argues against this interpretation (Wilson & Vaccaro 1997). According to the ionization model for symbiotic stars (e.g. Seaquist et al. 1984), the HII region, prolonged along the line joining the stars, could produce this wave-like variation by different projections of its optically thick part into the line of sight in different orbital phases (e.g. Skopal 1997a). This interpretation can easily explain the larger amplitude at shorter wavelengths (cf. Fig. 2 of Skopal 1996). However, the first possibility cannot be excluded. As a result, the author is of the opinion that a combination of both approaches is needed to explain this type of LCs of symbiotic stars successfully.

Table 1. U, B, V, R observations of EG And

Date	JD_{hel} -2 400 000	U	B	V	ΔR	Obs
12/01/96	50095.360	-1.704	-1.433	-1.501	-1.610	SP
23/01/96	50106.344	–	-1.476	-1.465	-1.584	SP
30/01/96	50113.318	-1.414	-1.378	-1.448	-1.568	SP
08/10/96	50365.473	-1.601	-1.439	-1.495	-1.594	SP
26/10/96	50383.368	-1.430	-1.322	-1.384	-1.503	SP
03/12/96	50421.349	-1.655	-1.283	-1.326	-1.442	SP
09/12/96	50427.469	–	–	–	-1.476	SP
10/12/96	50428.497	-1.456	-1.310	-1.364	-1.478	SP
12/12/96	50430.309	–	–	–	-1.487	SP
27/12/96	50445.355	-1.399	-1.176	-1.227	-1.361	SP
06/01/97	50455.355	–	–	–	-1.415	SP
14/01/97	50463.292	-1.399	-1.234	-1.306	-1.426	SP
17/01/97	50466.370	–	–	–	-1.409	SP
11/02/97	50491.234	-1.536	-1.328	-1.382	-1.492	SP
11/03/97	50519.263	-1.419	-1.431	-1.483	-1.570	SP
24/09/97	50716.368	-1.308	-1.271	-1.329	-1.441	SP
21/10/97	50743.580	-1.919	-1.304	-1.330	-1.449	SP
30/10/97	50752.462	-1.486	-1.356	-1.424	-1.531	SP
07/12/97	50790.425	-1.495	-1.345	-1.392	-1.497	SP
23/12/97	50806.380	-1.481	-1.392	-1.463	-1.561	SP
12/01/98	50826.301	-1.413	-1.347	-1.419	-1.529	SP

3.2. TX CVn

The results of our photometric measurements of TX CVn are in Table 2. Stars BD+382374 (SAO 63223, V=9.36, $B-V$=0.30, $U-B$=0.03) and HD 111113 (SAO 63189, m_v=8.4, m_{pg}=9.4) were used as the comparison and the check, respectively. Figure 2 displays U, B, V LCs compiled from the data published in our previous papers and those in Table 2. The LC reflects a gradual fading of the star's brightness. The most significant feature of our new observations is the minimum (ΔU ~0.6 mag, ΔB ~0.35 mag, ΔV ~0.2 mag) observed at JD 2 450 477.4. A period search in the U data, using Stellingwerf's (1978) method

