UBV photometry of Be stars at Hvar: 1972–1990^{*}

K. Pavlovski¹, P. Harmanec², H. Božić¹, P. Koubský², P. Hadrava², S. Kříž³, Ž. Ružić⁴, and S. Štefl²

¹ Opservatorij Hvar, Geodetski fakultet Sveučilišta u Zagrebu, Kačićeva 26, 10 000 Zagreb, Croatia

Internet: pavlovski@x400.srce.hr; hrvoje.bozic@x400.srce.hr

² Astronomický ústav Akademie věd České republiky, 251 65 Ondřejov, Czech Republic

Internet: hec(koubsky,had,sstefl)@sunstel.asu.cas.cz

³ SK Press, Masarykovo náměstí 35, 251 01 Říčany, Czech Republic

⁴ Odjel za fiziku i biofiziku, Medicinski fakultet Sveučilišta u Zagrebu, Šalata 3, 10 000 Zagreb, Croatia

Internet: zeljko.ruzic@x400.srce.hr

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Abstract. A summary of results of the systematic *UBV* photoelectric monitoring of bright northern Be stars carried out at the Hvar Observatory between 1972 and 1990 is presented. Altogether, 76 Be stars of all luminosity classes were observed and 13 848 *UBV* measurements secured. Simultaneously, 9 648 *UBV* measurements of 48 check stars (most of them of early spectral types) were obtained. A careful transformation of all observations into the standard Johnson system allowed detection and monitoring of even very mild long-term light and colour variations of these objects. Almost all early-type Be stars in the sample turned out to be variable. For several stars phase-locked light variations related to their binary nature were established. Sudden brightenings, on a time scale of a few days, were detected for *o* Cas and QR Vul.

Key words: stars: Be — stars: Omicron Cas; QR var — stars: variable

1. Introduction

Since their discovery (by Secchi 1867) until the end of the sixties the Be stars, challenging and all-time variable emission-line stars, have not been the subject of any systematic study aimed at detection of their possible light and colour variations. It is true that the astronomical literature of that period contains ample evidence that many Be stars *are* light variables but almost all such findings resulted as by-products of studies of different or wider groups of objects.

Send offprint requests to: K. Pavlovski

^{*} Tables 2 and 3 are only available in electronic form at CDS via ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via <http://cdsweb.u-strasbg.fr/Abstract.html>

The first discovery of the light variations of Be stars goes back to the times of Johannes Kepler (P Cyg). Feinstein (1968) was probably the first who pointed out explicitly that many Be stars are light variables. Perhaps the first study explicitly aimed at the detection of light variations of a large group of Be stars by means of differential photoelectric photometry was published by Haupt & Schroll (1974). The interest in systematic photometric studies of Be stars has been growing since then.

The history of discoveries of the light variability of Be stars and the new developments of this field in the seventies and early eighties has already been summarized in several reviews (cf., e.g., Harmanec 1983a,b; Percy 1987; Cuypers 1991) and need not be repeated here. More recent surveys of the photometric variability of Be stars were published, for instance, by Schuster & Alvarez (1983), Schuster & Guichard (1984), Percy et al. (1988b), Cuypers et al. (1989), Balona et al. (1992) or Percy & Attard (1992). A systematic program of *uvby* long-term monitoring of Be stars was initiated by Sterken (1983) within the framework of the ESO long-term monitoring program and the results are being published in a series of papers (Mennickent et al. 1994; Sterken et al. 1996).

In 1972, the Hvar Observatory was opened. Systematic photoelectric *UBV* observations of bright Be stars has become the main observing program of the photometric telescope of the Observatory. The original goal of the program was to search for new eclipsing binaries among them. However, already the first results attracted the interest of observers also to long-term and later to rapid variations of Be stars.

In realization that a systematic investigation of Be variability cannot be carried out from one observatory only, an international campaign on systematic photoelectric observations of all bright Be stars was organized and coordinated under the auspices of the Working Group on

Table 1. The Be stars observed

HD	Name	Sp.type	From	To	S N	V σ	B σ	U σ	Comp. HD	Check HD
144	10 Cas	B9IIIe	45307	46692	2	5.596	5.567	5.362	2626	2011
					10	.013	.012	.011		
2905	κ Cas	B1Iae	45307	46692	2	4.162	4.299	3.516	2626	2011
					10	.012	.011	.016		
4180	o Cas	B0IVe	45212	47915	6	4.430	4.400	3.813	4142	6114
					343	.038	.035	.033		
5394	γ Cas	B5IIIe	45307	46692	2	2.208	2.095	1.082	2626	2011
					10	.017	.019	.026		
6811	ϕ And	B7Ve	45212	47915	6	4.248	4.185	3.831	4142	6114
					148	.009	.010	.012		
10516	ϕ Per	B2Vep	44935	48278	8	4.017	3.935	3.027	12303	11291
					180	.024	.031	.034		
13854	HR 654	B1Iabe	44985	46691	2	6.468	6.743	6.101	12303	11291
					13	.018	.009	.012		
14818	10 Per	B2Iae	44935	48277	6	6.244	6.545	5.951	12303	11291
					104	.021	.023	.030		
18552	HR 894	B8Vne	44860	46441	5	6.137	6.073	5.675	18411	19736
					111	.010	.010	.011		
–	RX Cas	(B5)+K1III	42603	45309	4	9.033	10.229	10.4 95	18962	19193
					209	0.170	0.186	0.349		
21551	HR 1051	B8Ve	45307	46689	4	5.842	5.803	5.486	21278	21362
					29	.010	.007	.007		
22192	ψ Per	B5Ve	45307	46689	4	4.205	4.118	3.532	21278	21362
					29	.011	.008	.010		
22780	HR 1113	B7Vne	44988	45359	2	5.579	5.511	5.093	21856	23193
					34	.009	.008	.009		
23016	13 Tau	B9Vne	44863	44863	1	5.710	5.689	5.402	23324	23432, 23288
					3	.006	.008	.002		
23180	o Per	B1IIIe	44988	45359	2	3.841	3.889	3.165	21856	23193
					33	.014	.014	.014		
23302	17 Tau	B6IIIe	44863	44863	1	3.742	3.614	3.210	23324	23432, 23288
					3	.001	.004	.000		
23480	V971 Tau	B6IVe	44863	44863	1	4.221	4.147	3.754	23324	23432, 23288
					3	.001	.006	.005		
23552	HR 1160	B8Vne	45307	46689	3	6.187	6.245	5.927	21278	21362
					17	.008	.005	.007		
23630	η Tau	B7IIIe	44863	44863	1	2.896	2.777	2.426	23324	23432, 23288
					3	.005	.005	.012		
23862	BU Tau	B8Vpe	43140	44863	2	5.291	5.242	5.046	23324	23432, 23288
	Pleione				22	.017	.018	.062		
25940	MX Per	B3Ve	43136	46689	5	4.014	3.986	3.432	21278	21362
	48 Per				32	.019	.014	.012		
29866	HR 1500	B8IVne	44921	45689	3	6.087	6.152	5.849	33641	29722
					27	.009	.009	.014		
32343	BV Cam	B2.5Ve	45308	45697	2	5.168	5.094	4.356	39283	34233
	11 Cam				9	.019	.007	.008		
36576	V960 Tau	B2IV-Ve	44902	46694	5	5.659	5.674	4.909	36589	36819, 37711
	120 Tau				95	.033	.026	.035		
37202	ζ Tau	B1IIIpe	43135	47614	9	2.921	2.718	1.949	36589	36819, 37711
					699	.068	.082	.101		
37967	V731 Tau	B2.5Ve	43136	46694	6	6.246	6.172	5.543	36589	36819, 37711
					107	.013	.010	.020		

