Photometry of symbiotic stars

X. EG And, Z And, BF Cyg, CH Cyg, V1329 Cyg, AG Dra, RW Hya, AX Per and IV Vir

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Abstract. We present new photometric observations of EG And, Z And, BF-Cyg, CH Cyg, V1329 Cyg, AG Dra, RW Hya, AX Per and IV Vir made in the standard Johnson $UBVR$ system. The current issue summarizes observations of these objects to 2001 December. The main results can be summarized as follows: **EG And**: A periodic double-wave variation in all bands as a function of the orbital phase was confirmed. A maximum of the light changes was observed in U ($\Delta U \sim 0.5$ mag). **Z And**: Our observations cover an active phase, which peaked around 8.4 in U at the beginning of 2000 December. Consequently, a gradual decrease in the star's brightness has been observed. **BF Cyg**: A periodic wave-like variation in the optical continuum reflects a quiescent phase of this star. A complex light curve (LC) profile was observed. **CH Cyg**: The recent episode of activity ended in Spring 2000. We determined the position of an eclipse in the outer binary at JD 2 451 426±3. Recent observations indicate a slow increase in the star's brightness. **V1329 Cyg**: Observations were made around a maximum at 2001.2. **AG Dra**: Our measurements from the Autumn of 2001 revealed a new eruption, which peaked at ∼JD 2 452 217. **RW Hya**: The light minimum in our mean visual LC precedes the time of the spectroscopic conjunction of the giant in the binary. **AX Per**: A periodic wave-like variation was observed. Our recent observations revealed a secondary minimum at the orbital phase 0.5, seen best in the V and B bands. **IV Vir**: The LC displays a double-wave throughout the orbital cycle.

Key words: stars - binaries - symbiotic - photometry

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1. Introduction

Symbiotic stars are long-period (typically 1-3 years) interacting binaries consisting of a red giant and a hot compact object. The giant component loses mass, part of which is accreted by its companion. During *quiescent phases* the hot star ionizes a portion of the giant's wind, giving rise to nebular emission. During *active phases* the hot star expands in radius and becomes significantly cooler. An increase in the star's brightness, typically by 2-3 mag, represents the most impressive sign of such active stages.

The primary aim of our monitoring programme is to present the LCs of well-studied symbiotic stars, and thus to provide a good basis for their detailed future studies. In this respect, this paper continues the work of Skopal et al. (2000a), Skopal (1998) and another 7 campaign papers on the photometry of symbiotic stars, originally launched by Hric & Skopal (1989).

2. Observations

The majority of the U, B, V, R measurements were performed in the standard Johnson system 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). Larger uncertainties (about 0.1 mag) during some nights are marked in Tables by '::'. Further details about observation procedure are given in Skopal, Hric & Urban (1990) and Hric et al. (1991).

The U, B, V observations of RW Hya and IV Vir were secured at the San Pedro Mártir Observatory, Baja California, Mexico (M), during two weeks in June 2001. A 0.84-m Cassegrain reflector equipped with photon-counting photometer Cuentapulsos (utilizing a RCA 31034 photomultiplier) was used. These observations consisted from 10-second integrations in each filter. They were carefully reduced to the standard UBV system and corrected for differential extinction using the reduction program HEC 22 rel.13.2 (Harmanec & Horn 1998).

Some observations in the B and V bands were made with the 50/70/172 cm Schmidt telescope of the National Astronomical Observatory Rozhen, Bulgaria (R). A CCD camera SBIG ST-8 and a Johnson-Cousins set of filters were used. The chip of the camera is KAF 1600 (16 bit), with dimensions of 13.8×9.2 mm or 1530×1020 pixels. The pixel size is 9×9 μm and the scale 1".1/pixel. The readout noise was 10 ADU/pixel and the gain 2.3 e-/ADU. All frames were dark subtracted and flat fielded. Photometry was made with DAOPHOT routines.

In addition, 783 and 776 visual magnitude estimates of RW Hya and IV Vir, respectively, were obtained during 1989.0 – 2001.7 by one of us (AJ) with a private 12".5 f/5 reflector.

3. Results

3.1. EG And

We measured EG And (HD 4174, BD+39 167) with respect to HD 4143 (SAO 63-173, BD+37 2318). To obtain magnitudes in B and V we used the standard star HD 3914 (V = 7.00, $B-V$ = 0.44) and conversion between both stars, HD4143 – HD3914 = 4.640, 2.722 and 1.563 in the U, B and V bands, respectively (Hric et al. 1991). For the CCD measurements, stars SAO 36021 and HD 4127 were also used as comparison and check stars. The data are compiled in Table 1. Figure 1 shows the phase diagram for magnitudes in the U band from Table 1. A modulation displaying a double wave during the orbital period is the most significant feature of the U-LC. It is difficult to explain the large amplitude, ΔU_{max} ~0.5 mag, as an ellipsoidal variation due to tidal distortion of the red giant component (Wilson & Vaccaro 1997). The nature of such a type of variability is probably given by the shape of the nebula in the binary. A small and partially optically thick nebula can cause a double-wave variation in LCs as a function of the orbital phase and thus mimic the ellipsoidal variation (see Skopal 2001 for more detail).

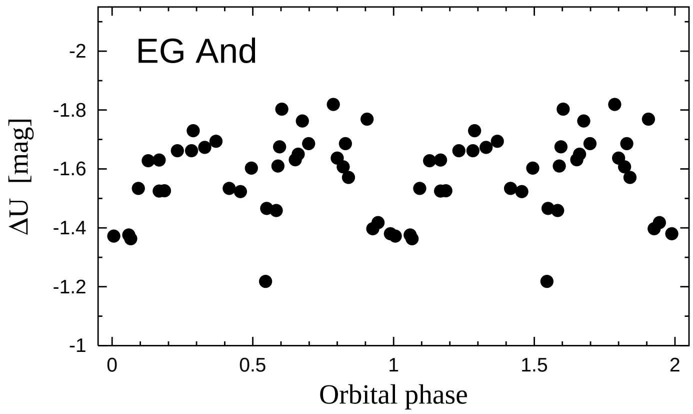

Figure 1. The LC of EG And in U. It consists of only the data published in this paper (Table 1). The data were folded with the ephemeris for the primary minima, $Min = JD\,2\,446\,336.7 + 482 \times E$ (Skopal 1997).