Table 2. U, B, V, R observations of TX CVn

Date	JD_{hel} -2 400 000	U	B	V	ΔR	Obs
12/01/96	50095.487	11.132	10.835	10.141	0.324	SP
13/01/96	50096.493	11.141	10.843	10.149	0.358	SP
21/01/96	50103.698	11.162	10.838	10.133	0.349	SP
22/01/96	50104.683	11.140	10.882	10.153	0.361	SP
23/01/96	50105.691	11.128	10.834	10.125	0.347	SP
24/01/96	50106.692	11.005	10.803	10.098	0.327	SP
30/01/96	50113.493	10.997	10.832	10.150	0.327	SP
25/02/96	50139.479	11.000	10.791	10.102	0.317	SP
08/03/96	50151.472	11.028	10.825	10.144	0.350	SP
18/03/96	50161.494	11.056	10.825	10.147	0.361	SP
20/04/96	50194.356	11.053	10.810	10.111	0.322	SP
03/12/96	50421.503	10.481	10.498	9.859	0.084	SP
09/12/96	50427.638	10.571	10.545	9.881	0.111	SP
10/12/96	50428.651	10.583	10.544	9.880	0.115	SP
27/12/96	50445.618	10.600	10.556	9.914	0.145	SP
06/01/97	50455.595	10.978	10.769	10.000	0.198	SP
07/01/97	50456.519	10.971	10.776	10.006	0.201	SP
18/01/97	50467.546	11.092	10.742	9.967	0.178	SP
02/02/97	50482.616	11.088	10.750	9.972	0.173	SP
19/02/97	50499.515	11.049	10.741	9.975	0.182	SP
01/03/97	50509.418	10.552	10.536	9.850	0.079	SP
10/03/97	50518.521	10.511	10.510	9.856	0.091	SP
11/03/97	50519.449	10.489	10.519	9.856	0.089	SP
24/04/97	50563.351	10.329	10.402	9.791	0.073	SP
15/05/97	50584.535	10.261	10.379	9.775	0.064	SP
30/10/97	50752.653	10.415	10.449	9.844	0.110	SP
07/12/97	50790.696	10.573	10.516	9.898	0.158	SP
23/12/97	50806.689	10.555	10.529	9.929	0.195	SP
13/01/98	50827.672	10.616	10.569	9.919	0.156	SP
18/02/98	50863.489	10.691	10.594	9.950	0.190	SP
26/02/98	50871.475	10.734	10.622	9.976	0.209	SP
10/05/98	50944.393	10.653	10.583	9.934	0.171	SP

showed the best period to be ~190 days, which is very close to that given by the orbital solution ($P_{\rm orb} = 198.3 \pm 3.0$; Kenyon & Garcia 1989). The shape, colour indices and timing of the minima suggest that they are caused by eclipses of the hot star by its cool giant companion. This indicates a high inclination of the orbital plane of TX CVn.

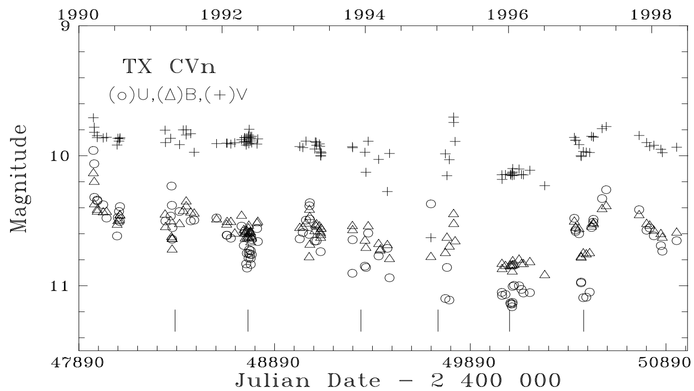

Figure 2. The U, B, V LCs of TX CVn. The observed minima correspond to eclipses of the hot star by the cool giant. Those, better covered by observations, are marked by vertical bars.

3.3. BF Cyg

The photometric measurements of BF Cyg are given in Table 3. Figure 3 shows the U, B, V LCs covering the recent outburst from 1990 to the present quiescent phase. The neighbouring stars HD 183650 (SAO 68384, V=6.96, $B-V$=0.71, $U-B$=0.34) and BD+30 3594 (LF2+3011, UBV 16553, V=9.54, $B-V$=1.20, $U-B$=1.70) were used as the comparison and check, respectively. A detailed study of this object was published by Skopal et al. (1997). Here we note a strong difference in the shapes of the minima observed during the maximum (JD 2 448 445) – nearly rectangular in profile – and those in quiescence – a sinusoid through the orbital period. This variation reflects the drastic change in the geometry of the source of the optical continuum. During the maximum of the star's brightness it is centred on the hot component simulating its photosphere, while during quiescence it occupies a large volume, the H II zone, in the binary. These changes are known to be connected with the change in temperature of the hot star at different levels of activity: $T_\star \sim 8 \times 10^4$ K in quiescent phases and $T_\star \sim 1.2 - 1.8 \times 10^4$ K in the maximum (e.g. Fernandez-Castro et al. 1990; Skopal et al. 1997).