Table 1. continued

HD	Name	Sp.type	From	To	S N	V σ	B σ	U σ	Comp. HD	Check HD
41335	HR 2142	B2Ven	44902	45716	3	5.216	5.155	4.318	42690	45546
					62	.017	.019	.022		
43285	HR 2231	B6Ve	44993	45661	3	6.064	5.946	5.439	44783	43526
					25	.010	.010	.015		
47054	HR 2418	B8Ve	44902	45661	3	5.516	5.429	5.057	42690	41692
					42	.010	.012	.014		
50658	ψ^9 Aur	B8IIIe	45014	45661	3	5.878	5.801	5.367	49949	52860, 50973
					27	.015	.013	.014		
58050	OT Gem	B2Ve	44977	46159	4	6.449	6.268	5.420	58187	59059
					125	.020	.017	.038		
58715	β CMi	B8Ve	44977	46159	4	2.889	2.784	2.517	58187	59059
					155	.011	.015	.017		
109387	κ Dra	B6IIIpe	42237	46110	6	3.809	3.697	3.144	107193	112429
					217	.025	.028	.030		
138749	θ CrB	B6Vnne	44801	48116	5	4.161	4.031	3.504	144206	142373
					113	.014	.019	.023		
			45916	45918					173664	172883
142926	V839 Her	B7Ve	41528	48114	14	5.746	5.643	5.282	144206	145389
	4 Her				296	.016	.018	.025		
162732	V744 Her	B6Ve	41535	48127	16	6.759	6.639	6.181	162132	162579, 158414
	88 Her				385	.070	.077	.125		
164284	V2048 Oph	B2Ve	45105	45153	1	4.667	4.638	3.785	164432	163641
	66 Oph				57	.015	.015	.017		
164447	HR 6720	B8Vne	45065	48123	4	6.515	6.447	6.070	166182	164852
					179	.020	.020	.024		
166014	$\circ$ Her	B9.5V	45065	48123	4	3.847	3.811	3.780	166182	164852
					179	.014	.022	.024		
168797	NW Ser	B3Ve	44433	48133	6	6.135	6.118	5.498	170200	169578
	MWC 601				328	.022	.022	.029		
174237	CX Dra	B2.5Ve	42977	48128	12	5.909	5.831	5.108	173664	172883
					1064	.057	.041	.070		
180968	ES Vul	B0.5IVe	46235	47374	4	5.435	5.474	4.698	180889	181751
	2 Vul				219	.015	.016	.020		
183656	V923 Aql	B6e	44073	48128	10	6.070	6.070	5.757	183324	183227, 184663
					408	.031	.035	.047		
183914	β^2 Cyg	B8Ve	46679	46695	1	5.149	5.059	4.743	188260	180889, 181751
					14	.006	.006	.004		
184279	V1294 Aql	B0.5IVe	44073	48128	10	7.050	7.111	6.405	183324	183227, 184663
					405	.115	.108	.158		
185859	HR 7482	B0.5Iae	46679	46695	1	6.498	6.887	6.277	188260	180889, 181751
					14	.008	.007	.008		
187399	V1507 Cyg	B8IIIe	43014	43760	3	7.016	7.176	6.767	188170	186357
					199	0.041	0.036	0.047		
187811	12 Vul	B2.5Ve	46679	46695	1	4.929	4.770	4.093	188260	180889, 181751
					15	.006	.007	.013		
189687	V1746 Cyg	B3IVe	46245	47386	4	5.157	5.023	4.296	188892	193369
	25 Cyg				132	.022	.014	.016		
191610	V1624 Cyg	B2.5Ve	42237	43019	7	4.950	4.803	4.030	many	many
	28 Cyg				360	.030	.030	.036		
			46262	47791					188892	193369
192044	20 Vul	B7Ve	44794	48128	6	5.915	5.803	5.351	190993	191747
					120	.011	.012	.015		