3.2. Z And

The results of our photometric measurements of Z And (HD 221650, BD+484093) are in Table 2. Stars SAO 53150 (BD+47 4192; V = 8.99, $B-V$ = 0.41, $U-B$ = 0.14) and SAO 63189 (BD+47 4188; V = 9.17, $B-V$ = 1.36, $U-B$ = 1.11), were used as a comparison and a check star, respectively. We obtained the magnitudes of both stars by their long-term measurement (1997 – 1999) with respect

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

Date	JD 24...	Phase*	ΔU	B	V	ΔR	Obs
Sep 03, 98	51060.429	0.800	-1.637	8.884	7.239	-1.446	SP
Sep 22, 98	51079.419	0.840	-1.571	8.851	7.208	-1.466	SP
Nov 12, 98	51130.380	0.945	-1.418	8.874	7.208	-1.465	SP
Dec 03, 98	51151.385	0.989	-1.380	8.884	7.230	-1.441	SP
Dec 11, 98	51159.434	0.006	-1.372	8.867	7.197	-1.474	SP
Jan 06, 99	51185.227	0.059	-1.376	8.877	7.226	-1.442	SP
Jan 22, 99	51201.351	0.093	-1.534	8.816	7.177	-1.481	SP
Feb 27, 99	51237.290	0.167	-1.630	8.844	7.200	–	SL
Sep 16, 99	51437.540	0.583	-1.459	8.838	7.182	-1.496	SP
Oct 30, 99	51482.371	0.676	-1.763	8.729	7.080	–	SL
Dec 22, 99	51535.315	0.786	-1.819	8.732	7.094	-1.567	SP
Jan 08, 00	51552.258	0.821	-1.607	8.826	7.171	-1.498	SP
Jan 12, 00	51556.220	0.829	-1.686	8.798	7.128	–	SL
Feb 18, 00	51593.231	0.906	-1.769	8.840	7.181	–	SL
Feb 28, 00	51603.245	0.926	-1.397	8.827	7.148	–	SL
Aug 17, 00	51774.481	0.282	-1.662	8.819	7.143	–	SL
Aug 20, 00	51777.480	0.288	-1.730	8.773	7.123	-1.545	SP
Sep 09, 00	51797.328	0.329	-1.673	8.812	7.151	–	SL
Sep 29, 00	51816.561	0.369	-1.694	8.787	7.155	-1.499	SP
Oct 21, 00	51839.334	0.416	-1.534	8.833	7.155	–	SL
Oct 29, 00	51847.441	0.433	–	8.81	7.34	–	R
Oct 20, 00	51848.451	0.435	–	8.87	–	–	R
Nov 09, 00	51858.417	0.456	-1.523	8.845	7.199	-1.483	SP
Nov 28, 00	51877.464	0.495	-1.603	8.876	7.233	-1.457	SP
Dec 22, 00	51901.270	0.545	-1.218	8.937	7.228	–	SL
Dec 24, 00	51903.214	0.549	-1.466	8.927	7.229	-1.439	SP
Dec 24, 00	51903.358	0.549	–	8.86	7.42	–	R
Jan 12, 01	51922.403	0.589	-1.610	8.834	7.185	-1.490	SP
Jan 15, 01	51925.359	0.595	-1.675	8.816	7.170	-1.510	SP
Jan 19, 01	51929.262	0.603	-1.803	8.813	7.138	–	SL
Feb 11, 01	51952.272	0.651	-1.631	8.820	7.143	–	SL
Feb 16, 01	51957.230	0.661	-1.650	8.793	7.146	-1.543	SP
Feb 17, 01	51958.302	0.663	–	8.72	7.23	–	R
Mar 06, 01	51975.281	0.698	-1.686	8.649	7.023	-1.618	SP
Aug 31, 01	52152.511	0.066	-1.363	8.944	7.302	-1.380	SP
Sep 30, 01	52182.582	0.128	-1.628	8.804	7.229	-1.481	SP
Oct 18, 01	52201.388	0.167	-1.525	8.887	7.238	-1.431	SP
Oct 27, 01	52210.380	0.186	-1.526	8.898	7.221	-1.431	SP
Nov 18, 01	52232.417	0.232	-1.662	8.818	7.191	-1.480	SP

* $Min = JD\,2\,446\,336.7 + 482 \times E$ (Skopal 1997)

to the previous comparison star (SAO 35642; V = 5.30, $B - V$ = -0.06, $U - B$ = -0.15). The resulting magnitudes of Z And were obtained using only the first comparison (SAO 53150) as the second one can be variable. CCD measurements were also compared to the star SAO 53150 and, in addition, to SAO 53133. The dominant feature of the presented LCs (Fig. 2) is a strong active phase, which began on 2000 August 31 (Skopal et al. 2000b). The star's brightness peaked around 8.4 in U at the beginning of December 2000 (see also Sokoloski et al. 2001). Consequently, its brightness has gradually been decreasing. Comparing its latest magnitudes, $U \sim 9.7$, $B \sim 10.8$, $V \sim 10.0$, with those observed prior to the outburst ($U \sim 11.5$, $B \sim 12$, $V \sim 10.5$), indicates that Z And still remains at a high level of its activity.

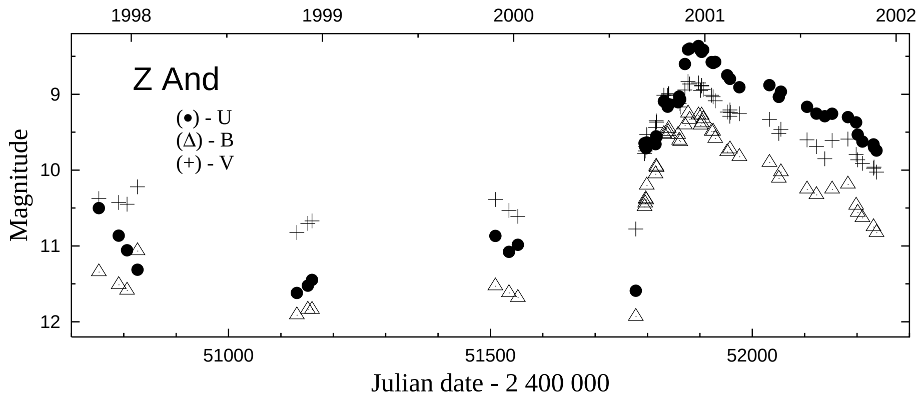

Figure 2. The U, B, V LCs of Z And.

3.3. BF Cyg

The photometric measurements of BF Cyg (MWC 315, Hen 1747) are given in Table 3. 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. In addition, for our CCD photometry we used the following sequence of standard stars: SAO 87137, BD+29 3581 and GSC 02137-02086. Figure 3 shows the U, B, V LCs from 1995.8. The periodic wave-like variation in the optical continuum reflects a quiescent phase of this star. The profile of LCs is not a simple sinusoid through the orbital period, but reflects the rather complex shape and variation of the nebula in the binary. For example, the star's brightness at the light minima gradually decreases. The JD 2 450 684.5 minimum occurred at $U \sim 12.5$, $B \sim 12.9$, $V \sim 12.4$, while the recent minimum observed around JD 2 452 173 showed magnitudes of $U \sim 12.8$, $B \sim 13.3$, $V \sim 12.7$. In addition, short-term unpredicted fading in the star's brightness, in all bands was observed at ~JD 2 451 089 ($\varphi \sim 0.55$) and at ~JD 2 451 700 ($\varphi \sim 0.38$). These events could be ascribed to an occultation of the hot component by an extra blob of the neutral material from the giant component. Finally, complex secondary minima can be recognized in the U, B, V LCs around 1998.6 and 2000.7 (see Fig. 3), when the hot star is in front ($\varphi \sim 0.5$). Such evolution reflects a shrinking of the nebula that is probably due to a decrease of the ionizing photons producing by the hot star.

