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The peculiar B[e] star HD 45677.[⋆,⋆⋆]
I. Photometric observations

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Abstract. — This short paper presents previously unpublished, as well as new, photometric observations of the peculiar B[e] star HD 45677. The photometric measurements were made in the Walraven $WULBV$, Strömgren $uvby$, Johnson/Cousins $UBV(RI)_{\rm C}$ and the ESO $JHKLM$ photometric systems between 1977 and 1994. Together with all the previously published photometry, these data will be analyzed in a separate paper, which will also investigate the spectroscopic behaviour of this fascinating object.

Key words: circumstellar matter — stars: emission-line — stars: HD 45677 — infrared: stars

1. Introduction

The peculiar emission line star HD 45677, also known as FS CMa or MWC 142, is a well known B[e] object. Many studies on its photometric and especially on its spectroscopic behaviour have been made. The photometric behaviour of this photometric variable was investigated by Swings & Swings (1972) using photographic magnitudes obtained from Harvard plates taken between 1899 and 1963. The main result of this study was the conclusion that a variability with an amplitude of $0\overset{\rm m}{.}3$–$0\overset{\rm m}{.}4$ is clearly present, but without the presence of a trend or periodicity. These conclusions were confirmed by Feinstein et al. (1976) who added that the weak increases of brightness in the photographic data-set were due to individual mass-loss events. The photoelectric measurements of Feinstein et al. (1976) were found to be about $0\overset{\rm m}{.}9$ fainter than the averaged data-set of 1899–1963 and explained by a cloud of material passing through a dust disk (or patches of dust) in the line of sight. Furthermore, short time scale variations were detected ranging from $0\overset{\rm m}{.}5$ over a year to $0\overset{\rm m}{.}02$ and less within a night. Important new photometric data consisting of four years of monitoring HD 45677 were presented by Halbedel et al. (1989). A quasi-periodicity of 296.5 days was detected in this dataset, but this does not agree well with the previously published photometric variations. No further evidence was found to explain the extreme photometric behaviour of HD 45677 in terms of a binary system.

Because of the problems of the previous authors in explaining the strange and large variations of HD 45677, and because it is often used as an example of peculiar Be stars it is interesting to extend the study of the photometric behaviour of this enigmatic object further. Therefore, we have collected previously unpublished photometry of this star in various photometric systems as well as newly obtained photometric observations, and we present these in this paper.

With these data we are able to investigate the variations in both brightness and colours, which can now also be studied on different time scales as our new observations include an intensive monitoring. The results of this analysis will be published in an accompanying paper (de Winter & van den Ancker 1996; Paper II). As we

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⋆Based on observations collected at the European Southern Observatory, La Silla, Chile, and on data collected in the long-term photometry of variables programme at ESO.
⋆⋆Tables 1–4 are also available in electronic form at the CDS via anonymous ftp 130.79.128.5.

collected all historical published spectra as well, Paper II also contains a description of the spectroscopic behaviour of HD 45677 and of possible connections of the different types of photometric variations with spectroscopic data.

2. Observations

Table 1. Walraven photometric data of HD 45677

JD −2440000	V	$V-B$	$B-L$	$B-U$	$B-W$	V_J
4596.774	−0.721	0.034	0.037	0.040	0.082	8.671
4597.699	−0.742	0.029	0.042	0.062	0.101	8.724
4599.788	−0.708	0.036	0.039	0.042	0.084	8.638
4601.797	−0.739	0.028	0.044	0.061	0.101	8.717
4604.771	−0.744	0.030	0.046	0.063	0.110	8.729
4607.692	−0.729	0.030	0.042	0.051	0.090	8.692
4617.749	−0.717	0.036	0.045	0.057	0.100	8.661
4618.744	−0.719	0.034	0.043	0.061	0.104	8.666
4620.669	−0.708	0.036	0.036	0.035	0.081	8.638
4621.668	−0.732	0.030	0.041	0.047	0.088	8.699
4622.729	−0.743	0.029	0.049	0.071	0.113	8.727
4623.716	−0.721	0.030	0.044	0.064	0.106	8.672
4624.712	−0.720	0.032	0.040	0.053	0.097	8.669
4630.718	−0.717	0.031	0.043	0.063	0.106	8.661
4631.733	−0.727	0.030	0.045	0.063	0.104	8.687
4632.731	−0.727	0.032	0.044	0.066	0.108	8.686
4633.720	−0.720	0.032	0.045	0.060	0.100	8.669