Table 1. continued

HD	Name	Sp.type	From	To	S N	V σ	B σ	U σ	Comp. HD	Check HD
192685	QR Vul	B3Ve	44794	48128	6	4.751	4.583	3.844	190993	191747
	HR 7739				144	.053	.040	.055		
193237	P Cyg	B2pe	46287	47376	3	4.770	5.181	4.616	188892	193369
					113	.030	.031	.033		
193911	25 Vul	B8IIIne	44817	48128	6	5.533	5.440	5.008	190993	191747
					115	.010	.012	.017		
194335	HR 7807	B2Ven	46238	47022	3	5.859	5.695	4.752	188892	193369
					142	.028	.026	.038		
195554	MWC 637	B9Vne	44431	47443	7	5.908	5.847	5.637	197770	194668, 194883
					126	.012	.015	.017		
198478	V1661 Cyg	B3Iae	41528	47791	5	4.821	5.219	4.778	199311	199479
	55 Cyg				113	.024	.024	.028		
198625	HR 7983	B4Ve	46696	46696	1	6.395	6.339	5.786	199311	199479
					3	.007	.005	.017		
199478	HR 8020	B8Iae	46696	46696	1	5.694	6.147	5.816	201836	
					3	.008	.005	.003		
200120	V832 Cyg	B1ne	46258	47791	4	4.784	4.708	3.773	199311	199479
	59 Cyg				127	.043	.030	.029		
200310	V1931 Cyg	B1Ve	46281	47791	4	5.397	5.202	4.274	199311	199479
	60 Cyg				127	.028	.024	.035		
201733	HR 8103	B4IVpe	46696	46715	1	6.623	6.483	5.817	199311	199479
					9	.011	.009	.007		
202904	v Cyg	B2Vne	44817	44818	1	4.352	4.263	3.428	204403	202349
					6	.004	.006	.006		
203467	6 Cep	B3IVe	45536	48123	2	5.198	5.157	4.590	208218	202214
					43	.014	.015	.021		
205551	HR 8259	B9IIIe	45155	45194	1	6.176	6.164	5.906	207330	206259, 207793
					18	.014	.017	.020		
208392	EM Cep	B1IVe	41954	48123	3	7.037	7.292	6.725	208218	202214
					9	.049	.065	.065		
214168	8 Lac	B2Ve	43013	47791	8	5.727	5.572	4.684	214680	217101
					125	.018	.020	.021		
			46673	46703					217101	214680
216057	MWC 393	B5Vne	44432	48115	9	6.147	6.067	5.573	218470	218407, 219080
					204	.012	.012	.014		
216200	V360 Lac	B3IV:e	44473	47791	9	5.927	6.010	5.499	214680	217101
	14 Lac				197	.021	.023	.026		
			46664	47458					217101	214680
217050	EW Lac	B4IIIep	41534	41537	17	5.262	5.159	4.554	212593	218407, 219080
					1112	.067	.075	.117		
			42240	48128					218470	219080
217543	MWC 395	B3Vpe	42261	47791	11	6.527	6.414	5.722	214680	217101
					249	.026	.030	.039		
217675	o And	B6IIIpe	42614	42716	14	3.622	3.518	2.996	217782	214680
					954	.035	.042	.052		
			42981	46340					214680	217101, 222439
			46649	46715					217101	214680
			46690	47061					214680	217101
			47353	47458					217101	214680
218393	KX And	B0:e	42261	48128	16	7.020	7.354	6.963	218470	218407
					1197	.060	.070	.138		

Table 1. continued

HD	Name	Sp.type	From	To	S N	V σ	B σ	U σ	Comp. HD	Check HD
218674	KY And	B3e	42614	48128	16 953	6.766 .029	6.753 .030	6.163 .043	218470	218407
224559	LQ And	B4Ven	44433	44959	7 326	6.555 .014	6.462 .014	5.867 .018	222439	224166
			45239	45269					222439	224166
			45293	45344					223229	222439, 224166
			45591	45646					223229	224166
			46287	47457					223229	222439
225094	V639 Cas	B3Iae	45307	46692	2 10	6.242 .022	6.572 .018	6.042 .020	2626	2011

Notes: Columns “From” and “To” contain JD-2400000 of the first and last observation of each star. “S” is the number of seasons in which the given star was observed, and “N” is the number of individual observations, respectively. The errors (σ) quoted along with the mean *UBV* magnitudes are the rms errors of one observation of unit weight. They represent an objective measure of the level of variability of each observed star. Whenever available, the spectral types were taken from Slettebak (1982).

Be Stars of the IAU Com. 29 by Harmanec et al. (1980b, 1981a,b, 1982a,b). Since the aim of the program was to accumulate statistically significant data on the Be phenomenon without any prejudice, the list of objects (with obligatory comparisons) included all emission-line B stars of *all luminosity classes* and – for most part – brighter than the magnitude limit of the Bright Star Catalogue.

The Be program at Hvar has become an important part of this effort. We tried to observe all groups of variables defined in the program which were observable from Hvar. In practice, however, not all of the selected objects were intensively or are at all observed that location, for one reason or another. Observations of only a few emission-line stars of luminosity classes Ia–II were secured, for instance.

Many of the findings which resulted from the Be program have been subsequently published in a series of papers devoted to individual Be stars (see Table 4 below), in Progress Reports in the Be Star Newsletters Nos. 2 to 10 and partly also in the following summary reports: Harmanec et al. (1980a), Koubský & Pavlovski (1982), Pavlovski & Božić (1982), and Harmanec (1983a,b, 1987b, 1994).

The principal finding of our studies was that the long-term light variations of Be stars are usually the most pronounced ones and that they are somehow related to the long-term spectral variations of respective stars. While we failed to discover new eclipsing binaries among Be stars, we did find phase-locked periodic light variations for several known Be binaries (KX And, LQ And, RX Cas, V1507 Cyg, CX Dra, V360 Lac, φ Per, ζ Tau). The data from Hvar, supplemented with nearly simultaneous observations from other stations were also used, especially for studies of rapid light variations. The “minicampaign”

organized in 1983 (see Stagg et al. 1988) may serve as a good example.

The publication of this study was substantially delayed after we had realized that the simple bilinear formulae which we used did not ensure sufficiently-stable seasonal transformations to the standard *UBV* system and can even lead to false reports of light variability if, for instance, an A or F star is used as a comparison for an early B star, or for reddened objects. Only the recent development of new reduction procedures (based on nonlinear transformation equations) and a careful determination of more accurate *UBV* magnitudes of all comparison and standard stars used in the Be program (Harmanec et al. 1994a) opened the way to completion of this study. In a preliminary form, an overview of the *UBV* photometry of Be stars at Hvar was given by Pavlovski et al. (1994).