3.4. CH Cyg

Our unpublished photometry is summarized in Table 4. Other data obtained at the SP and SL since 1996 have already been published by Skopal (1997b). Stars HD 182691 (SAO 31623, V=6.525, $B-V$=-0.078, $U-B$=-0.24) and HD 183123 (SAO 48428, m_v=8, m_{pg}=8.6) were used as the comparison and check, respectively. Figure 4 displays the U and V LCs covering the period since the 1992 active phase. Our photometry shows that CH Cyg persisted in a quiescent phase

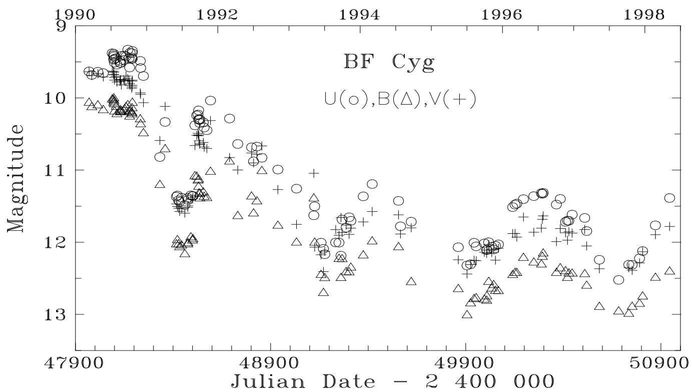

Figure 3. The LCs of BF Cyg covering the recent (1989) outburst and the present quiescence. Note a strong difference in the shape of minima during the active and quiescent phases.

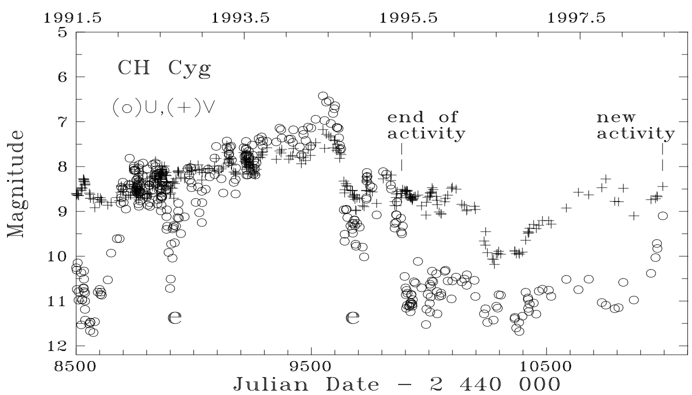

Figure 4. The U and V LCs of CH Cyg covering the period of the recent, 1992, activity, the subsequent quiescence and the beginning of a new active phase. Eclipses in the inner binary are denoted by **e**.

till May 1998. However, the last observations indicate a brightening of ~1.5 mag in U, showing that CH Cyg just entered a new active phase. Detailed studies of this unique triple-star system have recently been published by Skopal et al. (1996a, 1996b, 1998a, 1998b).