Photometric data in the Walraven $WULBV$ system of HD 45677 were obtained in December 1980 and January 1981 at the 90 cm Dutch Light Collector at the European Southern Observatory (ESO), La Silla, Chile, but were unpublished up to now. Measuring and reduction procedures have been explained by Lub & Pel (1977). Typical errors in these data, given in $\log_{10}$ intensity values, are 0.004, 0.003, 0.009, 0.004, and 0.006, for V, $V-B$, $B-L$, $B-U$, and $B-W$, respectively. The measurements obtained through a 21.″5 diaphragm are listed in Table 1. The last column in this table lists the corresponding V magnitude in the Johnson system, computed using the formula derived by Pel (1976).

Photometric data in the Strömgren *uvby* system of HD 45677 were obtained in January 1979 at ESO, in February 1993 at the Cerro Tololo Inter-American Observatory (CTIO) and in August 1993 and January 1994 at ESO. The 1993 CTIO observations, during which the β index was also measured, were done with the Lowell 60 cm telescope, equipped with an RCA 31034A (Quantacon) photomultiplier, whereas the ESO observations were carried out with the Danish 50 cm telescope equipped with an identical photomultiplier and using a 17″ diaphragm. The August 1993 observations were part of the long-term photometry of variables (LTPV) programme at ESO (Manfroid et al. 1991; Sterken et al. 1993, 1995). The new