2. Observations and reductions

All observations reported in this paper were obtained with the 0.65-m Cassegrain reflector of the Ondřejov Observatory installed at the Hvar Observatory of the Faculty of Geodesy, University of Zagreb, Croatia. A single-channel photoelectric photometer with an unrefrigerated EMI 6256S photomultiplier has been used (for more details on the instrumentation and reduction, see Harmanec et al. 1977a, Harmanec et al. 1994a and references therein).

Since 1972 until summer 1978 the data were recorded with a strip-chart recorder and a D.C. amplifier with 16 (later 15) gains in about 0^m.6 steps. Then, the recorder was replaced by a voltage–frequency digital converter with four decimal digits and thirty 0^m.5 gains defined by very stable resistors. The converter was designed at the Vienna University Observatory, and manufactured by

Anton Paar, KG, in Graz, Austria. Careful calibrations of the gains of the original system were carried out, and properly used, in each observing season. The gains of the voltage-frequency converter turned out to be so stable that a mean calibration, based on several seasons of measurements, was invariably used in the final reductions.

The data reduction was carried out with the help of the reduction program HEC22 Rel. 12 (Harmanec et al. 1994a) which ensures a stable and accurate transformation into the standard Johnson *UBV* system. A careful determination of accurate *UBV* magnitudes of all comparison, check and standard stars by the same authors allowed to utilize virtually every measurement of standard and comparison stars on good nights to the definition of the nightly transformation coefficients (extinction, zero point and its derivative in each passband), thus ensuring the best possible reduction of the available data. The seasonal transformation coefficients were derived in such a way as to take into account all inevitable changes of the detection system, mirror aluminizations, etc.

A typical observing sequence consisted of 3 to 5 individual differential observations per star each night. Depending on the scatter of individual observations, we classified all observing nights into three categories, “excellent”, “normal”, and “poor” and assigned them weights 2, 1, and 0.5, respectively. Corresponding typical rms errors per one observation *for all-sky* observations are listed in Table 3 of Harmanec et al. (1994a).

The rms values for *differential* observations are generally lower. Judging by the results for the check stars, we estimate that the constant stars have the rms per one observation lower than 0^m015 in *V* and *B* and 0^m017 in *U*. There are, of course, other effects, affecting the accuracy. The accuracy is generally higher for later observations with the voltage-frequency converter and decreases for fainter stars and for stars with lower declination. In spite of the extent of our material, we are not able to properly evaluate all these effects on a statistical basis. Yet, we believe that some conclusions about variability or constancy are possible.

Table 1 gives the basic information about all objects ever observed in the course of the Be program at Hvar, including information about the comparison and check stars used. Mean *UBV* magnitudes of all program stars and the associated rms errors *per one observation of unit weight* are also given. It is seen that low-amplitude microvariables have rms errors only slightly larger than those of supposedly constant stars. Perhaps the best example is the well-known periodic variable LQ And, with a full amplitude of 0^m04 in all three passbands, which has the rms errors of 0^m014 , 0^m014 , and 0^m018 in *V*, *B* and *U*, respectively. The rms errors should be treated with caution for stars with a small number of observations for which accidental larger errors can affect them substantially. It seems, however, that all stars with a sufficient number of observations

Fig. 1. Photometry of *o* Cas

(say over 30) and rms errors higher than 0^m015 in *V* and *B* and 0^m020 in *U* should be suspected of variability.

The standard *UBV* magnitudes of all comparison stars, adopted from Harmanec et al. (1994a), are given for convenience in Table 2¹. Table 3 gives the mean *UBV* magnitudes of all check stars used by us and their associated rms errors. For more frequently observed stars these rms errors give an idea about the accuracy of observations and constancy of the comparison stars.

Some changes in the choice of comparison and check stars turned out inevitable because of a slight variability of the originally selected ones. This is documented individually in Table 1. Thanks to the new reduction, there are no or only negligibly small differences between the observations of the same variable relative to two or more different comparisons.

Complete differential and all-sky archives of all *UBV* observations secured in the course of the Be program at Hvar, along with the data retrieval program VYPAR, written by Dr. J. Horn (see Harmanec & Horn 1995) will be

¹ Tables 2 and 3 are only available in electronic form: see the Editorial in A&AS 103, No. 1 (1994).

Fig. 2. Light and color variations of ζ Tau

made available in a digital form in a separate publication (Harmanec et al. 1997).

3. Variability of individual Be stars

Our observational program was mainly oriented on monitoring the medium and long-term changes of Be stars. In many cases, only one series of observations of a particular star was obtained during the observing night. Later, however, some Be stars were also observed more intensively to study their rapid changes. Here, we report in detail only the cases of well-documented variations; otherwise, we only estimated possible timescales of variations on a statistical basis.

Information about the character of variability of frequently-observed stars is summarized in Table 4. The bibliographical remarks in this section *are not* aimed to provide complete reviews of known variability of individual stars. We only refer to important or principal reports of photometric variability of stars in question. Spectroscopic changes are reported only if they are clearly related to the photometric variations observed. In such cases, we shall often refer to the study of Hubert-Delplace & Hubert (1979), hereafter referred to as “Atlas”.

Those stars of Table 1 for which we cannot conclude anything about their variability, and for which we were unable to find any report of light variability in the astronomical literature, are simply omitted from the discussion below.

HD 2905 (κ Cas):

Percy & Welch (1983) found variations of 0^m05 in b on a time scale of 3 – 8 days, but no significant variability on a time scale of hours. Rapid variations were reported, however, by Elst (1979) and by Badalia & Gurm (1982). Rather limited Hvar observations have the rms errors below the detection threshold for variables established from the observations of check stars.