3.4. CH Cyg

Our new photometry of CH Cyg (HD 182917, BD+49 2999) is listed in Table 4. Measurements were done with respect to the same standard stars as in Paper IX (Skopal et al. 2000a). Additional comparison stars, SAO 48428, SAO 31628 and BD+49 3005, were used for our CCD photometry. Figure 4 displays the U, B, V LCs covering the period from 1995.8. It shows that the recent episode of activity

Table 2. U, B, V, R observations of Z And

Date	JD 24...	Phase*	U	B	V	ΔR	Obs
Oct 30, 97	50752.390	0.654	10.501	11.344	10.375	3.671†	SP
Dec 07, 97	50790.366	0.704	10.864	11.513	10.428	3.766†	SP
Dec 23, 97	50806.321	0.726	11.057	11.587	10.449	3.826†	SP
Jan 12, 98	50826.257	0.752	11.313	11.068	10.221	0.896	SP
Nov 13, 98	51130.532	0.153	11.620	11.912	10.823	4.167†	SP
Dec 03, 98	51151.325	0.180	11.524	11.838	10.702	4.090†	SP
Dec 11, 98	51159.378	0.191	11.447	11.841	10.670	4.050†	SP
Nov 26, 99	51509.430	0.652	10.867	11.530	10.388	0.289	SP
Dec 22, 99	51535.364	0.686	11.078	11.620	10.532	0.437	SP
Jan 08, 00	51552.321	0.709	10.984	11.684	10.610	0.487	SP
Aug 20, 00	51777.449	0.005	11.590	11.933	10.777	0.752	SP
Sep 06, 00	51794.368	0.028	9.645	10.485	9.783	–	SL
Sep 08, 00	51795.531	0.029	9.691	10.438	9.748	0.106	SP
Sep 09, 00	51796.555	0.031	9.689	10.383	9.691	3.512†	SP
Sep 09, 00	51797.363	0.032	9.711	10.396	9.695	–	SL
Sep 11, 00	51798.612	0.033	9.635	10.202	9.532	3.406†	SP
Sep 27, 00	51815.331	0.055	9.658	10.054	9.436	3.318†	SP
Sep 29, 00	51816.510	0.057	9.555	9.952	9.350	-0.186	SP
Sep 29, 00	51817.263	0.058	9.562	9.970	9.367	-0.176	SP
Oct 13, 00	51831.276	0.076	9.094	9.524	9.013	–	SL
Oct 20, 00	51838.286	0.086	9.163	9.533	9.015	–	SL
Oct 21, 00	51839.369	0.087	9.135	9.495	8.998	–	SL
Oct 22, 00	51840.475	0.088	9.131	9.455	8.991	-0.387	SP
Nov 09, 00	51858.360	0.112	9.106	9.533	9.064	-0.347	SP
Nov 11, 00	51860.249	0.114	9.029	9.610	9.122	–	SL
Nov 13, 00	51862.326	0.117	9.068	9.627	9.167	-0.284	SP
Nov 22, 00	51871.313	0.129	8.601	9.408	8.944	–	SL
Nov 28, 00	51877.428	0.137	8.410	9.252	8.832	-0.557	SP
Dec 01, 00	51880.311	0.141	8.398	9.334	8.864	–	SL
Dec 18, 00	51897.240	0.163	8.364	9.278	8.850	–	SL
Dec 22, 00	51901.309	0.169	8.420	9.410	8.949	–	SL
Dec 24, 00	51903.184	0.171	8.441	9.280	8.883	-0.606	SP
Dec 24, 00	51903.344	0.171	–	9.380	8.890	–	R
Dec 27, 00	51906.276	0.175	8.415	9.328	8.935	-0.647	SP
Jan 12, 01	51922.346	0.196	8.575	9.492	9.013	-0.465	SP
Jan 15, 01	51925.304	0.200	8.588	9.491	9.033	-0.447	SP
Jan 19, 01	51929.212	0.205	8.573	9.586	9.086	–	SL
Feb 11, 01	51952.236	0.236	8.749	9.761	9.234	–	SL
Feb 16, 01	51957.229	0.242	–	–	9.290	–	R
Feb 16, 01	51957.276	0.242	8.797	9.725	9.207	-0.331	SP
Feb 17, 01	51958.228	0.244	–	–	9.240	–	R
Mar 06, 01	51975.248	0.266	8.907	9.824	9.257	-0.286	SP
May 03, 01	52032.553	0.342	8.880	9.902	9.331	–	SL
May 21, 01	52050.526	0.365	9.035	10.111	9.516	–	SL
May 25, 01	52054.503	0.370	8.966	10.026	9.461	–	SL
Jul 13, 01	52104.462	0.436	9.166	10.254	9.601	–	SL
Jul 31, 01	52122.470	0.460	9.255	10.327	9.690	–	SL
Aug 16, 01	52138.387	0.481	9.3	–	9.85	–	SL::
Aug 30, 01	52152.472	0.500	9.257	10.254	9.610	3.366†	SP
Sep 29, 01	52182.479	0.539	9.302	10.188	9.591	-0.066	SP
Oct 15, 01	52198.281	0.560	9.370	10.467	9.794	–	SL
Oct 18, 01	52201.276	0.564	9.532	10.560	9.865	0.079	SP
Oct 27, 01	52210.211	0.576	9.623	10.630	9.910	0.095	SP
Nov 17, 01	52231.369	0.604	9.661	10.751	9.975	–	SL
Nov 18, 01	52232.342	0.605	9.700	–	9.960	0.150	SP::
Nov 23, 01	52237.255	0.611	9.74	10.83	10.03	–	SL::

* $JD_{\rm sp.conj.} = 2\,445\,703.0 + 758.8 \times E$ (Mikolajewska & Kenyon 1996)

† $\Delta R =$ Z And - SAO 35642

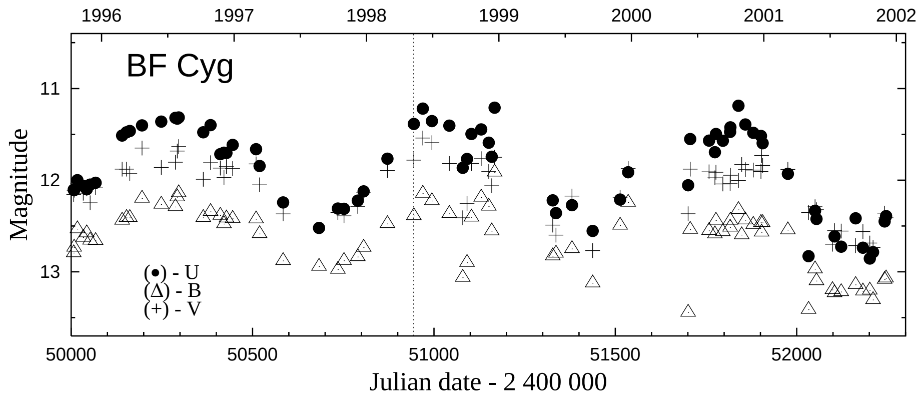

Figure 3. The UBV LCs of BF Cyg. New data presented in this paper are plotted on the right of the vertical dotted line.