3.5. AG Dra

Our measurements cover the recent eruption centred around JD 2 450 670 (1997.6) and the following minimum, just prior to the next expected brightening. Stars

Table 3. U, B, V, R observations of BF Cyg

Date	JD_{hel} -2 400 000	U	B	V	ΔR	
25/02/96	50140.588	11.513	12.440	11.879	4.108	SP
09/03/96	50152.600	11.478	12.411	11.879	4.114	SP
18/03/96	50161.581	11.464	12.411	11.929	4.079	SP
20/04/96	50195.533	11.402	12.201	11.650	3.878	SP
13/06/96	50248.510	11.361	12.266	11.861	3.998	SP
22/07/96	50287.440	11.320	12.293	11.805	3.942	SP
27/07/96	50292.442	11.329	12.187	11.682	3.966	SP
31/07/96	50296.503	11.316	12.141	11.634	3.919	SP
07/10/96	50364.337	11.478	12.410	11.991	4.131	SP
27/10/96	50384.293	11.399	12.345	11.810	4.077	SP
23/11/96	50411.232	11.717	12.386	11.868	4.159	SP
03/12/96	50421.193	11.701	12.479	11.972	4.226	SP
10/12/96	50428.202	11.703	12.417	11.853	4.158	SP
27/12/96	50445.198	11.616	12.420	11.874	4.166	SP
01/03/97	50509.583	11.663	12.427	11.823	4.145	SP
11/03/97	50519.612	11.845	12.587	12.051	4.324	SP
15/05/97	50584.436	12.243	12.881	12.368	4.703	SP
22/08/97	50683.371	12.522	12.943	–	–	SP
13/10/97	50735.237	12.310	12.976	12.353	4.709	SP
30/10/97	50752.241	12.313	12.879	12.389	4.720	SP
07/12/97	50790.201	12.223	12.838	12.286	4.576	SP
23/12/97	50806.216	12.122	12.736	12.131	4.424	SP
26/02/98	50871.642	11.766	12.477	11.895	4.233	SP
10/05/98	50944.508	11.387	12.391	11.781	3.960	SP

BD+67 925 (SAO 16952, V=9.88, $B-V$=0.56, $U-B$=-0.04) and BD+67 923 (SAO 16935, V=9.46, $B-V$=1.50, $U-B$=1.89) were used as the comparison and check, respectively. The data are summarized in Table 5. Figure 5 shows the profiles of the U, B, V LCs covering the recent active phase. According to the energy distribution in the spectrum of AG Dra, obtained in the quiescent and active phases (cf. Fig. 5 of Greiner et al. 1997), the brightening in the optical region during eruptions may be due to increased radiation of the nebula (the H II zone). Extension of the ionized zone in the binary is determined through the parameter (e.g. Seaquist et al. 1984)

$$X = \frac{4\pi\mu^2 m_{\rm H}^2}{\alpha_{\rm B}} a L_{\rm ph} \left(\frac{v_\infty}{\dot{M}}\right)^2, \tag{1}$$

which depends only upon the physical properties of the binary. Other parameters, $\alpha_{\rm B}$ stands for the total hydrogenic recombination coefficient for case B, μ is the mean molecular weight, v_∞ is the terminal velocity of the wind and $m_{\rm H}$ is the mass of the hydrogen atom. We calculated the number of hydrogen ionizing

Table 4. U, B, V, R observations of CH Cyg

Date	JD_{hel} -2 440 000	U	B	V	ΔR	Obs
15/05/97	10584.340	10.516	10.512	8.924	0.257	SP
05/07/97	10635.512	10.745	10.366	8.573	-0.066	SP
18/08/97	10679.440	10.514	10.295	8.632	0.035	SP
13/10/97	10735.296	11.034	10.366	8.472	-0.163	SP
30/10/97	10752.320	11.093	10.194	8.278	-0.297	SP
07/12/97	10790.284	11.170	10.548	8.776	0.108	SP
23/12/97	10806.265	11.148	10.567	8.786	0.098	SP
12/01/98	10826.209	10.584	10.203	8.484	-0.143	SP
26/02/98	10871.585	10.978	10.730	9.100	0.316	SP
10/05/98	10944.452	10.383	10.733	8.738	0.082	SP
29/05/98	10963.407	10.031	10.211	8.720	–	SL
04/06/98	10969.412	9.714	9.974	8.653	0.128	SP
06/06/98	10971.413	9.829	10.071	8.673	–	SL
29/06/98	10994.381	9.100	9.476	8.444	0.076	SP