HD 4180 (o Cas):

This is the brighter component of the visual binary ADS 622. o Cas is a known long-term spectral variable, which changes between the B and Be phases cyclically over intervals of a few years. Photometric variations of o Cas were suspected by Haupt & Schroll (1974). Also Alvarez & Schuster (1981) and Schuster & Guichard (1984) listed it as a variable. Hvar observations of 1982–1984 have shown significant photometric activity of this star (Horn et al. 1985). The variations are shown in Fig. 1. Rapid flare-like brightenings were recorded during two consecutive seasons. Moreover, a secular brightening over the whole interval of observations can also be noted.

HD 5394 (γ Cas, 27 Cas):

This is one of the most frequently observed Be stars, both in the optical and in other spectral regions. The long-term light variability was summarized by Doazan et al. (1983). Only a few observations were obtained during two seasons at Hvar; they fit into their light curve.

HD 6811 (ϕ And, 42 And):

This star is the brighter component of the close visual binary ADS 940 composed of two B stars with an orbital period of 371.6 years (Abt & Cardona 1984). Only a weak and variable H α emission is reported in Atlas. Alvarez & Schuster (1981) have reported this star as “possibly variable” while Božić et al. (1995) argued in favour of its secular constancy. No light or colour changes are indicated by the Hvar observations.

Fig. 3. Color behaviour of ζ Tau during long-term light variations. Luminosity classes V, II and Ia represented by a solid, dotted and dashed line, respectively. Epoch of the first and last observation is indicated

HD 10516 (ϕ Per):

This Be star is a peculiar double-line spectroscopic binary consisting of two emission-line objects. Its very detailed spectroscopic and photometric study was published by Božić et al. (1995) who critically summarized the existing knowledge and analyzed all published radial-velocity and photometric data along with new spectroscopic and photometric observations. Complicated low-amplitude light variations are a combination of the long-term ones (on a time scale of years), orbital variations with a period of 126^d6731 and rapid variations on a time scale of less than a day. The long-term variations show a positive correlation between the H α emission strength, brightness and colours. For this type of correlation, the apparent *photometric* spectral type is gradually changing from a main-sequence object to a bright supergiant as the brightness and emission increase and vice versa (Harmanec 1983b).

HD 13854 (HR 654):

Alvarez & Schuster (1981) list this star as a possible variable. Scarce Hvar observations show only marginal light variations in the V passband and apparently no variations above the detection threshold in B and U.

HD 14818 (10 Per):

Alvarez & Schuster (1981) list this star as a variable. This supergiant is definitively variable according to the rms errors in all three passbands (cf. Table 1).

HD 18552 (HR 894):

This object was announced to be a double-line spectroscopic binary with a cool secondary (Polidan & Peters 1976) but this finding has never been confirmed. A gradual increase of the emission strength between 1953 and 1976 is reported in Atlas but no light variations have been detected. Over almost 4 months of intensive monitoring at Hvar during the 1980/81 season, no light and colour variations exceeding 0^m02 were detected (Pavlovski & Božić 1982). The constancy of the star was confirmed by continuing Hvar observations.

RX Cas (BD+67°244)

RX Cas is a strongly interacting binary in which the hotter and more massive component is completely hidden in an accretion disk which mimics a stellar photosphere of a spectral type later than the central star (Andersen et al. 1989). Emission in the Balmer lines is seen during the whole orbital cycle and – if not seen equator-on – this object would certainly be classified as a typical Be star. It was observed at Hvar from 1975 to 1977 (cf. Kříž et al. 1980) and in 1982. A pronounced long-term modulation of the light curve is present. Kalv (1979), who observed the star systematically, concluded that its light curve varied with a period of 516 d. Cycle-to-cycle variations of the orbital light curves, possibly similar to that of RX Cas, were also found for some other Be binaries (CX Dra, KX And, β Lyr, V360 Lac).

HD 21551 (HR 1051):

This star is a member of the α Per cluster. A shell spectrum was once observed by Kraft (1967). Hvar observations scatter within 0^m04 in all three passbands.

HD 22192 (ψ Per, 37 Per):

This star is also a member of the α Per cluster. Slettebak (1982) found no obvious emission-line variations between 1949 and 1980. Neither light nor colour variations were detected at Hvar.

HD 23862 (BU Tau, 28 Tau, Pleione):

The long-term light variations of this star are well documented especially thanks to systematic *UBV* observations by Sharov and Lyutyj (see Sharov & Lyutyj 1992, 1994 and references therein). A few Hvar observations fit in their light curve.

HD 25940 (MX Per, 48 Per):

This star shows only slight variations in the emission line profiles and brightness. Light variations for about 0^m02 on a time-scale of hours were reported by Percy & Lane (1977). Limited Hvar data provide no compelling evidence of light variations. However, the rms error in the

Table 4. The incidence of light variability among Be stars observed at the Hvar. Only well-observed stars are included here. The early- and late-Be stars are separately presented on the left and right side of the Table, respectively. Abbreviations L, R, O, and S denote (by black dots) the presence of variations on a time scale of years and months (L), days or fraction of day (R), orbital (O) and sudden light changes (S), respectively