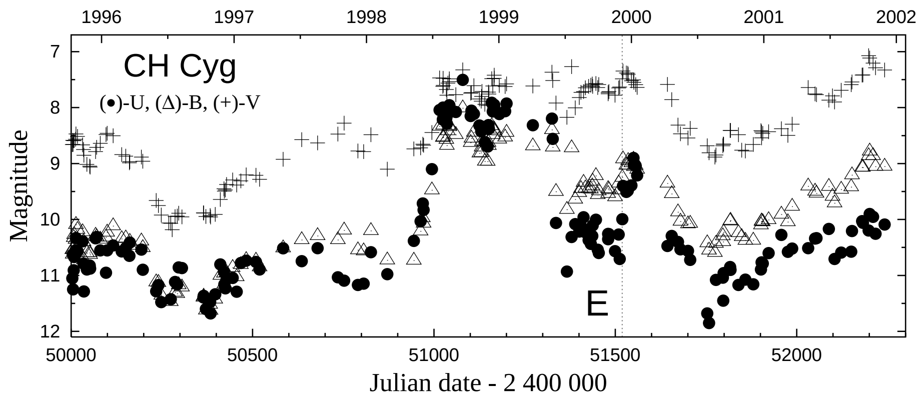

Figure 4. As in Fig. 3, but for CH Cyg. **E** denotes the eclipse in the outer binary.

ended in Spring 2000. A more detailed analysis of this active phase is given by Eyres et al. (2002). Our observations allowed us to determine the position of a broad minimum at JD 2 451 426±3, caused by the eclipse of the active star in the inner binary (the symbiotic pair) by the cool giant on the outer orbit. The profile of the U, B, V LCs observed after the recent activity, around 2000.7, is similar to that which occurred after the previous active phase, around 1996.5. Recent observations indicate a slow increase in the star's brightness.

3.5. V1329 Cyg

Our observations of the symbiotic nova V1329 Cyg (HBV 475) are given in Table 5. The stars BD+35 4290 (V=10.34, $B-V$=1.07, $U-B$=0.88) and BD+35 4294 (V=10.16, $B-V$=1.07) were used as the comparison and check, respectively.

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

Date	JD 24...	Phase*	U	B	V	ΔR	Obs
May 11, 98	50944.508	0.378	11.387	12.391	11.781	3.960	SP
Jun 04, 98	50969.458	0.411	11.219	12.147	11.540	3.830	SP
Jun 29, 98	50994.428	0.444	11.356	12.228	11.592	3.847	SP
Aug 16, 98	51042.484	0.508	11.406	12.366	11.819	4.054	SP
Sep 22, 98	51079.341	0.556	11.866	13.064	12.410	4.286	SP
Oct 04, 98	51091.252	0.572	11.769	12.900	12.253	4.190	SP
Oct 16, 98	51103.281	0.588	11.496	12.406	11.817	4.124	SP
Nov 12, 98	51130.278	0.624	11.447	12.189	11.766	4.096	SP
Dec 03, 98	51151.201	0.651	11.592	12.287	11.906	4.254	SP
Dec 11, 98	51159.228	0.662	11.744	12.557	12.061	4.316	SP
Dec 19, 98	51167.322	0.672	11.210	11.915	11.750	4.300	SP
May 29, 99	51327.533	0.884	12.220	12.830	12.490	4.770	SP
Jun 07, 99	51336.500	0.896	12.36	12.8	12.6	3.38†	SP::
Jul 21, 99	51380.507	0.954	12.273	12.750	12.174	4.605	SP
Sep 15, 99	51437.353	0.029	12.554	13.125	12.768	4.994	SP
Nov 30, 99	51513.273	0.129	12.212	12.494	12.187	2.451†	SP
Dec 22, 99	51535.205	0.158	11.913	12.244	11.874	4.478	SP
Jun 04, 00	51700.487	0.376	12.055	13.445	12.367	4.131	SP
Jun 10, 00	51706.488	0.384	11.551	12.540	11.880	–	SL
Aug 01, 00	51758.388	0.453	11.569	12.552	11.909	–	SL
Aug 17, 00	51774.372	0.474	11.695	12.589	11.975	–	SL
Aug 20, 00	51777.369	0.478	11.496	12.441	11.914	4.094	SP
Sep 08, 00	51796.461	0.503	11.570	12.566	12.041	4.172	SP
Sep 28, 00	51816.455	0.530	11.474	12.516	12.038	4.175	SP
Sep 29, 00	51817.299	0.531	11.424	12.440	11.946	4.133	SP
Oct 21, 00	51839.293	0.560	11.188	12.324	12.004	–	SL
Oct 30, 00	51848.233	0.571	–	12.60	11.83	–	R
Nov 09, 00	51858.230	0.585	11.392	12.437	11.885	4.076	SP
Dec 01, 00	51880.236	0.614	11.484	12.486	11.890	–	SL
Dec 22, 00	51901.193	0.641	11.517	12.464	11.905	–	SL
Dec 24, 00	51903.188	0.644	–	12.57	11.73	–	R
Dec 27, 00	51906.191	0.648	11.597	12.466	11.840	4.020	SP
Mar 07, 01	51975.614	0.740	11.931	12.545	11.882	4.111	SP
May 02, 01	52032.491	0.815	12.830	13.413	12.354	–	SL
May 20, 01	52050.431	0.839	12.334	12.972	12.290	–	SL
May 24, 01	52054.425	0.844	12.423	13.101	12.322	–	SL
Jul 07, 01	52098.436	0.902	–	13.198	12.699	4.384	SP::
Jul 13, 01	52104.431	0.910	12.614	13.231	12.551	–	SL
Jul 31, 01	52122.411	0.934	12.726	13.220	12.556	–	SL
Sep 09, 01	52162.288	0.986	12.417	13.142	12.715	–	SL
Sep 29, 01	52182.419	0.013	12.737	13.213	12.561	4.985	SP
Oct 18, 01	52201.335	0.038	12.855	13.203	12.686	4.994	SP
Oct 27, 01	52210.332	0.050	12.786	13.306	12.735	5.007	SP
Nov 28, 01	52242.257	0.092	12.450	13.085	12.360	4.751	SP

* $Min = JD\,2\,415\,065 + 757.3 \times E$ (Pucinskas 1970)

† ΔR = BF Cyg - BD+30 3594

Figure 5 shows the U, B, V LCs from 1987.5. A wave-like variation, which mimics a reflection effect, represents the dominant feature of these LCs. At light maxima the star's brightness is highest in the U band, while at the minima, $U \sim V$. This indicates a strong nebular component of radiation in the system resulting from both a high luminosity of the hot ionizing object and a high mass loss rate from the cool component (M6 III giant).