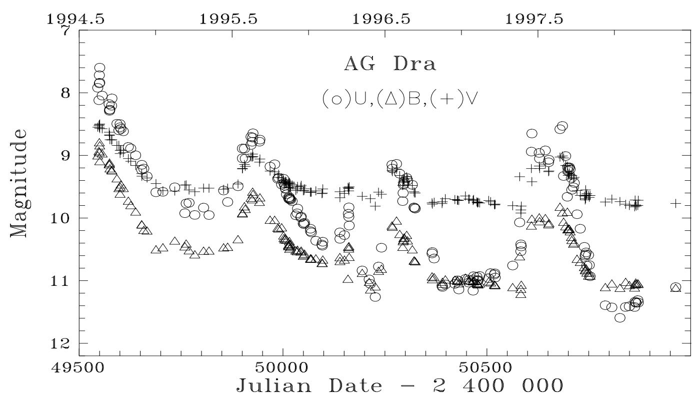

Figure 5. The U, B, V LCs of AG Dra covering the period of the active phase, which began in 1994.5. Recently published data by Tomova & Tomov (1998) and Petrík et al. (1998) are also included.

photons, $L_{\rm ph}$ [photons s^{-1}], as

$$L_{\rm ph} = \frac{L_{\rm h}}{\sigma T_{\rm eff}^4}\pi(hc)^{-1}\int_0^{912}\lambda B_\lambda(T_{\rm eff})\,d\lambda, \qquad (2)$$

where $L_{\rm h}$ [erg s^{-1}] is the total luminosity of the hot star. For $T_{\rm eff} = 10^5$ K, $L_{\rm h} = 2500\,L_\odot$ (Mikolajewska et al. 1995), Eq. 2 yields $L_{\rm ph} = 1.8\times10^{47}$ photons s^{-1}. Finally, for separation of the stars, a=350 $R_\odot$, the mass loss rate from the gi-

Table 5. U, B, V, R observations of AG Dra

Date	JD_{hel} -2 400 000	U	B	V	ΔR	Obs
15/12/95	50067.601	10.209	10.643	9.583	–	SP
17/12/95	50069.586	10.229	10.647	9.587	–	SP
28/12/95	50080.677	10.362	10.645	9.566	–	SP
12/01/96	50095.543	10.423	10.716	9.610	–	SP
13/01/96	50096.550	10.440	10.718	9.603	–	SP
14/01/96	50097.599	10.378	10.663	9.535	–	SP
25/02/96	50139.656	10.332	10.686	9.675	–	SL
25/02/96	50139.524	10.229	10.623	9.579	–	SP
07/03/96	50150.565	10.272	10.664	9.607	-0.720	SP
17/03/96	50160.461	9.931	10.459	9.530	-0.786	SP
18/03/96	50161.440	9.980	10.486	9.566	-0.732	SP
20/04/96	50194.311	10.837	10.876	9.653	-0.807	SP
30/05/96	50234.372	10.774	10.842	9.588	-0.843	SP
06/06/96	50241.500	10.474	10.809	9.620	-0.774	SP
13/07/96	50278.541	9.135	10.041	9.220	-1.145	SP
21/07/96	50286.408	9.292	10.254	9.321	-1.077	SP
09/08/96	50305.357	9.401	10.358	9.371	-1.040	SP
08/10/96	50365.608	10.565	10.933	9.757	-0.719	SP
09/10/96	50366.342	10.542	10.976	9.778	–	SL
13/10/96	50370.627	10.646	10.944	9.747	-0.708	SP
03/12/96	50421.454	11.051	10.985	9.705	-0.694	SP
09/12/96	50427.584	10.996	10.997	9.712	-0.701	SP
10/12/96	50428.689	10.995	11.003	9.716	-0.704	SP
29/12/96	50447.530	10.972	10.952	9.648	-0.781	SP
06/01/97	50455.636	11.030	10.999	9.699	-0.687	SP
07/01/97	50456.586	10.990	10.997	9.697	-0.697	SP
17/01/97	50466.514	10.980	11.004	9.716	-0.688	SP
18/01/97	50467.626	10.928	10.996	9.702	-0.691	SP
26/01/97	50475.612	10.939	11.036	9.741	-0.673	SP
02/02/97	50482.498	10.925	11.041	9.759	-0.655	SP
01/03/97	50509.524	10.879	11.027	9.738	-0.683	SP
10/03/97	50518.420	10.902	11.061	9.780	-0.640	SP
11/03/97	50519.500	10.882	11.071	9.790	-0.649	SP
24/04/97	50563.417	10.758	11.102	9.803	-0.651	SP
15/05/97	50584.384	10.454	11.064	9.809	-0.622	SP
18/08/97	50679.503	8.582	9.820	9.027	-1.372	SP
21/10/97	50743.613	10.548	10.804	9.634	-0.838	SP
07/12/97	50790.640	11.391	11.102	9.743	-0.674	SP
23/12/97	50806.600	11.426	11.045	9.698	-0.704	SP
12/01/98	50826.534	11.593	11.114	9.737	-0.669	SP
12/02/98	50863.562	11.336	11.060	9.712	-0.678	SP
26/02/98	50871.531	11.349	11.054	9.716	-0.676	SP
29/05/98	50963.380	11.102	11.113	9.762	–	SL

