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ASTRONOMY AND ASTROPHYSICS

VBLUW photometry of the magnetic Ap stars HD 137949 (33 Lib), HD 201601 (γ Equ), HD 203006 (Θ Mic), and the peculiar shell star HD 190073

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Summary. *VBLUW* photometry (Walraven system) of three magnetic Ap stars and one peculiar shell star is presented. HD 137949 (33 Lib) shows no optical variations exceeding 0.01 mag, with respect to the proposed periods of $18^{\mathrm{d}}.4$ and $23^{\mathrm{d}}.26$. The peculiar shell star HD 190073 shows irregular light variations on a time scale of months, although the presence of shorter variations cannot be ruledout. For the star HD 201601 (γ Equ) it is still hard to except any of the three proposed periods: 317^{d}, $1785^{\mathrm{d}}.7$, and 72 yr, because of the limitations of the observations. The star HD 203006 (θ Mic) showing a periodic light variation with a double wave, has the revised period of $2^{\mathrm{d}}.1215 \pm 0^{\mathrm{d}}.0001$.

Key words: peculiar A stars – magnetic stars – variable stars – photometry

1. Introduction

VBLUW photometry (Walraven system) has been made in 1971 up to 1978, to study the variability of light and colours of three magnetic Ap stars HD 137949 (33 Lib), HD 201601 (γ Equ), and HD 203006 (θ Mic) and one peculiar shell star HD 190073. The reductions of the observations of these four stars are given and discussed.

2. The observations and reductions

The observations have been made with the Walraven *VBLUW* simultaneous photometer attached to the 90-cm light collector of the former Leiden Southern Station (at the SAAO annex) South Africa from 1971 up to 1978. A description of this system is given by Walraven and Walraven (1960), Rijf et al. (1969), and Lub and Pel (1977).

The program stars were measured relative to the comparison stars. Usually the variable was measured 4–8 times alternated by the comparison star. One such a series lasting about 15–30 min delivered one normal point. The sky brightnesses were taken nearby the program stars. Corrections for differential extinction were applied using extinction coefficients derived from standard stars at widely different sec *z*.

To make comparison with the *UBV* system possible, the *V* of the *UBV* system [called V_J], has been computed with the aid of Pel's (1976) formula. *B–V* of the *UBV* system [called $(B-V)_J$], has been transformed from the $V-B$ by means of Table 7 in Walraven et al. (1964), but corrected for a slight change in the response curve of the *V* band (Lub and Pel, 1977).

The values tabulated in Table 1 were derived from comparison with the standard stars and are generally the mean of three nights. The *VBLUW* data of the normal points of the variable stars are given in Table 2. The average mean errors of these normal points for each star are listed in Table 3. In Table 4 the average brightness and colours for the variable stars are given. The normal practice in the *VBLUW* system is that brightness and colours are expressed in terms of logarithm of the intensity rather than in magnitude.

3. Discussion on the individual stars

This section describes the analysis of the photometric variability and the periods.

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Table 1. Average brightness and colours of the comparison stars

Variable Star	Comparison Star	HD Sp	V	(V-B)	(B-U)	(U-W)	(B-L)	V_J	$(B-V)_J$
			in logarithm of intensity					in magnitude	
HD 137949	HD 138485	B3	.5502	-.0454	.0480	-.0083	.0163	5.506	-.145
			.0077	.0020	.0042	.0042	.0020	.019	.006
HD 190073	HD 189851	F0	-.6752	.1929	.4206	.1781	.2341	8.531	.480
			.0044	.0061	.0056	.0159	.0027	.011	.010
HD 201601	HD 201616	A2	.3226	.0126	.4267	.1135	.1636	6.065	.029
			.0048	.0035	.0069	.0260	.0050	.012	.007
HD 203006	HD 203585	A0p	.4236	-.0185	.3173	.0716	.1190	5.818	-.058
			.0103	.0029	.0010	.0046	.0018	.026	.007

Table 2. Brightness and colours of the program stars (normal points)