Table 2. Unpublished and new Strömgren photometric data of HD 45677

JD −2440000	y	$b-y$	m_1	c_1	β
3887.6222	8.664	0.112	0.018	0.114	–
3887.6389	8.669	0.113	0.015	0.114	–
3887.6538	8.673	0.111	0.018	0.109	–
3887.6677	8.672	0.115	0.022	0.105	–
3888.6365	8.677	0.109	0.004	0.162	–
3888.6490	8.682	0.095	0.019	0.172	–
3888.6615	8.683	0.098	0.018	0.166	–
3888.6740	8.678	0.098	0.024	0.163	–
3890.6490	8.666	0.110	0.020	0.086	–
3890.6649	8.649	0.116	0.009	0.100	–
3890.6802	–	0.104	0.023	0.107	–
3892.6302	8.589	0.109	0.029	0.084	–
3892.6441	8.581	0.113	0.028	0.086	–
3892.6583	8.578	0.117	0.024	0.078	–
3892.6743	8.594	0.110	0.027	0.092	–
3892.6896	8.606	0.113	0.017	0.094	–
3893.6406	8.571	0.100	0.018	0.061	–
3893.6576	8.550	0.118	0.006	0.052	–
3893.6747	8.554	0.112	0.015	0.046	–
3893.6910	8.582	0.104	0.015	0.054	–
3893.7066	8.568	0.109	0.013	0.056	–
3893.7229	8.561	0.111	0.015	0.052	–
3894.6295	8.611	0.101	0.023	0.114	–
3894.6354	8.603	0.110	0.010	0.131	–
3894.6628	8.606	0.104	0.023	0.115	–
9022.6223	8.1857	0.1023	0.0288	0.0157	2.3176
9022.6256	8.1703	0.1011	0.0229	0.0216	2.3159
9022.6272	8.1787	0.0977	0.0360	0.0199	2.3086
9022.7278	8.1770	0.1004	0.0320	0.0221	2.3163
9022.7311	8.1804	0.1060	0.0386	0.0059	2.3098
9022.7327	8.1856	0.1003	0.0180	0.0239	2.3116
9023.6490	8.2016	0.1102	0.0314	0.0184	2.3049
9023.6524	8.2056	0.1108	0.0317	0.0189	2.2999
9023.6539	8.2116	0.1061	0.0422	0.0186	2.3187
9023.7215	8.1546	0.0906	0.0147	0.0125	2.3221
9023.7249	8.1997	0.1053	0.0484	0.0159	2.3184
9023.7265	8.2076	0.1093	0.0473	0.0241	2.3232
9024.6409	8.2214	0.1108	0.0288	0.0199	2.3085
9024.6448	8.2385	0.1073	0.0370	0.0234	2.3122
9024.6465	8.2587	0.1092	0.0453	0.0206	2.3098
9025.6255	8.1776	0.1149	0.0367	0.0101	2.3343
9025.6291	8.1674	0.1245	0.0359	0.0029	2.3284
9025.6309	8.1839	0.1231	0.0311	0.0060	2.3293
9221.8888	8.152	0.104	0.013	0.139	–
9222.8971	8.153	0.107	0.008	0.134	–
9224.8964	8.212	0.101	0.013	0.174	–
9225.8924	8.170	0.105	0.011	0.130	–
9226.8989	8.219	0.106	0.005	0.158	–
9228.8812	8.177	0.102	0.011	0.156	–
9356.60930	8.143	0.103	0.014	0.107	–
9356.65652	8.149	0.099	0.022	0.113	–
9356.65858	8.147	0.104	0.011	0.127	–
9356.66070	8.150	0.102	0.006	0.135	–
9356.66278	8.157	0.098	0.018	0.134	–
9356.66686	8.148	0.108	0.005	0.130	–
9356.66892	8.166	0.096	0.022	0.125	–

Table 2. continued

JD −2440000	y	$b-y$	m_1	c_1	β
9356.67090	8.154	0.103	0.009	0.138	
9356.67500	8.151	0.104	0.009	0.131	–
9356.67836	8.147	0.105	0.014	0.114	–
9356.68038	8.145	0.108	0.010	0.126	–
9356.68252	8.152	0.107	0.003	0.141	–
9356.68460	8.153	0.103	0.013	0.132	–
9356.68668	8.170	0.100	0.021	0.124	–
9356.68884	8.157	0.104	0.016	0.118	–
9356.69010	8.155	0.104	0.015	0.127	–
9356.69378	8.151	0.109	0.004	0.129	–
9356.69740	8.157	0.106	0.009	0.129	–
9356.70114	8.159	0.106	0.000	0.150	–
9356.70488	8.153	0.101	0.022	0.121	–
9356.70692	8.164	0.104	0.005	0.147	–
9356.70902	8.159	0.104	0.010	0.134	–
9356.71118	8.170	0.095	0.017	0.138	–
9357.60288	8.177	0.097	0.021	0.123	–
9357.64538	8.174	0.088	0.031	0.144	–
9357.64730	8.162	0.098	0.019	0.147	–
9357.64920	8.164	0.100	0.018	0.150	–
9357.65110	8.178	0.084	0.029	0.155	–
9357.65308	8.167	0.093	0.025	0.145	–
9357.65496	8.167	0.098	0.020	0.144	–
9357.65688	8.161	0.096	0.022	0.154	–
9357.65888	8.166	0.092	0.023	0.152	–
9357.66078	8.169	0.096	0.016	0.153	–
9357.66270	8.166	0.099	0.018	0.145	–
9357.66466	8.169	0.094	0.020	0.153	–
9357.66666	8.169	0.093	0.024	0.145	–
9357.66856	8.170	0.098	0.017	0.156	–
9357.67048	8.163	0.097	0.019	0.157	–
9357.67240	8.169	0.088	0.033	0.142	–
9357.67430	8.159	0.100	0.018	0.148	–
9357.67624	8.166	0.094	0.022	0.155	–
9357.67816	8.163	0.096	0.020	0.149	–
9357.68008	8.163	0.100	0.014	0.156	–
9357.68206	8.161	0.102	0.014	0.155	–
9357.68400	8.170	0.093	0.025	0.147	–
9357.68588	8.174	0.092	0.020	0.162	–
9357.68780	8.171	0.100	0.014	0.158	–
9357.68968	8.170	0.090	0.028	0.150	–
9357.69160	8.169	0.094	0.021	0.158	–
9357.69352	8.169	0.095	0.022	0.148	–
9358.57532	8.160	0.097	0.006	0.118	–
9358.61388	8.172	0.087	0.011	0.125	–
9358.61578	8.177	0.092	0.013	0.115	–
9358.61978	8.170	0.093	0.007	0.114	–
9358.62178	8.167	0.093	0.009	0.118	–
9358.62308	8.162	0.100	0.001	0.118	–
9358.62520	8.165	0.090	0.013	0.122	–
9358.62716	8.177	0.093	0.006	0.127	–
9358.62922	8.166	0.094	0.011	0.108	–
9358.63128	8.168	0.092	0.014	0.109	–
9358.63486	8.180	0.087	0.019	0.108	–
9358.63696	8.166	0.096	0.005	0.117	–
9358.63826	8.176	0.101	−0.009	0.143	–