HD	Name	L	R	O	S	ref		HD	Name	L	R	O	S	ref
10516	ϕ Per	•	•	•	•	38, 40		4180	o Cas	•	•	•	•	20
25940	MX Per	•	•	•	•	-		6811	ϕ And	•	•	•	•	-
36576	V960 Tau	•	•	•	•	15		18552	HR 894	•	•	•	•	15
37202	ζ Tau	•	•	•	•	6, 15, 19, 26		-	RX Cas	•	•	•	•	8
41335	HR 2142	•	•	•	•	15, 18		21551	HR 1051	•	•	•	•	-
58050	OT Gem	•	•	•	•	12		22192	ψ Per	•	•	•	•	-
164284	V2048 Oph	•	•	•	•	-		29866	HR 1500	•	•	•	•	15
168797	NW Ser	•	•	•	•	-		37967	V731 Tau	•	•	•	•	15
174237	CX Dra	•	•	•	•	5, 6, 7, 9, 14		47054	HR 2418	•	•	•	•	15
180968	ES Vul	•	•	•	•	-		50658	ψ^9 Au r	•	•	•	•	15
184279	V1294 Aql	•	•	•	•	6, 11, 14, 16		58715	β CMi	•	•	•	•	12
189687	V1746 Cyg	•	•	•	•	-		109387	κ Dr a	•	•	•	•	39
191610	V1624 Cyg	•	•	•	•	30, 34, 35, 36		138749	θ Cr B	•	•	•	•	-
192685	QR Vul	•	•	•	•	15, 17		142926	V839 Her	•	•	•	•	6
194335	HR 7807	•	•	•	•	-		162732	V744 Her	•	•	•	•	2, 6, 13
200120	V832 Cyg	•	•	•	•	29		164447	HR 6720	•	•	•	•	-
200310	V1931 Cyg	•	•	•	•	21		166014	o Her	•	•	•	•	-
214168	8 Lac	•	•	•	•	-		183656	V923 Aql	•	•	•	•	6, 14
216200	V360 Lac	•	•	•	•	37		187399	V1507 Cyg	•	•	•	•	4
217050	EW Lac	•	•	•	•	3, 6, 19, 22, 32, 34, 35		192044	20 Vul	•	•	•	•	15
217543	MWC 395	•	•	•	•	-		193911	25 Vul	•	•	•	•	15
218393	KX And	•	•	•	•	1, 6, 27, 28, 31		195554	MWC 637	•	•	•	•	-
218674	KY And	•	•	•	•	6, 14, 19, 24		216057	MWC 393	•	•	•	•	6, 14
224559	LQ And	•	•	•	•	33		217675	o And	•	•	•	•	6, 10, 23, 25

References to Table: 1) Harmanec et al. (1977b), 2) Harmanec et al. (1978), 3) Harmanec et al. (1979), 4) Pavlovski et al. (1979), 5) Koubský et al. (1980a), 6) Harmanec et al. (1980a), 7) Koubský et al. (1980b), 8) Kříž et al. (1980), 9) Harmanec et al. (1981c), 10) Horn et al. (1982a), 11) Horn et al. (1982b), 12) Božić et al. (1982), 13) Doazan et al. (1982), 14) Koubský & Pavlovski (1982), 15) Pavlovski & Božić (1982), 16) Horn et al. (1983), 17) Pavlovski et al. (1983), 18) Harmanec et al. (1983), 19) Pavlovski (1983), 20) Horn et al. (1985), 21) Harmanec et al. (1986), 22) Pavlovski (1987), 23) Harmanec et al. (1987b), 24) Pavlovski & Ružić (1988), 25) Harmanec et al. (1988), 26) Božić & Pavlovski (1988), 27) Štefl et al. (1990), 28) Pavlovski & Ružić (1989), 29) Hadrava et al. (1989), 30) Pavlovski & Ružić (1990), 31) Štefl et al. (1991), 32) Pavlovski & Ružić (1991), 33) Harmanec et al. (1991), 34) Pavlovski et al. (1993a), 35) Pavlovski et al. (1993b), 36) Ružić et al. (1994), 37) Pavlovski et al. (1994), 38) Harmanec et al. (1994b), 39) Juza et al. (1994), 40) Božić et al. (1995).

V passband is 0^m019 , hence, some slight variations are probably present.

HD 29866 (HR 1500):

We are not aware of any report of photometric variability. A very slight change of the $H\alpha$ emission is reported in Atlas. No photometric variations larger than the detection threshold were found at Hvar.

HD 32343 (BV Cam, 11 Cam):

In spite of many spectroscopic studies, only a few photometric measurements were published. Percy et al. (1981) observed probable variations of about 0^m02 within a few hours. Alvarez et al. (1987) reported small quasi-periodic fluctuations on a time scale of days (or possibly years). Limited Hvar data suggest light variations in V but not in B or U .

HD 36576 (V960 Tau, 120 Tau):

Variations up to 0^m1 in V were detected by Pavlovski & Božić (1982). Bossi et al. (1989) confirmed the variations on a short time-scale, but not their large amplitude. They interpreted them as multiperiodic nonradial pulsations.

HD 37202 (ζ Tau, 123 Tau):

This is a single-line spectroscopic binary with a period of 132^d9735 (Harmanec 1984c). A light decrease by 0^m2 during 1968 – 1969 was reported by Haupt & Schroll (1974). Results of systematic Hvar photometry were published by Božić & Pavlovski (1988). Three types of variations are combined in a complicated way:

i) Secular light variations with an amplitude of a few tenths of the magnitude on a time-scale of years;

Fig. 4. *UBV* photometry of 4 Her

II) peculiar phase-locked orbital changes: a light minimum centered on the phase of expected mid-eclipse of the Be star was observed during some cycles but not on others; and

III) rapid variations with a period of either $0^d.8$ or $1^d.6$.

The latter finding is especially interesting in the light of the spectroscopic result of Yang et al. (1990). Using high-S/N spectra, they found line-profile variations with periods of $0^d.683$ and $0^d.110$, and also with the orbital period. However, a recent analysis of a series of He I $\lambda 4921$ Å line profiles by Hahula & Gies (1994) revealed single-periodic variations with a period of 0.80 ± 0.06 d. Complete Hvar photometry of ζ Tau is shown in Fig. 2 while the accompanying colour changes are presented in Fig. 3. Recently, new photometric observations were obtained by Percy et al. (1994).

HD 37967 (V731 Tau):

Small variations with a scatter of $0^m.04$ in season 1981/82 were reported by Pavlovski & Božić (1982) from Hvar observations.