Variable Star	J.D. -2440000	n	V	(V-B)	(B-U)	(U-W)	(B-L)	V_J	$(B-V)_J$
				in logarithm of intensity				in magnitude	
HD 137949	1061.326	15	+.0673	+.1490	+.4244	+.1160	+.2588	6.682	+.380
	1062.368	17	.0733	.1490	.4204	.1230	.2588	6.667	.380
	1063.326	14	.0803	.1470	.4154	.1260	.2578	6.643	.378
	1064.472	12	.0743	.1490	.4134	.1310	.2578	6.664	.380
	1069.319	9	.0683	.1490	.4154	.1300	.2588	6.679	.380
	1078.306	14	.0703	.1480	.4227	.1180	.2558	6.674	.377
	1079.368	17	.0713	.1490	.4164	.1270	.2588	6.672	.380
	1086.316	10	.0713	.1490	.4114	.1280	.2568	6.672	.380
	1087.299	10	.0683	.1480	.4204	.1240	.2588	6.679	.377
	1088.295	11	.0763	.1460	.4204	.1160	.2578	6.660	.370
	1089.396	10	.0703	.1490	.4194	.1250	.2588	6.674	.380
	1096.434	11	.0703	.1490	.4234	.0970	.2578	6.674	.380
	1102.451	10	.0703	.1480	.4234	.0890	.2568	6.674	.377
	1103.375	11	.0683	.1490	.4314	.1100	.2578	6.679	.380
	1104.229	10	.0713	.1480	.4114	.1300	.2578	6.672	.377
	1110.288	12	.0673	.1490	.4114	.1340	.2578	6.683	.380
	1112.358	11	.0733	.1480	.4154	.1260	.2598	6.667	.377
	1113.351	10	.0703	.1480	.4174	.1260	.2598	6.674	.377
	1118.229	10	.0733	.1490	.4134	.1280	.2588	6.667	.380
	1121.135	10	.0713	.1480	.4134	.1230	.2578	6.672	.377
	1134.271	9	.0733	.1490	.4174	.1260	.2588	6.667	.380
	1135.250	10	.0693	.1480	.4194	.1230	.2588	6.677	.377
	1136.149	10	.0723	.1490	.4204	.1220	.2588	6.669	.380
	1142.156	8	.0703	.1480	.4174	.1240	.2508	6.674	.377
	2548.396	6	.0656	.1516	.4143	.1435	.2598	6.685	.382
	2590.308	2	.0681	.1512	.4158	.1352	.2590	6.679	.381
	2590.353	6	.0688	.1523	.4136	.1368	.2556	6.677	.383
	2609.354	5	.0681	.1497	.4153	.1436	.2596	6.679	.380
	2924.437	5	.0706	.1440	.4160	.1176	.2574	6.674	.365
	2938.260	5	.0714	.1409	.4197	.1184	.2610	6.673	.357
	2966.259	6	.0720	.1418	.4174	.1243	.2585	6.671	.360
	2986.283	6	.0679	.1435	.4199	.1184	.2582	6.681	.363
	2995.261	3	.0677	.1436	.4149	.1190	.2570	6.681	.363
	3187.561	6	.0706	.1427	.4158	.1196	.2577	6.674	.360
	3258.509	7	.0693	.1463	.4108	.1245	.2560	6.677	.371
	3319.392	3	.0689	.1454	.4140	.1247	.2538	6.678	.379
	3651.287	5	.0751	.1452	.4146	.1206	.2577	6.663	.379
HD 190073	3258.534	6	-.3845	+.0318	+.4012	+.0655	+.1260	7.830	.058
	3268.543	6	.3877	.0318	.4073	.0632	.1291	7.838	.058
	3277.534	5	.3963	.0333	.4183	.0746	.1321	7.859	.082