Table 2. continued

JD −2440000	y	$b-y$	m_1	c_1	β
9358.64034	8.171	0.099	0.004	0.110	
9358.64246	8.162	0.098	0.008	0.115	–
9358.64458	8.172	0.089	0.014	0.117	–
9358.64672	8.172	0.093	0.013	0.118	–
9358.64870	8.171	0.095	0.007	0.121	–
9358.65070	8.179	0.087	0.015	0.119	–
9358.65282	8.175	0.098	−0.003	0.123	–
9358.65690	8.170	0.095	0.010	0.109	–
9358.65900	8.169	0.099	0.003	0.112	–
9358.66098	8.171	0.091	0.015	0.115	–
9358.66306	8.173	0.099	0.001	0.121	–
9358.66514	8.166	0.099	0.004	0.114	–
9358.66720	8.168	0.093	0.008	0.120	–
9358.66908	8.193	0.100	−0.003	0.137	–
9358.67118	8.167	0.101	0.001	0.111	–
9358.69634	8.190	0.098	−0.001	0.130	–
9358.69840	8.164	0.102	0.004	0.104	–
9358.70046	8.177	0.090	0.018	0.104	–
9358.70400	8.182	0.096	0.012	0.101	–
9358.70610	8.172	0.103	−0.001	0.110	–
9358.70820	8.173	0.093	0.010	0.110	–
9358.71032	8.173	0.093	0.011	0.108	–
9358.71240	8.168	0.095	0.016	0.096	–
9358.71566	8.177	0.102	0.000	0.119	–
9358.71776	8.166	0.097	0.012	0.099	–
9358.71986	8.170	0.099	0.004	0.110	–
9358.72200	8.174	0.094	0.011	0.107	–
9358.72720	8.172	0.096	0.008	0.106	–
9358.72942	8.170	0.104	−0.006	0.120	–
9358.73158	8.168	0.102	0.000	0.108	–
9358.73578	8.171	0.105	−0.003	0.103	–
9358.73782	8.170	0.100	0.006	0.108	–
9358.73994	8.168	0.099	0.002	0.110	–

Strömgren photometric data are listed in Table 2. Typical errors in these data are $0\overset{m}{.}007$, $0\overset{m}{.}008$, $0\overset{m}{.}010$, and $0\overset{m}{.}012$ for y, $b-y$, m_1, and c_1, respectively.