HD 41335 (HR 2142):

This Be star is a spectroscopic binary with a period of $80^d.860$ which regularly exhibits phase-locked shell phases lasting about 3 days prior, and 1 day after the lower conjunction of the Be component (Peters 1983). Light variations of a small amplitude were reported by Lynds (1959a). No measurable light variations corresponding to recurrent shell phases were found by Harmanec et al. (1983) and Dorren et al. (1984), who also excluded the presence of a $0^m.13$ light decrease in January 1983, reported by Sterken (1983). However, long-term variations with an amplitude as large as $0^m.1$ in *u* were found by Mennickent et al. (1994). Periodic light variations with a period of either $3^d.69$ or $0^d.79$ and an amplitude growing towards ultraviolet wavelengths were reported by Barrera

Table 5. Spectroscopic binaries

HD	Name	Sp. class	Period	Re
10516	ϕ Per	B2Vep	$126^d.6731$	1
—	RX Cas	(B5)+K1III	$32^d.33$	2
37202	ζ Tau	B1IIIpe	$132^d.9735$	3
41335	HR 2142	B2Ven	$80^d.860$	4
109387	κ Dra	B6IIIpe	$61^d.55$	5
142926	V839 Her	B7Ve	$46^d.194$	6
162732	V744 Her	B6Ve	$86^d.722$	7
174237	CX Dra	B2.5Ve+F5III	$6^d.69603$	8
183656	V923 Aql	B6e	$214^d.75$	9
187399	V1507 Cyg	B8IIIe	$27^d.9705$	10
200120	V832 Cyg	B1ne	$29^d.14$	11
200310	V1931 Cyg	B1Ve	$2^d.48?$	12
216200	V360 Lac	B3IVe	$10^d.0854$	13
217675	σ And	B6IIIpe	$33^d.0847$	14
218393	KX And	B2IIIe+KOII	$38^d.918$	15
224559	LQ And	B4Ven	$7^d.413$	16

Sources: 1) Božić et al. (1995); 2) Kříž et al. (1980), Andersen et al. (1989); 3) Harmanec (1984c); 4) Peters (1983); 5) Juza et al. (1991); 6) Harmanec et al. (1976); 7) Doazan et al. (1982); 8) Koubský (1978), Horn et al. (1992), Šimon (1996); 9) Koubský et al. (1989); 10) Pavlovski et al. (1979); 11) Tarasov & Tuominen (1987); 12) Harmanec et al. (1986); 13) Hill et al. (1996); 14) Harmanec et al. (1987a); Hill et al. (1989); 15) Štefl et al. (1991); Floquet et al. (1995); 16) Matthews et al. (1991).

et al. (1991). Rapid variations were also reported by Adelman (1992).

HD 47054 (HR 2418):

Peters (1976) classified the star as a long-period binary, but no report of light variations has been published as yet. The star is not a light variable according to limited Hvar observations.

HD 50658 (ψ^9 Aur, HR 2568):

Alvarez & Schuster (1981) list this star as possibly variable. Hvar observations have the rms errors just above the detection threshold.

HD 58050 (OT Gem):

Although Figer (1981) announced rapid light variations based on visual estimates in 1979, 1980 and the beginning of 1981, two later studies (Božić et al. 1982; Poretti 1982), based on photoelectric photometry, did not confirm any variations above the detection limit. Very pronounced emission-line variations of this star over two decades were reported in Atlas. This prompted us to include this star among regularly observed objects during the season 1981/82. No convincing evidence of rapid changes was found. However, the Hvar data indicate a secular brightness decrease over four consecutive

Fig. 5. The light and colour variations of 88 Her

seasons. Pronounced long-term emission-line changes were observed by Hubert-Delplace et al. (1982).

HD 58715 (β CMi, 3 CMi):

The intense photometric monitoring at Hvar between 1981 and 1983 did not reveal any sign of light variability on any time scale (Božić et al. 1982). Variations of the H α emission intensity were detected by Andriolat & Fehrenbach (1982) and Slettebak & Reynolds (1978).

HD 109387 (κ Dra, 5 Dra):

This bright Be star was classified as strongly variable by Schuster & Guichard (1984). Juza et al. (1994 and references therein) confirmed the long-term photometric variations, known for a long time, and derived the period of intensity variations of the Balmer emission lines and continuum polarimetry of about 23 years. The brightness attains

maximum during the rise of the emission while the brightness minimum coincides with the maximum strength of the Balmer emission.

HD 138749 (θ CrB, 4 CrB):

This is a relatively little-studied bright Be star. Roark (1971) detected a large decrease of its brightness (0^m7) with superimposed rapid variations. Harmanec (1983c) speculated that θ CrB could be an eclipsing binary with a period of about 511 days. This speculation was based on the coincidence between the time of primary minimum derived from radial velocity data and the occurrence of a steep light decrease observed by Roark (1971). However, the subsequent spectroscopic and photometric data (Hubert et al. 1990; Percy et al. 1988b; Papoušek 1986 and Fernandes et al. 1985) safely excluded Harmanec's

Fig. 6. The colour behaviour of 88 Her in the long-term cycle

Fig. 7. Photometry of 66 Oph

suggestion. Significant photometric variations on a time scale of days occurred in 1986 and 1987 (Percy et al. 1988b). Percy & Attard (1992) did not detect any significant photometric variations of this star in 1990 or 1991. Fernandes et al. (1985) also found the star constant within a few hundreds of a magnitude in May, June and July 1984. Guerrero et al. (1992) reported rapid light variations with a full amplitude of about 0^m03 which they interpreted as a combination of a slow variation (possible period of about 8 d) and a rapid variation with either 0^d869 or 0^d459 period. According to Hvar data, this star is a low-amplitude light variable, just above the detection limit.

HD 142926 (V839 Her, 4 Her):

This star is an interacting binary (Table 5). The long-term spectral changes (transition Be $\leftrightarrow$ B) were summarized by Koubský et al. (1994). Hill et al. (1976), Landis et al. (1977), Papoušek (1979), Dapergolas et al. (1981),

Fig. 8. Light variations of MWC 601

and Alvarez & Schuster (1981) did not detect any phase-locked light variations and concluded that the star was apparently constant in light and colour for quite a long time. Percy & Attard (1992) reported fading by 0^m09 in *B* and *V* and 0^m04 in *U* in 1991. Our systematic monitoring of the star for 19 years clearly reveals the presence of the long-term light and colour changes with a positive correlation between brightness and emission-line strength (Fig. 4).