	3284.485	4	.3871	.0363	.3980	.1162	.1291	7.836	.090
	3294.530	6	.3847	.0326	.4014	.0762	.1273	7.830	.080
	3302.506	4	.3832	.0436	.4068	.0744	.1337	7.826	.085
	3308.468	6	.3933	.0334	.4136	.0805	.1348	7.852	.082
	3315.493	5	.3895	.0355	.4151	.0701	.1313	7.842	.088
	3320.443	5	.3993	.0327	.4110	.0640	.1343	7.867	.080
	3326.481	8	.3881	.0348	.4184	.0586	.1342	7.830	.086
	3332.511	3	.3903	.0361	.4218	.0655	.1296	7.844	.089
	3336.547	8	.3931	.0341	.4213	.0864	.1367	7.851	.084
	3341.473	6	.3948	.0311	.4138	.1010	.1327	7.856	.064
	3351.345	5	.3896	.0371	.4137	.0763	.1311	7.842	.092
	3359.428	4	.3940	.0334	.4124	.0825	.1304	7.854	.082
	3364.428	5	.3896	.0322	.4074	.0732	.1287	7.843	.080
	3373.401	7	.3935	.0325	.4126	.0657	.1287	7.853	.080
	3378.329	8	.3952	.0317	.4170	.0654	.1319	7.857	.078
	3384.3 4	9	.3935	.0343	.4106	.0720	.1316	7.852	.084
	3389.409	8	.3925	.0334	.4067	.0807	.1319	7.850	.082
HD 201601	2683.308	8	+.8644	+.0974	+.4073	+.1204	+.2307	4.697	+.247
	2714.275	6	.8618	.0975	.4081	.1231	.2312	4.704	.247
	2963.298	7	.8645	.0991	.4052	.1270	.2376	4.697	.250
	2990.439	5	.8621	.0979	.4067	.1258	.2307	4.705	.249
	3022.439	10	.8642	.0974	.4060	.1265	.2297	4.698	.247
	3064.252	5	.8639	.0970	.4070	.1272	.2326	4.698	.246
	3078.318	7	.8619	.0970	.4064	.1266	.2312	4.703	.246
	3377.364	3	.8585	.1009	.4060	.1244	.2321	4.711	.256
HD 203006	1998.194	9	+.8115	+.0117	+.3674	+.1020	+.1444	4.843	.027
	1999.191	9	.8134	.0196	.3614	.1042	.1478	4.837	.048
	2000.184	9	.8131	.0094	.3641	.1042	.1425	4.840	.022
	2004.198	12	.8161	.0078	.3643	.1052	.1424	4.832	.017
	2010.201	9	.8109	.0105	.3661	.1006	.1442	4.845	.024
	2012.215	11	.8107	.0161	.3646	.0997	.1465	4.845	.039
	2020.188	10	.8137	.0151	.3606	.1001	.1451	4.837	.036
	2021.194	7	.8150	.0136	.3628	.1033	.1439	4.834	.032
	2036.205	10	.8134	.0092	.3647	.0989	.1453	4.839	.022
	2037.201	10	.8182	.0139	.3569	.0983	.1454	4.826	.033
	2969.253	7	.8118	.0122	.3649	.1002	.1469	4.843	.029
	2996.454	5	.8155	.0168	.3632	.1024	.1485	4.835	.040
	3028.458	7	.8120	.0158	.3662	.1043	.1458	4.841	.038
	3059.302	2	.8099	.0136	.3647	.1031	.1445	4.847	.032
	3084.303	6	.8145	.0111	.3629	.1016	.1452	4.836	.026
	3383.303	3	.8115	.0077	.3657	.1069	.1419	4.844	.017
	3410.364	2	.8130	.0190	.3622	.1062	.1460	4.838	.047
	3422.288	4	.8096	.0176	.3691	.1069	.1497	4.847	.041