Johnson UBV photometric data of HD 45677 were obtained with the Bochum 61 cm telescope at ESO during two observing runs in February 1977 and in January 1979. Additional Cousins VRI photometry was observed with the ESO 50 cm telescope at La Silla in December 1980, but both were again not published up to now. Furthermore, new observations in the Johnson/Cousins $UBV(RI)_{\rm C}$ photometric system were obtained during observing runs in March and December 1992, December 1993 and January 1994 on the ESO 50 cm and 1 m photometric telescopes at La Silla. Both telescopes were equipped with an EMI 9658RA photomultiplier, using a $7\overset{''}{.}5$ diaphragm. Typical errors are $0\overset{m}{.}01$, $0\overset{m}{.}01$, $0\overset{m}{.}02$, $0\overset{m}{.}01$, $0\overset{m}{.}02$ for the V, $B-V$, $U-B$, $V-R$ and $V-I$ data, respectively. The new $UBV(RI)_{\rm C}$ data are listed in Table 3.

Table 3. Unpublished and new $UBV(RI)_C$ observations of HD 45677

JD −2440000	V	$U-B$	$B-V$	$V-R$	$V-I$
3124.5	8.568	−0.646	0.041	–	–
3177.560	8.542	−0.674	0.024	–	–
3177.619	8.543	−0.662	0.022	–	–
3177.658	8.540	−0.664	0.023	–	–
3177.678	8.542	−0.659	0.020	–	–
3177.729	8.546	−0.648	0.020	–	–
3178.602	8.543	−0.656	0.043	–	–
3178.613	8.530	−0.670	0.028	–	–
3178.623	8.526	−0.692	0.030	–	–
3178.654	8.530	−0.660	0.022	–	–
3178.671	8.522	−0.661	0.031	–	–
3178.687	8.517	−0.668	0.035	–	–
3179.538	8.514	−0.679	0.043	–	–
3179.555	8.498	−0.682	0.042	–	–
3179.564	8.501	−0.679	0.041	–	–
3179.580	8.503	−0.685	0.038	–	–
3179.597	8.509	−0.683	0.045	–	–
3179.605	8.515	−0.682	0.032	–	–
3179.623	8.507	−0.672	0.054	–	–
3180.738	8.547	−0.647	0.028	–	–
3181.542	8.558	−0.641	0.042	–	–
3181.558	8.563	−0.655	0.041	–	–
3181.573	8.557	−0.645	0.037	–	–
3181.580	8.559	−0.653	0.035	–	–
3181.719	8.564	−0.620	0.050	–	–
3181.729	8.549	−0.630	0.056	–	–
3182.534	8.483	−0.669	0.050	–	–
3182.549	8.479	−0.655	0.047	–	–
3182.679	8.485	−0.667	0.038	–	–
3183.572	8.505	−0.725	0.055	–	–
3183.581	8.467	−0.717	0.052	–	–
3183.608	8.484	−0.718	0.039	–	–
3183.616	8.482	−0.721	0.050	–	–
3183.628	8.479	−0.710	0.039	–	–
3183.635	8.480	−0.712	0.047	–	–
3183.649	8.468	−0.716	0.055	–	–
3183.658	8.473	−0.707	0.048	–	–
3183.673	8.493	−0.697	0.046	–	–
3183.683	8.463	−0.702	0.047	–	–
3183.691	8.505	−0.702	0.036	–	–
3184.536	8.510	−0.680	0.034	–	–
3184.545	8.522	−0.681	0.021	–	–
3184.554	8.521	−0.673	0.028	–	–
3184.563	8.511	−0.680	0.035	–	–
3184.596	8.520	−0.678	0.034	–	–
3184.606	8.522	−0.674	0.028	–	–
3184.620	8.519	−0.684	0.042	–	–
3184.630	8.527	−0.676	0.034	–	–
3184.639	8.528	−0.675	0.029	–	–
3184.647	8.527	−0.668	0.033	–	–
3184.661	8.531	−0.682	0.030	–	–
3184.669	8.518	−0.675	0.039	–	–
3184.679	8.523	−0.682	0.034	–	–
3897.4	8.673	−0.663	0.055	–	–
3898.4	8.725	−0.622	0.053	–	–
3899.4	8.665	−0.651	0.082	–	–