ant star, $\dot{M} = 2 \times 10^{-7} M_{\odot}\,yr^{-1}$, and the terminal velocity of the wind of 20-30 $km\,s^{-1}$ (cf. Mikolajewska et al. 1995; Greiner et al. 1997), the parameter

$$X > 10, \tag{3}$$

which corresponds to the *open* HII zone (cf. Seaquist et al. 1984). Consequently, the hot star wind, which developed during the outburst (Viotti et al. 1994), will consume the excess of the L_{ph} photons (note that the HII region is open) and thus produce a surplus of recombinations in addition to the quiescent phase, resulting in an increased flux of optical photons. However, a quantitative model is needed to verify this idea.

3.6. AX Per

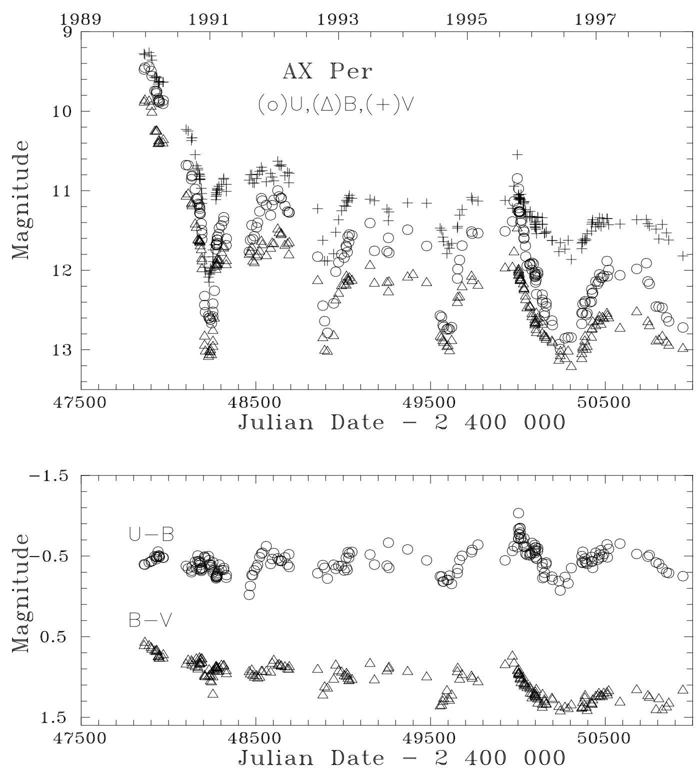

Figure 6. Top: The LCs of AX Per from its maxium to quiescence. A very broad minimum around ~JD 2 450 280 results probably from eclipse of the symbiotic pair by a giant star. Bottom: The $B - V$ and $U - B$ colour indices demonstrate reddening of the object during eclipses.