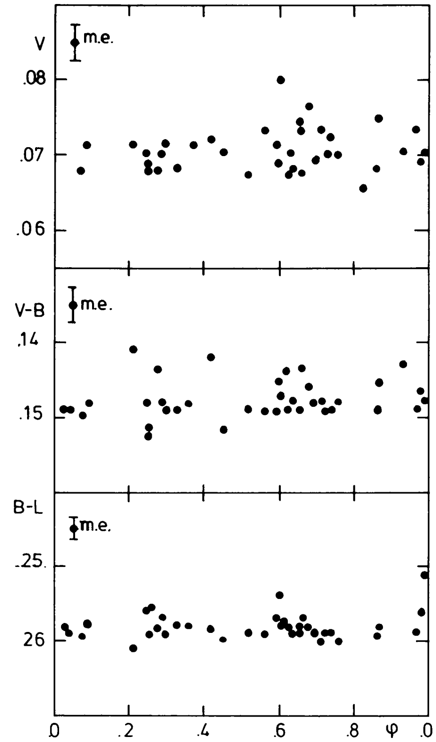

Fig. 1. The light- and colour-curves (in log intensity scale) of HD 137949 using a period of $23^{d}.26$

3.1. HD *137949 (33* Lib*)*

3.1.1. Introduction

The literature gives of this cool magnetic star of spectral type F0p a few surveys of photometry. Abt and Golson (1962) give four dates on which they observed this star. They concluded that the star is non-variable. Wolff (1975) found no variability that exceeded 0.01 mag in brightness and colours. Vogt and Faundez (1979) published three observations of the star. The V_J mag given by them (6.674) agrees very well with ours (6.678, Table IV). Van Dijk et al. (1978) find no variability in the ultra violet region and Bonsack (1974) concludes non-variability on the basis of spectroscopic equivalent line width observations. Determinations of $V \sin i$ suggest a long period (Preston, 1970).

3.1.2. Light- and colour curves

Magnetic field observations yield distinct variations. According to van den Heuvel (1971) a period of $18^{d}.4$ fits his observations. Wolff (1975) however, with a high degree of certainty, suggests the following equation for magnetic field periodicity:

$$\mathrm{HJD(magn.\ max.)} = 2441468 + 23^{d}.26\,E\,.$$

Using this formula Fig. 1 shows no periodic variations. The proposed period of $18^{d}.4$ yields an identical conclusion. The scatter is very large in $B-U$ and $U-W$ panels, which therefore have been omitted. The average mean error bars are indicated at the left top part of the panels. In V this error bar amounts to ± 0.006 mag. Our observations thus confirm the previous reports, that no optical variations are present exceeding 0.01 mag, although now and then the scatter is much larger than one would expect in view

Table 3. The average mean errors of the normal points. The second row lists the standard deviation of the average mean errors

Variable Star	V	(V-B)	(B-U)	(U-W)	(B-L)	V_J	$(B-V)_J$
		(in logarithm of intensity)				(in magnitude)	
HD 137949	.0022	.0016	.0026	.0064	.0016	.006	.004
	.0002	.0012	.0014	.0040	.0013	.001	.003
HD 190073	.0012	.0008	.0015	.0051	.0012	.003	.003
	.0006	.0003	.0005	.0026	.0004	.002	.001
HD 201601	.0014	.0011	.0014	.0035	.0014	.004	.003
	.0012	.0005	.0009	.0009	.0007	.003	.002
HD 203006	.0012	.0008	.0013	.0021	.0010	.003	.002
	.0011	.0004	.0010	.0014	.0008	.003	.001

Table 4. Average brightness and colours of the variable stars

Variable Star	Sp.	V	(V-B)	(B-U)	(U-W)	(B-L)	V_J	$(B-V)_J$
			(in logarithm of intensity)				(in magnitude)	
HD 137949	F0p	.0689	.1478	.4154	.1220	.2581	6.678	.375
HD 190073	A0ep	-.3910	.0336	.4115	.0756	.1313	7.846	.072
HD 201601	A6.5p	.8627	.0980	.4067	.1251	.2307	4.701	.249
HD 203006	A2p	.8086	.0131	.3634	.1034	.1457	4.850	.030

of the derived average mean errors. However this is possible from a statistical point of view.

3.2. HD *201601 (γ* Equ*)*

3.2.1. Introduction

The first photometric observations of HD 201601 (γ Equ) of spectral type A6.5p by Wehlau (1962) show no real variations in yellow or blue light. Huchra and Willner (1972) suggest on the other hand that this star is variable on the basis of their *UBV* photometry and the observations of Abt and Golson (1962), Osawa (1965), and Stepién (1968). Steinitz and Pyper (1971) prefer a very long period of 1785^d.7 based on magnetic field variations. Van Genderen (1971) used Renson's (1969) period of $314^d \pm 3^d$ (also based on magnetic field variations) to construct light- and colour curves. Because of the too short time interval in which these observations were made compared with the length of the proposed period, the result was not convincing. Similarly if $P = 1785^d.7$ is used, the phases of van Genderen's observations lie between 0.18 and 0.25 only (Scholz, 1975). Bonsack and Pilachowski (1974) and Scholz (1979) report very slowly declining magnetic field strengths over a time interval of ~30 yr. In the first reference the suggestion is even made that the period could be as long as 72 yr.