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

Date	JD 24...	Phase*	U	B	V	ΔR	Obs
Dec 08, 99	51521.168	0.451	9.400	8.921	7.346	–	SL
Dec 17, 99	51530.181	0.463	9.507	9.036	7.380	–	SL
Dec 21, 99	51534.175	0.468	9.486	9.034	7.385	–	SL
Dec 22, 99	51535.261	0.470	9.414	8.952	7.408	-0.951	SP
Dec 31, 99	51544.222	0.482	9.391	8.992	7.520	–	SP
Jan 06, 00	51550.190	0.490	8.900	8.929	7.503	–	SL
Jan 07, 00	51551.186	0.491	9.023	9.058	7.547	–	SL
Jan 12, 00	51556.184	0.498	9.045	9.037	7.590	–	SL
Jan 16, 00	51560.202	0.503	9.212	9.108	7.639	–	SL
Apr 09, 00	51643.566	0.613	10.473	9.357	7.586	–	SL
Apr 20, 00	51655.386	0.629	10.294	9.545	7.858	–	SL
May 08, 00	51672.509	0.651	10.402	9.869	8.313	-0.257	SP
May 15, 00	51679.534	0.661	10.534	10.036	8.469	-0.114	SP
Jun 04, 00	51700.415	0.688	10.562	10.084	8.543	-0.057	SP
Jun 10, 00	51706.404	0.696	10.721	10.073	8.370	–	SL
Jul 27, 00	51753.381	0.758	11.680	10.422	8.683	–	SL
Aug 01, 00	51758.335	0.765	11.852	10.552	8.808	–	SL
Aug 17, 00	51774.322	0.786	12.420	10.595	8.885	–	SL
Aug 20, 00	51777.411	0.790	11.079	10.431	8.847	0.219	SP
Sep 08, 00	51796.408	0.815	11.040	10.297	8.683	0.086	SP
Sep 09, 00	51797.274	0.816	11.452	10.401	8.651	–	SL
Sep 11, 00	51798.576	0.818	10.960	10.230	8.656	0.034	SP
Sep 28, 00	51816.407	0.842	10.850	10.031	8.408	-0.159	SP
Sep 29, 00	51817.344	0.843	10.900	10.020	8.407	-0.160	SP
Oct 21, 00	51839.253	0.872	11.170	10.240	8.485	–	SL
Oct 30, 00	51848.257	0.884	–	10.31	8.76	–	R
Nov 09, 00	51858.288	0.897	11.076	10.379	8.774	0.089	SP
Dec 01, 00	51880.195	0.926	11.159	10.375	8.658	–	SL
Dec 22, 00	51901.230	0.954	10.894	10.101	8.413	–	SL
Dec 24, 00	51903.205	0.957	–	10.04	8.54	–	R
Dec 24, 00	51903.256	0.957	10.767	10.032	8.436	-0.132	SP
Dec 27, 00	51906.239	0.961	10.787	10.046	8.462	-0.113	SP
Jan 13, 01	51922.682	0.982	10.602	10.009	8.431	-0.196	SP
Feb 17, 01	51957.571	0.029	10.275	9.912	8.378	-0.225	SP
Mar 07, 01	51975.554	0.052	10.579	10.047	8.497	-0.143	SP
Mar 19, 01	51987.502	0.068	10.519	9.769	8.297	-0.249	SP
May 01, 01	52031.431	0.126	10.513	9.406	7.641	–	SL
May 20, 01	52050.387	0.151	10.342	9.501	7.756	–	SL
May 24, 01	52054.384	0.157	10.334	9.534	7.770	–	SL
Jun 27, 01	52088.417	0.202	10.17	9.42	7.87	-0.72	SP:
Jul 07, 01	52098.375	0.215	–	9.591	7.789	-0.661	SP
Jul 13, 01	52104.350	0.223	10.706	9.708	7.899	–	SL
Jul 31, 01	52122.377	0.247	10.591	9.465	7.690	–	SL
Aug 28, 01	52150.314	0.283	10.575	9.420	7.590	–	SL
Aug 30, 01	52152.372	0.286	10.207	9.207	7.540	-0.886	SP
Sep 27, 01	52180.373	0.323	10.029	9.070	7.417	-1.005	SP
Sep 29, 01	52182.371	0.326	10.060	9.073	7.416	-0.998	SP
Oct 15, 01	52198.234	0.347	10.197	8.866	7.071	–	SL
Oct 18, 01	52201.231	0.351	9.902	8.783	7.113	-1.223	SP
Oct 27, 01	52210.332	0.363	9.953	8.864	7.205	-1.169	SP
Nov 03, 01	52217.275	0.372	10.256	9.055	7.287	–	SL
Nov 28, 01	52242.308	0.405	10.091	9.053	7.328	-1.006	SP

* $Min = JD\,2\,445\,888 + 756 \times E$ (Skopal 1995)

3.6. AG Dra

Observations of AG Dra (SAO 16931, BD+67 922) are compiled in Table 6. We used the same standard stars as in Paper VIII (Skopal 1998a). For the CCD

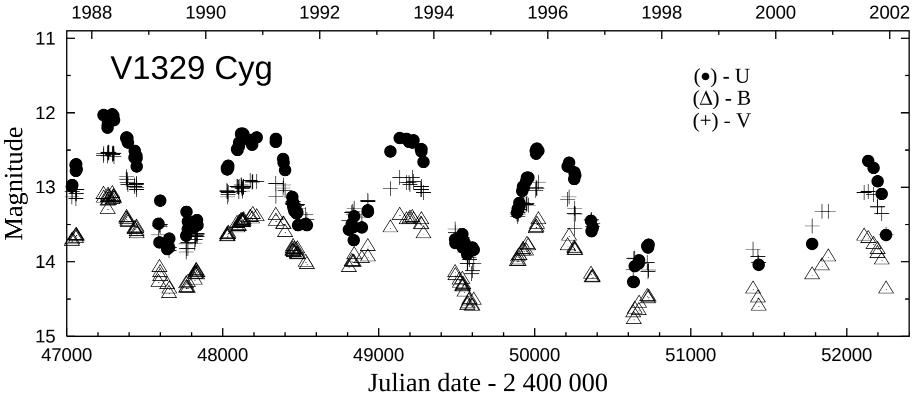

Figure 5. As in Fig. 3, but for V1329 Cyg. Our data (from 1999 August 9) are compiled with those of Chochol et al. (1999).

Table 5. U, B, V observations of V1329 Cyg.

Date	JD 24...	Phase*	U	B	V	Obs
Aug 09, 99	51399.566	0.752	–	14.370	13.830	SL
Sep 08, 99	51430.468	0.784	–	14.490	13.930	SL
Sep 13, 99	51435.410	0.790	14.040	14.600	14.010	SL
Aug 21, 00	51778.417	0.148	13.760	14.180	13.520	SL
Oct 23, 00	51841.249	0.213	–	14.060	13.320	SL
Oct 30, 00	51848.278	0.221	–	13.96	13.13	R
Dec 02, 00	51881.193	0.255	–	13.940	13.320	SL
Jul 21, 01	52111.518	0.495	–	13.660	13.070	SL
Aug 15, 01	52137.392	0.522	12.647	13.692	13.055	SL
Sep 19, 01	52172.313	0.559	12.740	13.770	13.100	SL
Oct 13, 01	52196.279	0.584	–	13.894	13.266	SL
Oct 15, 01	52198.326	0.586	12.920	13.840	13.260	SL
Nov 10, 01	52224.322	0.613	13.090	13.980	13.350	SL
Dec 08, 01	52252.191	0.642	13.64	14.37	13.63	SL::

* $JD_{\rm eclipse} = 2\,427\,687 + 958.0 \times E$ (Schild & Schmid 1997)

measurements we used an additional standard star, GSC 04195-00369. Our measurements cover the recent two eruptions with maxima at 1998.6 and 2001.8. Figure 6 shows the U, B, V LCs covering the recent active phase of AG Dra, which began in 1994.5 displaying a massive eruption. Our data in the figure are compiled with those published by Montagni et al. (1996), Greiner et al. (1997), Mikolajewski (1997), Tomova & Tomov (1998), Petrík et al. (1998) and Tomov & Tomova, (2000). Agreement between all data sets is very good. All eruptions are most pronounced in the U band. For example, for the recent 2000.8 small eruption $\Delta U \sim 1.2$, $\Delta B \sim 0.5$ and $\Delta V \sim 0.2$ mag. Such behaviour suggests a nebular origin of the light during the activity. This is also supported by the SED presented by Greiner et al. (1997), and the fact that the yellow cool giant (spectrum K2) in the system dominates the V band.