The recent, 1995.78 to 1998.35, measurements of AX Per in the U, B, V, R bands are given in Table 6. Star BD+54 331 (HD 9839, SAO 22444, V=7.43, $B-V$=1.02, $U-B$=0.63) and the neighbouring star (α_{1950} = 01 h 33.5 m, δ_{1950} = 53° 59′.5) were used as the comparison and check, respectively. We measured the check star with respect to the comparison and found its brightness as V=9.48, $B-V$=1.37, $U-B$=1.20. Figure 6 shows the U, B, V LCs obtained at our observatories. The presented photometry revealed a deep minimum lasting about 400 days centred at ~JD 2 450 280 (1996.5). Two other minima, similar in profile to that recently observed, were recorded around JD 2 433 280 (1950.0) and JD 2 416 280 (1903.5) (Wenzel 1956; Lindsay 1932). The timing and shapes of these minima and the significant reddening of the light measured during the recent minimum suggest that the minima could be eclipses caused by a third giant star ($R \approx 200 - 300\,R_\odot$) orbiting the inner binary (the symbiotic pair) in a long-period (46.5-yr) orbit.

Table 6. U, B, V, R observations of AX Per

Date	JD_{hel} -2 440 000	U	B	V	ΔR	Obs
14/10/95	50005.265	110.03	12.011	11.055	–	SL
15/10/95	50006.520	11.268	12.043	11.099	2.972	SP
17/10/95	50008.485	11.264	12.031	11.089	2.964	SP
21/10/95	50012.282	11.269	12.118	11.104	–	SL
21/10/95	50012.302	11.258	12.101	11.094	–	SL
22/10/95	50013.465	11.289	12.081	11.118	2.977	SP
25/10/95	50016.512	11.402	12.111	11.115	2.988	SP
26/10/95	50017.606	11.372	12.103	11.045	2.915	SP
09/11/95	50031.466	11.494	12.158	11.162	2.972	SP
12/11/95	50034.592	11.592	12.212	11.146	2.948	SP
13/11/95	50035.211	11.515	12.235	11.136	–	SL
13/11/95	50034.458	11.602	12.218	11.142	2.961	SP
21/11/95	50043.402	11.693	12.310	11.237	2.999	SP
22/11/95	50044.389	11.827	12.357	11.269	3.024	SP
29/11/95	50051.442	11.946	12.460	11.340	3.091	SP
15/12/95	50067.430	11.929	12.436	11.326	3.109	SP
17/12/95	50069.499	11.918	12.455	11.321	3.111	SP
18/12/95	50070.522	11.925	12.446	11.260	3.066	SP
28/12/95	50080.250	11.907	12.570	11.323	–	SL
28/12/95	50080.370	11.996	12.533	11.341	3.124	SP
05/01/96	50088.513	11.920	–	–	3.045	SP
13/01/96	50096.245	12.080	12.641	11.419	–	SL
13/01/96	50096.386	12.035	12.673	11.455	3.221	SP
14/01/96	50097.508	12.07:	12.61:	11.40:	3.235	SP
15/01/96	50098.210	12.051	12.657	11.426	–	SL