3.2.2. Light- and colour curves

Figure 2 shows the recent observations (circles) together with those of van Genderen (1971) (dots), using Renson's period revised into $317^d \pm 2^d$, resulting in a better connection between the two groups of observations than with the period of 314^d. Phases have been computed with the aid of the formula:

$$JD = 2435624.9 + 317^d\,E\,.$$

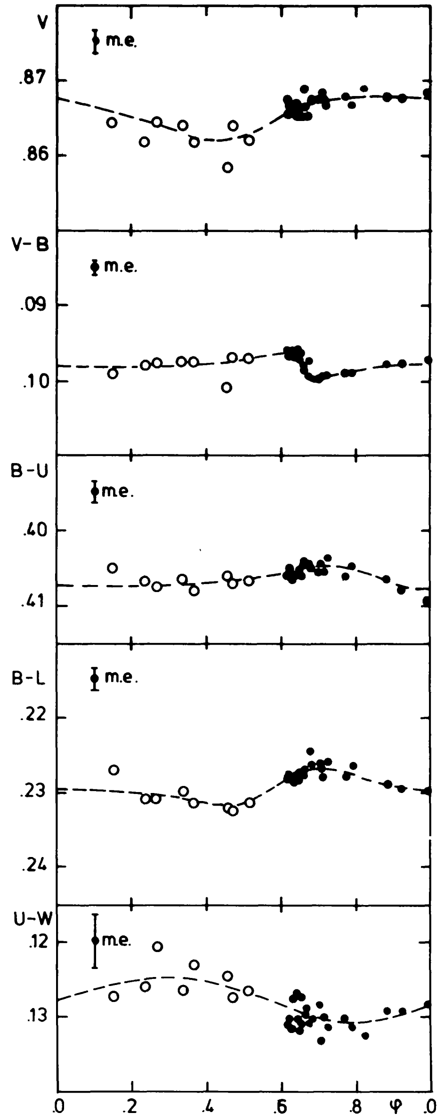

Fig. 2. The light- and colour-curves (in log intensity scale) of HD 201601 using the period of 317^d

We also tried to fit all observations with the 1785^d.7 period of Steinitz and Pyper (1971) resulting in Fig. 3. Phases have been calculated with the aid of the formula:

$$JD = 2433627.5 + 1785^d.7\,E\,.$$

Both sets seem to fit the proposed periods more or less, however confirmation is urgently required. Especially for the second period the cycle is not complete at all. It speaks that it is even more difficult to proof or disproof the 72 yr period with observations made in a time interval of 12 yr only.

3.3. HD *203006 (θ* Mic*)*

3.3.1. Introduction

The first period determination of HD 203006 (θ Mic) of spectral type A2p is by Morrison and Wolff (1971) based on *uvby* photometry, resulting in a period of 1^d.062. Maitzen et al. (1974) ruled this one out, because they found a double wave periodicity in their *UBV* and *uvby* observations, with a substantial difference