Table 6. U, B, V, R observations of AG Dra

Date	JD 24...	Phase*	U	B	V	ΔR	Obs
May 29, 98	50963.380	0.341	11.102	11.113	9.767	–	SL
Jun 06, 98	50971.366	0.356	11.062	11.150	9.795	–	SL
Jun 29, 98	50994.468	0.398	10.800	11.052	9.755	-0.651	SP
Jul 20, 98	51015.372	0.436	10.086	10.721	9.631	–	SL
Jul 21, 98	51016.361	0.438	9.531	10.427	9.461	-0.868	SP
Jul 29, 98	51024.362	0.452	9.107	10.169	9.291	–	SL
Jul 30, 98	51025.355	0.454	9.111	10.231	9.316	–	SL
Aug 05, 98	51031.331	0.465	9.3	–	–	–	SP::
Aug 09, 98	51034.524	0.471	9.264	10.244	9.338	-1.021	SP
Aug 15, 98	51041.328	0.483	9.086	10.296	9.394	–	SL
Aug 17, 98	51042.563	0.486	9.097	10.227	9.346	-1.055	SP
Sep 04, 98	51060.553	0.518	9.473	10.514	9.531	-0.926	SP
Sep 23, 98	51079.593	0.553	9.834	10.617	9.546	-0.906	SP
Oct 14, 98	51101.290	0.592	10.350	10.881	9.677	–	SL
Oct 23, 98	51110.245	0.609	10.444	10.878	9.683	–	SL
Nov 07, 98	51125.255	0.636	10.727	10.914	9.712	–	SL
Nov 12, 98	51130.478	0.645	10.815	10.925	9.684	-0.729	SP
Dec 12, 98	51159.657	0.699	11.097	10.989	9.699	-0.678	SP
Jan 06, 99	51185.389	0.745	11.230	11.060	9.774	-0.644	SP
Jan 21, 99	51200.278	0.772	11.277	11.036	9.740	–	SL
Jan 24, 99	51202.566	0.777	11.294	11.000	9.749	-0.643	SP
Feb 27, 99	51237.330	0.840	11.282	11.081	9.747	–	SL
Apr 03, 99	51272.473	0.904	11.347	11.161	9.815	–	SL
May 28, 99	51327.463	0.004	11.406	11.144	9.746	-0.663	SP
Sep 14, 99	51436.311	0.202	11.316	11.108	9.773	–	SL
Sep 15, 99	51437.290	0.204	11.332	11.116	9.767	-0.635	SP
Sep 25, 99	51446.609	0.221	11.462	11.154	9.822	-0.592	SP
Nov 27, 99	51509.658	0.335	11.190	11.048	9.707	-0.682	SP
Nov 28, 99	51510.606	0.337	11.163	11.085	9.727	-0.654	SP
Dec 23, 99	51535.625	0.382	11.174	11.029	9.645	-0.730	SP
Jan 09, 00	51552.515	0.413	11.096	11.072	9.743	-0.644	SP
Feb 22, 00	51597.472	0.495	11.027	11.038	9.721	-0.660	SP
Apr 20, 00	51655.344	0.600	–	11.028	9.764	–	SL
Jun 04, 00	51700.372	0.682	11.062	11.146	9.790	-0.606	SP
Aug 17, 00	51774.415	0.817	11.161	11.109	9.779	–	SL
Aug 21, 00	51777.566	0.823	–	11.22	9.92	-0.47	SP:
Sep 09, 00	51797.298	0.858	11.174	11.069	9.722	–	SL
Sep 28, 00	51816.302	0.893	11.292	11.136	9.758	-0.606	SP
Oct 21, 00	51839.226	0.935	11.528	11.109	9.732	–	SL
Oct 30, 00	51848.200	0.951	–	11.03	9.80	–	R
Dec 22, 00	51900.694	0.047	11.657	11.162	9.772	–	SL
Dec 24, 00	51903.354	0.051	–	–	9.703	-0.846	SP
Dec 25, 00	51904.638	0.054	–	11.07	9.86	–	R
Jan 10, 01	51919.652	0.081	11.703	11.161	9.776	–	SL
Jan 13, 01	51922.616	0.086	11.684	11.186	9.775	-0.600	SP
Feb 16, 01	51957.401	0.150	11.560	11.147	9.780	-0.560	SP
Feb 17, 01	51958.540	0.152	–	11.10	9.91	–	R
Mar 06, 01	51975.495	0.183	11.501	11.171	9.794	-0.607	SP
Mar 18, 01	51987.446	0.204	11.442	11.182	9.799	-0.574	SP
Mar 18, 01	51987.411	0.204	11.360	11.129	9.778	–	SL
May 01, 01	52031.400	0.284	11.133	11.036	9.704	–	SL
May 20, 01	52050.352	0.319	11.101	11.040	9.699	–	SL
Jul 13, 01	52104.386	0.417	10.804	11.012	9.693	–	SL
Aug 01, 01	52122.535	0.450	10.548	10.964	9.704	–	SL
Aug 30, 01	52152.422	0.504	10.560	11.071	9.823	-0.606	SP
Sep 20, 01	52173.268	0.542	10.571	10.988	9.735	–	SL
Sep 27, 01	52180.314	0.555	10.456	10.863	9.674	-0.691	SP
Sep 29, 01	52182.313	0.559	10.429	10.916	9.695	-0.691	SP
Oct 16, 01	52199.234	0.590	10.147	10.745	9.609	–	SL

Table 6. continued

Date	JD 24...	Phase*	U	B	V	ΔR	Obs
Oct 18, 01	52201.441	0.594	10.309	10.779	9.623	-0.749	SP
Oct 27, 01	52210.455	0.610	9.93	–	–	–	SP::
Oct 31, 01	52214.210	0.617	9.877	10.632	9.540	–	SL
Nov 03, 01	52217.244	0.622	9.830	10.619	9.533	–	SL
Nov 23, 01	52237.197	0.659	10.117	10.744	9.580	–	SL
Dec 02, 01	52246.277	0.675	10.291	10.753	9.625	–	SL

* $Min = JD\,2\,443\,629.17 + 549.73 \times E$ (Gális et al. 1999)