Table 3. continued

JD −2440000	V	$U-B$	$B-V$	$V-R$	$V-I$
3902.3	8.647	−0.663	0.072	–	–
4589.734	8.660	–	–	0.279	0.403
4590.794	8.713	–	–	0.279	0.392
8700.305	7.958	−0.618	0.073	0.177	0.348
8702.317	7.940	−0.638	0.081	0.186	0.329
8706.230	7.941	−0.595	0.069	0.195	0.341
8707.260	7.935	−0.620	0.063	0.177	0.318
8957.810	8.049	−0.657	0.074	0.207	0.331
8958.774	8.105	−0.589	0.055	0.199	0.306
8960.781	8.073	−0.655	0.067	0.209	0.316
9347.3322	8.14	−0.62	0.09	0.24	0.37
9347.3485	8.15	−0.60	0.07	0.25	0.37
9348.2546	8.15	−0.56	0.03	0.25	0.35
9348.8209	8.13	−0.53	0.04	0.23	0.33
9349.2523	8.07	−0.64	0.07	0.25	0.37
9370.7534	8.145	−0.547	0.045	0.241	0.403
9371.6530	8.117	−0.617	0.135	0.211	0.330
9371.7253	8.134	−0.599	0.117	0.209	0.341
9371.7796	8.146	−0.622	0.165	0.221	–

Table 4. Unpublished $JHKLM$ photometry of HD 45677

JD −2440000	J	H	K	L	M
3922.404	7.79	6.49	4.83	2.13	1.07
3925.406	7.70	6.44	4.63	1.94	1.00
4299.622	7.93	6.76	4.81	2.11	1.30
4307.518	7.91	6.79	4.86	2.22	1.35
4618.729	7.65	6.69	4.80	2.16	1.21
4621.721	7.58	6.74	4.81	2.19	1.28

Near-IR photometric measurements in the ESO $JHKLM$ system (Bouchet et al. 1989, 1991) of HD 45677 were obtained in February 1979, March 1980 and January 1981, respectively, using the ESO 1 m telescope at La Silla. During these observations the telescope was equipped with an InSb detector. The observations were made through a 15″ diaphragm. Sky subtraction was achieved by chopping, with a frequency of 8 Hz, in the east-west direction with a throw of 30″ amplitude. Typical errors in the data are $0\overset{m}{.}04$, $0\overset{m}{.}04$, $0\overset{m}{.}03$, $0\overset{m}{.}05$, $0\overset{m}{.}06$ for the J, H, K, L and M magnitudes, respectively. These data are listed in Table 4.

3. Transformation formulae for visual magnitudes

To study the photometric behaviour of HD 45677 we have analyzed in Paper II the data listed in the last section, together with data from the literature. To be able to compare the visual magnitudes measured in the different photometric systems, we transformed all visual data to V

magnitudes in the Johnson system. Cousins V magnitudes can be transformed to Johnson V magnitudes using:

$$V_{\rm J} = V_{\rm C} + 0.080 \tag{1}$$

Strömgren y magnitudes can be transformed to Johnson V magnitudes using:

$$V_{\rm J} = y + 0.065 \tag{2}$$

V intensities in the Walraven $WULBV$ system can be transformed to Johnson V magnitudes using the formula derived by Pel (1976):

$$V_{\rm J} = 6.874 - 2.5\{V_W + 0.065(V-B)_W\} \tag{3}$$

The transformed V magnitudes are, additionally, also given in Table 1, Col. 7. The error in these transformed V magnitudes will be about $0\overset{\rm m}{.}015$.

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