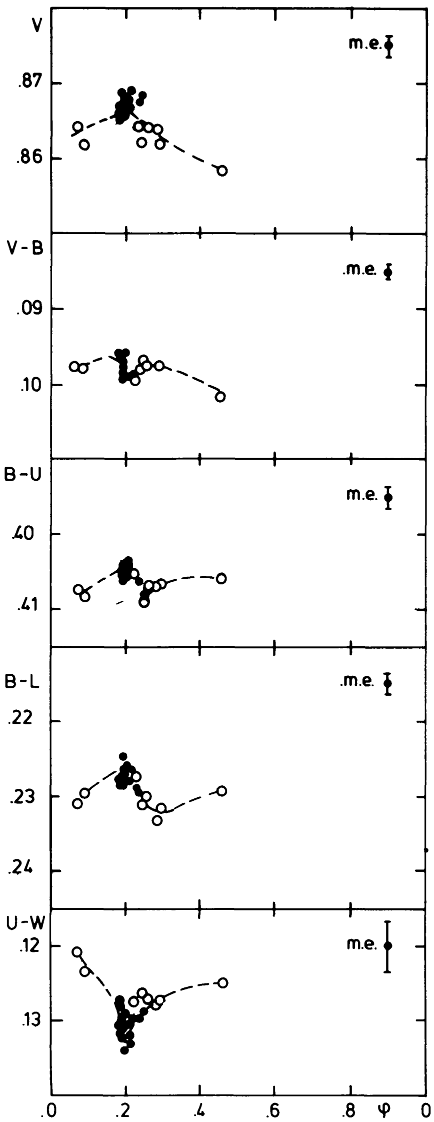

Fig. 3. The light- and colour-curves (in log intensity scale) of HD 201601 using the period of $1785\stackrel{d}{.}7$

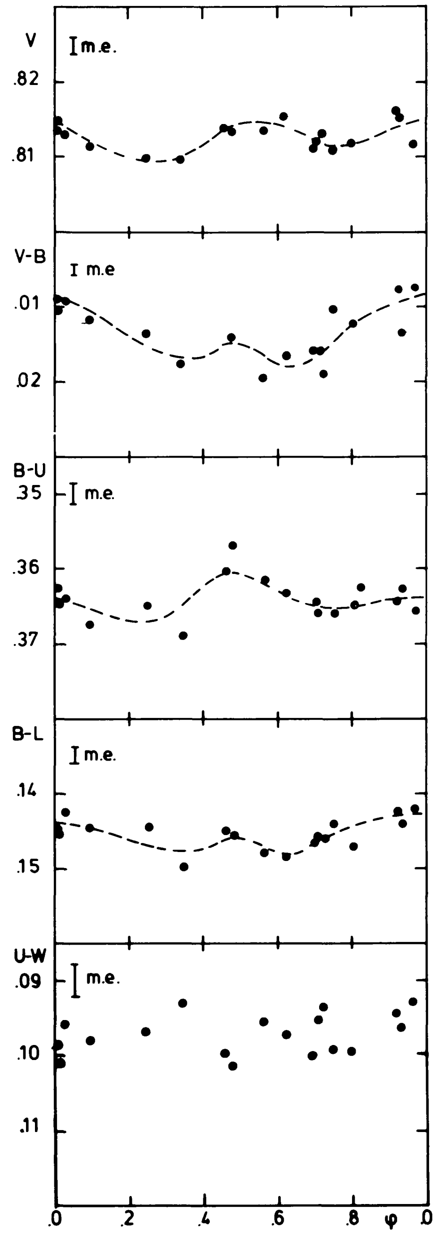

Fig. 4. The light- and colour-curves (in log intensity scale) of HD 203006 using the period of $2\stackrel{d}{.}1215$

of height between the two maxima in the violet and blue passbands. They calculated phases with the formula:

$$\mathrm{HJD(max.\ light)} = 2440345.32 + 2\stackrel{d}{.}1219\,E\,.$$

3.3.2. Light- and colour curves

According to Maitzen et al. (1974) the two maxima should be at phases 0.0 and 0.5. Our observations plotted with their period showed that the two maxima were near phases 0.3 and 0.8. In trying to shift both maxima to the appropriate phases (0.5 and 0.0, respectively) we derived a shorter period. The phases were now computed with the formula:

$$\mathrm{JD(max.\ light)} = 2440345.32 + 2\stackrel{d}{.}1215\,E\,.$$
$$\pm\stackrel{d}{.}0001$$

The error in the period is estimated and based on the criterion on how well both maxima fit the appropriate phases (see above). The results are shown in Fig. 4. The average mean error bars are indicated at the left top part of the panels. By accident the comparison star HD 203585 is also a peculiar star (A0p). Apparently it does not show any variability in light and colour, in view of the normal scatter displayed in Fig. 4.