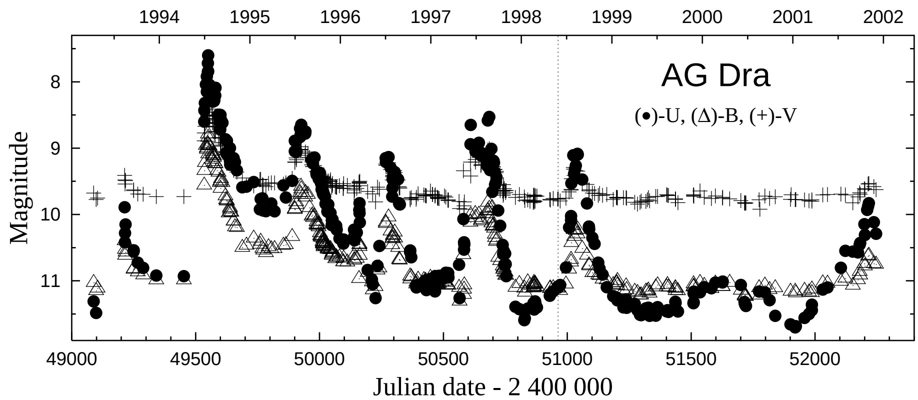

Figure 6. As in Fig. 3, but for AG Dra.

3.7. RW Hya

The U, B, V measurements of RW Hya (HD 117970) are listed in Table 7. Observation was carried out at the San Pedro Observatory during June 2001 (Sect. 2). Stars HD 118102 (CD-24 10984; V = 8.94, $B - V$ = 0.53, $U - B$ = 0.11) and HD 117971 (CD-25 9879; V = 9.69, $B - V$ = 0.44, $U - B$ = -0.03), were used as a comparison and a check star, respectively. Our photoelectric observations are in very good agreement with those published by Munari et al. (1992). This star was also observed visually during the period from 1989.0 to 2001.7.

Figure 7 shows the phase diagrams of our visual observations. Photoelectric measurements in the U band show a steep decrease of the brightness towards the orbital phase 0. This suggests a large amplitude of the LC in U. However more observations covering a larger part of the orbital cycle are needed to determine the acurate profile of the LC in the blue continuum. Visual data displays a complex wave-like variation throughout the orbital cycle. The data were folded according to ephemeris of the inferior spectroscopic conjunction of the giant star in RW Hya (Schild et al. 1996). We can see that the light minimum precedes the time of the spectroscopic conjunction of the giant (given in the figure by the orbital phase 0 or 1). This is consistent with revealing of Skopal (1998b), who showed that during quiescent phases the light minima occur prior to the time of the inferior conjunction of the cool component. The effect is best seen in eclipsing systems.

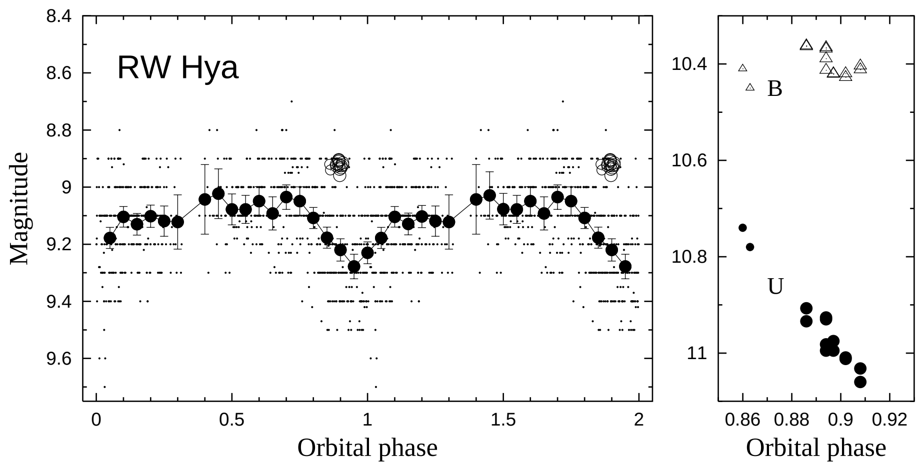

Figure 7. Left: Phase diagram for our visual estimates of RW Hya: (dots) - all individual observations, (•) - mean values made in bins of $\Delta\varphi = 0.05$ with corresponding uncertainty (rms). The average uncertainty of the individual estimates was adopted to 0.3 mag. Our photoelectric V measurements (◯) and those of Munari et al. (1992) (∘) are compared. The difference between the visual and photoelectric data sets is probably caused by the different comparison stars used. Right: Detail of a phase diagram for our photoellectric measurements in U and B. The smaller marks denote the data of Munari et al. (1992).

Table 7. U, B, V observations of RW Hya

Date	JD 24...	Phase*	U	B	V	Obs
Jun 02, 01	52062.684	0.886	10.907	10.362	8.926	M
——	52062.685	0.886	10.934	10.364	8.919	M
Jun 05, 01	52065.664	0.894	10.995	10.413	8.922	M
——	52065.669	0.894	10.926	10.389	8.910	M
——	52065.674	0.894	10.930	10.369	8.904	M
——	52065.674	0.894	10.982	10.366	8.906	M
Jun 06, 01	52066.671	0.897	10.975	10.420	8.959	M
——	52066.677	0.897	10.995	10.421	8.937	M
Jun 08, 01	52068.675	0.902	11.009	10.420	8.932	M
——	52068.680	0.902	11.012	10.428	8.925	M
Jun 10, 01	52070.700	0.908	11.060	10.412	8.922	M
——	52070.705	0.908	11.032	10.404	8.915	M

* $JD_{\rm sp.conj.} = 2\,449\,512 + 370.4 \times E$ (Schild, Mürset & Schmutz 1996)

3.8. AX Per

The recent measurements of AX Per (MWC 411, GCRV 896) in the U, B, V, R bands are given in Table 8 and showed in Fig. 8. Also in this case we used the same standard stars as in Paper IX. For our CCD photometry the stars BD+53 340, GSC 03671-00025 and GSC 03671-00791 were used as standards.

Observations of this star show a periodic wave-like variation – a typical feature of a quiescent phase. The minima profiles and their depths are different during different orbital cycles. Recently, a secondary minimum at/around the orbital phase 0.5 was seen best in the V and B bands. As in the case of BF Cyg, this behaviour reflects the evolution in the nebula around the hot ionizing source after the recent active phase, which started in 1988.2. Note that BF Cyg also underwent a phase of activity, which began in 1989.3.

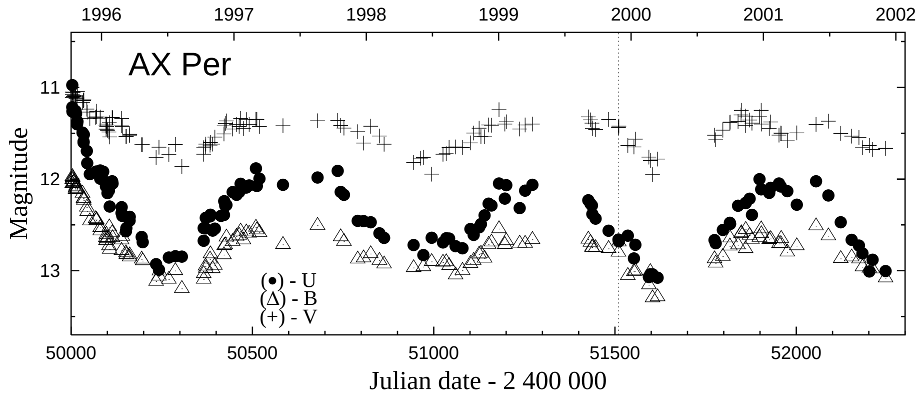

Figure 8. As in Fig. 3, but for AX Per.