Table 6. continued

Date	JD$_{hel}$ -2 440 000	U	B	V	ΔR	Obs
16/01/96	50099.226	12.082	12.656	11.455	–	SL
17/01/96	50100.414	12.154	12.643	11.468	–	SL
21/01/96	50104.210	12.125	12.731	11.486	–	SL
22/01/96	50105.376	12.057	12.525	11.385	3.185	SP
23/01/96	50106.293	12.3::	12.77:	11.54:	3.29:	SP
30/01/96	50113.374	12.02:	12.59:	11.33:	3.147	SP
31/01/96	50114.221	12.048	12.644	11.332	–	SL
25/02/96	50139.245	12.371	12.782	11.419	–	SL
25/02/96	50139.317	12.307	12.667	11.339	3.250	SP
27/02/96	50141.336	12.402	12.628	11.425	3.246	SP
08/03/96	50151.254	12.570	12.808	11.536	3.353	SP
09/03/96	50152.266	12.535	12.828	11.535	–	SL
18/03/96	50161.318	12.453	12.854	11.527	–	SL
18/03/96	50161.617	12.412	12.831	11.512	3.314	SP
20/04/96	50194.562	12.632	12.877	11.626	3.399	SP
23/04/96	50197.561	12.689	12.895	11.626	3.408	SP
30/05/96	50234.506	12.929	13.119	11.766	3.486	SP
07/06/96	50242.464	12.990	13.062	11.653	3.460	SP
08/06/96	50243.492	12.8::	13.01::	11.6::	–	SL
04/07/96	50269.427	12.856	13.097	11.734	3.518	SP
22/07/96	50287.521	12.842	13.003	11.623	3.445	SP
09/08/96	50305.553	12.846	13.197	11.864	3.620	SP
08/10/96	50365.533	12.674	13.097	11.729	3.495	SP
08/10/96	50365.563	12.536	13.035	11.658	–	SL
13/10/96	50370.575	12.539	12.953	11.649	3.439	SP
14/10/96	50371.275	12.424	12.97::	11.62::	–	SL
26/10/96	50383.309	12.408	12.876	11.629	3.409	SP
27/10/96	50384.232	12.389	12.819	11.602	3.432	SP
02/11/96	50390.348	12.5::	12.9::	11.618	–	SL
08/11/96	50396.364	12.5::	12.94:	11.541	–	SL
25/11/96	50413.222	12.402	–	–	3.292	SP
03/12/96	50421.403	12.392	12.829	11.507	3.281	SP
04/12/96	50422.259	12.241	12.730	11.420	–	SL
07/12/96	50425.246	12.292	12.721	11.394	–	SL
10/12/96	50428.330	12.283	12.636	11.365	3.197	SP
27/12/96	50445.458	12.143	12.684	11.454	3.235	SP
07/01/97	50456.337	12.172	12.626	11.406	3.205	SP
14/01/97	50463.339	12.142	12.617	11.427	3.164	SP
18/01/97	50467.330	12.052	12.571	11.338	3.161	SP
26/01/97	50475.235	12.094	12.667	11.450	3.216	SP
03/02/97	50483.387	12.092	12.581	11.351	3.163	SP
11/02/97	50491.276	12.070	12.594	11.406	3.175	SP

Table 6. continued

Date	JD_{hel} -2 440 000	U	B	V	ΔR	Obs
01/03/97	50509.639	11.884	12.529	11.348	3.112	SP
04/03/97	50512.271	12.076	12.559	11.350	3.151	SP
11/03/97	50519.318	11.996	12.585	11.427	3.185	SP
15/05/97	50584.478	12.063	12.717	11.418	3.161	SP
18/08/97	50679.578	11.983	12.509	11.364	3.103	SP
13/10/97	50735.352	11.91:	–	11.36:	3.144	SP
21/10/97	50743.542	12.141	12.633	11.415	3.211	SP
30/10/97	50752.528	12.172	12.684	11.444	3.224	SP
07/12/97	50790.497	12.456	12.876	11.483	3.253	SP
23/12/97	50806.443	12.459	12.864	11.607	3.386	SP
12/01/98	50826.354	12.472	12.818	11.424	3.258	SP
05/02/98	50850.381	12.593	12.890	11.530	–	SL
18/02/98	50863.364	12.642	12.930	11.620	3.431	SP
10/05/98	50944.544	12.72::	12.97::	11.82:	3.57:	SP

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