3.4. HD *190073*

3.4.1. Introduction

HD 190073 is, unlike the other stars, a peculiar shell star of spectral type A0ep. Several authors (Merrill, 1951; Beals, 1955; Surdej and Swings, 1976a, b, 1977) have found that the spectral

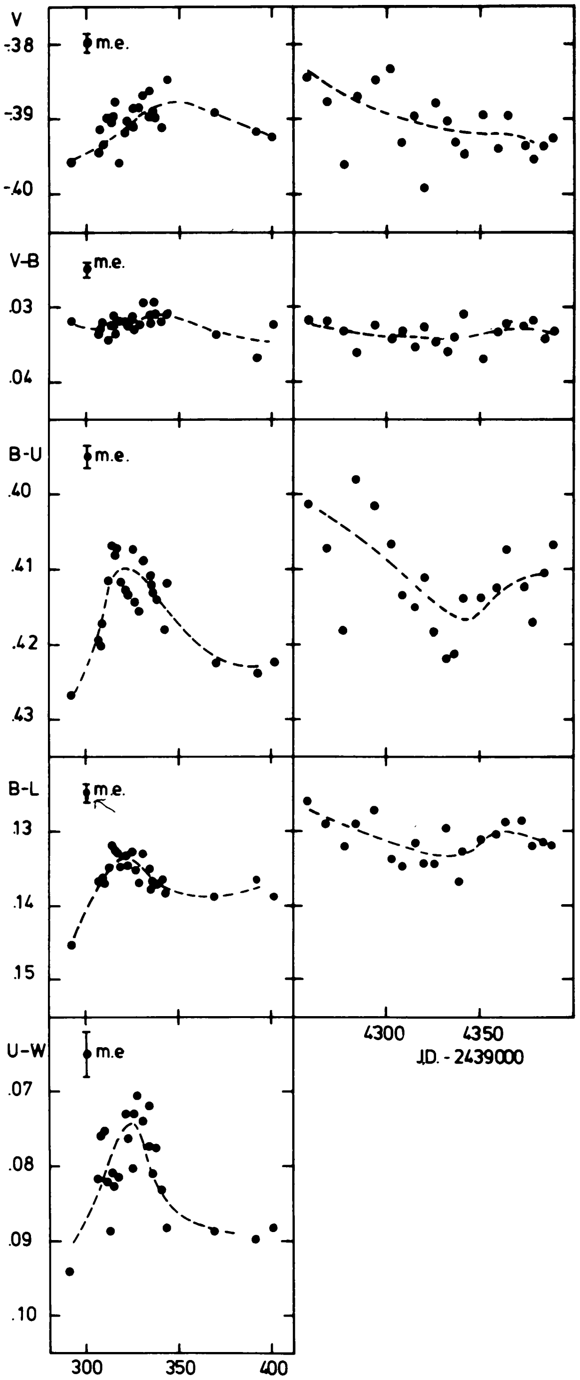

Fig. 5. The light- and colour-curves (in log intensity scale) of HD 190073 plotted against the date

lines show P Cygni characteristics. According to Surdej and Swings (1976a, b, 1977) the Ca II H and K lines have complex structures, showing variations on a time scale of days. Van Genderen (1971) found in his 1966 photometric observations variations in the order of 100^d. We will use the latter observations to compare them with the more recent observations presented in this paper.

3.4.2. Light- and colour curves

Figure 5 shows the observations of 1966 at the left hand side, as a function of the date, while the 1977 observations are at the right hand side also as a function of the date. The average mean error bars are indicated at the left top part of the panels. Due to a large scatter in the $U-W$ of the 1977 observations, they have been omitted and only the mean is represented by an arrow at the left hand side. Also for the second set of observations confirmation of variability is present. The total variations are smallest in visual ($\sim$0.03 mag) and increase at shorter wavelengths up to at least 0.1 mag in the W band ($\lambda_{\mathrm{eff}} \sim 3250$ Å). Definite brightness fluctuations amounting to about 0.01 mag or more in the course of five to ten days are presumably present in the second set of observations, but confirmation by further photometry is necessary. A remarkable fact is that the maxima of the colour curves (blue at the top) of the first set of observations do not coincide with the maximum in the visual, but rather are situated midway the rising branch. Apparently the photosphere of the star, where most of the continuum radiation originates is also subject to irregular variations, but with a longer time scale than the spectroscopic variations.

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