3.9. IV Vir

The U, B, V measurements of IV Vir (BD-21 3873) are listed in Table 9. Observations were carried out at the San Pedro Observatory during June 2001 (Sect. 2). Stars HD 124991 (BD-21 3877; $V = 8.07$, $B - V = 1.05$, $U - B = 0.73$) and HD 125081 (MX Vir; $V = 7.27$, $B - V = 0.43$, $U - B = 0.16$), were used as standards. This star was also observed visually by one of us (AJ) during the period 1989.0 to 2001.7.

Figure 9 shows the phase diagram of our observations of IV Vir. It displays a double-wave variation throughout the orbital cycle. The data were folded according to the ephemeris of the inferior spectroscopic conjunction of the cool component in the system. The LC profile is similar to that measured in the Strömgren y band (Fig. 8 of Smith et al. 1997). The maximum amplitude ($\sim$ depth of the primary minimum) is about 0.2 mag, while the secondary minimum is only about 0.15 mag deep. Currently such periodic light variations are

Table 8. U, B, V, R observations of AX Per

Date	JD 24...	Phase*	U	B	V	ΔR	Obs
Dec 22, 99	51535.406	0.859	12.618	13.055	11.634	3.438	SP
Jan 08, 00	51552.377	0.884	12.867	13.012	11.650	3.452	SP
Jan 12, 00	51556.247	0.890	12.717	13.006	11.565	–	SL
Feb 18, 00	51593.290	0.944	13.070	13.158	11.760	–	SL
Feb 22, 00	51597.367	0.950	13.040	13.013	11.797	3.582	SP
Feb 28, 00	51603.304	0.959	13.040	13.300	11.952	–	SL
Mar 13, 00	51617.313	0.980	13.077	13.288	11.781	3.547	SP
Aug 17, 00	51774.452	0.211	12.666	12.874	11.522	–	SL
Aug 21, 00	51777.518	0.215	12.701	12.920	11.571	3.334	SP
Sep 09, 00	51797.394	0.245	12.556	12.847	11.466	–	SL
Sep 29, 00	51816.614	0.273	12.478	12.735	11.384	3.198	SP
Sep 30, 00	51817.625	0.274	12.490	12.647	11.378	3.153	SP
Oct 21, 00	51839.340	0.306	12.292	12.722	11.373	–	SL
Oct 29, 00	51847.464	0.318	–	12.60	11.30	–	R
Oct 30, 00	51848.462	0.319	–	12.59	11.25	–	R
Nov 11, 00	51860.285	0.337	12.263	12.763	11.416	–	SL
Nov 12, 00	51860.629	0.338	12.26	12.6	11.31	3.13	SP::
Nov 22, 00	51871.386	0.353	12.215	12.617	11.356	–	SL
Nov 29, 00	51877.606	0.363	12.391	12.661	11.390	3.169	SP
Dec 19, 00	51898.433	0.393	12.002	12.639	11.320	–	SL
Dec 24, 00	51903.309	0.400	12.112	12.547	11.250	3.057	SP
Dec 24, 00	51903.372	0.400	–	12.60	11.40	–	R
Jan 15, 01	51925.415	0.433	12.151	12.664	11.449	3.190	SP
Jan 19, 01	51929.310	0.439	12.095	12.654	11.377	–	SL
Feb 11, 01	51952.315	0.472	12.049	12.708	11.520	–	SL
Feb 16, 01	51957.326	0.480	12.081	12.707	11.498	3.242	SP
Feb 17, 01	51958.319	0.481	–	12.65	11.50	–	R
Mar 06, 01	51975.330	0.506	12.133	12.800	11.583	3.218	SP
Apr 01, 01	52001.292	0.544	12.280	12.732	11.496	–	SL
May 25, 01	52054.523	0.623	12.024	12.514	11.404	–	SL
Jun 27, 01	52088.484	0.673	12.179	12.623	11.369	3.131	SP
Aug 01, 01	52122.503	0.723	12.472	12.871	11.502	–	SL
Aug 31, 01	52152.550	0.767	12.664	12.854	11.532	3.296	SP
Sep 20, 01	52172.608	0.796	12.726	12.875	11.547	3.318	SP
Sep 30, 01	52182.537	0.811	12.811	12.962	11.658	3.441	SP
Oct 18, 01	52201.487	0.839	13.009	12.976	11.634	3.401	SP
Oct 27, 01	52210.409	0.852	12.9	12.99	11.678	3.434	SP::
Dec 02, 01	52246.315	0.904	13.004	13.083	11.665	–	SL

* $Min = JD\,2\,436\,673.3 + 679.9 \times E$ (Skopal 1991)

Table 9. U, B, V observations of IV Vir

Date	JD 24...	Phase*	U	B	V	Obs
Jun 05, 01	52065.681	0.827	12.525	12.040	10.653	M
Jun 08, 01	52068.702	0.837	12.553	12.031	10.640	M
——	52068.705	0.837	12.694	12.013	10.625	M
Jun 10, 01	52070.733	0.845	12.716	12.059	10.634	M
——	52070.737	0.845	12.777	12.102	10.625	M
Jun 12, 01	52072.714	0.852	12.643	12.043	10.628	M
——	52072.718	0.852	12.579	12.021	10.624	M

* $JD_{\rm sp.conj.} = 2\,449\,016.9 + 281.6 \times E$ (Smith et al. 1997)

attributed to the ellipsoidal shape of the cool component due to the tidal distortions by the companion (e.g. Wilson and Vaccaro 1997). A rival interpretation, based on the extent of the nebula, was suggested by Skopal (2001).

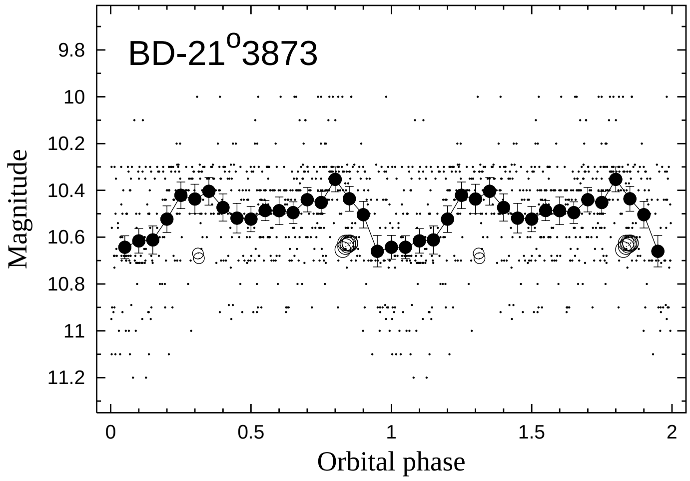

Figure 9. As in Fig. 7, but for IV Vir.

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