HD 162732 (V744 Her, 88 Her):

This star is a single-line spectroscopic binary with a well determined orbit (Table 5). Long-term light variations were first announced by Harmanec et al. (1978) and further investigated by Doazan et al. (1982) and by Barylak & Doazan (1986). The star has shown only slight variations on time scales from days to months (see, e.g., Baldinelli et al. 1981). The long-term light and spectral changes have an inverse correlation between the brightness and emission-line strength (Doazan et al. 1982). Here, we show (Fig. 5) a smoothed light curve defined by the Hvar data and also the colour behaviour of 88 Her in the *U* – *B* vs. *B* – *V* diagram (Fig. 6).

HD 164284 (V2048 Oph, 66 Oph):

Cousins (1952) observed small and irregular brightness variations within 0^m07 . Page & Page (1970) reported large flare-like events detected on patrol photographs on two different nights in 1969. The star was listed as variable by Haupt & Schroll (1974) and as a suspected variable by Hill et al. (1976). The latter authors abandoned their observations after the season 1971 since they did not succeed to confirm any variations in excess of 0^m02 .

Fig. 9. Light and colour variations of V923 Aql

Percy et al. (1988b) detected small variations on a time scale as short as a few hours in each season between 1981 and 1987. A monotonic decrease of $0^m.1$ in b during 60 days was found by Adelman (1992). The star is reported as a spectroscopic binary (Hoffleit 1982) and RV variable (Crampton 1968). Conspicuous variations of emission line-profiles and other kinds of spectral variability were described by Reynolds & Slettebak (1980), Andriolat & Fehrenbach (1982), Grady et al. (1987), Peters (1988) and Hanuschik et al. (1995), among others. At Hvar it was observed from May to July 1982. The measurements definitely indicate variations (Fig. 7), but their true period is still unclear. Both, a period close to 1 day or periods of 22 – 25 days fit the Hvar data.

HD 164447 (HR 6720):

Alvarez & Schuster (1981) listed this shell star as a possible variable. We observed it in four seasons beginning 1982 and found some indication of variability (cf. the rms errors in Table 1).

HD 166014 (o Her, 103 Her):

This star was classified as a Be star by Irvine (1975) who observed $H\alpha$ emission in its spectrum. Hvar observations indicate that the star varies with a period of about 55 d.

HD 168797 (NW Ser, MWC 601):

Alvarez & Schuster (1981) listed this star as possibly variable. Percy et al. (1988b) classified NW Ser as an “active” star which showed short-term variations up to $0^m.1$ on time scales from hours to years. In a subsequent paper, Percy & Attard (1992) confirmed the short-term variability. The star was observed at Hvar since 1980. It is definitely a short-term variable, with an amplitude of about $0^m.15$ in all three passbands (Fig. 8). Moreover, it seems that the amplitude of the light changes varies from season to season.

HD 174237 (CX Dra):

This is an interacting Be binary (Table 5). The orbit was determined for both components (Horn et al. 1992; Šimon 1996). The long-term fluctuations of its

Fig. 10. Photometry for V1294 Aql

brightness were found by Koubský et al. (1980a). Moreover, low-amplitude orbital residual light variations were detected. The character of the orbital light variations is reminiscent of an ellipsoidal variable. However, large cycle-to-cycle variations in the depth of the primary minimum were observed (cf., e.g., Harmanec 1987b). The long-term variations were confirmed by Percy et al. (1988b) and by Percy & Attard (1992). The binary was regularly monitored at Hvar in almost all seasons since 1974.

HD 180968 (ES Vul, 2 Vul):

Regular light variations of this early B star with period of about 0.61 d and a range of 0.06^m were found by Lynds (1959a) in his photometric survey. The variability has been confirmed by Percy et al. (1988b) and is also obvious from the Hvar data. From a recent line-profile study, Hahula & Gies (1994) reported changes with a period of about 1.27 d. The Hvar observations indicate low-amplitude variations with a period of either $0^d.6$ or $1^d.2$.

HD 183656 (V923 Aql):

The star is a single-line spectroscopic binary (Table 5). It is also one of the first stars for which periodic rapid light variations were found (a period of 0.8518 day and a variable amplitude up to $0^m.1$, Lynds 1960). V923 Aql exhibits variations in radial velocity and V/R ratio of the double emission peaks on a time scale of about six years (Koubský et al. 1989). Small photometric variations on several time scales were reported by Percy et al. (1988b). Mennickent et al. (1994) indicated quasi-periodic long-term variations with a period of about 7 years and an amplitude up to $0^m.25$ in u and short-term variations up to $0^m.1$ within a few days. We observed V923 Aql at Hvar during 9 seasons. Significant light and colour variations are found (Fig. 9) on both, long-term and short-term time scales.

HD 184279 (V1294 Aql):

This star was used as a secondary photometric standard for the Johnson UBV system. Its variability was first discovered by Lynds (1959a). History of its light variations was summarized by Horn et al. (1982b). Photoelectric observations were also accumulated by Percy et al. (1981,

1988b) and Percy & Attard (1992). Correlated long-term photometric and spectroscopic variations were investigated by Horn et al. (1982b), Horn et al. (1983) and Alvarez et al. (1987). Mennickent et al. (1994) confirmed the cyclic light variability of this star with a period of about 5.9 years. They reported also occasional short-term variations up to a few 0^m01 in 10 days. The Hvar observations cover 9 seasons, starting 1975 (Fig. 10).

HD 185859 (HR 7482):

13-colour photometry of the star was published by Schuster (1982). Rather scarce Hvar observations did not indicate any light variations.

HD 187399 (V1507 Cyg, MWC 321):

Detailed spectroscopic study by Hutchings & Redman (1973) of this long-period binary system revealed its complex nature. They suggested that the primary, i.e. the star dominating in the optical spectrum, loses mass while the more massive component is observationally undetectable due to its huge circumstellar envelope. In this respect, V1507 Cyg is similar to β Lyr, RX Cas and other strongly interacting binaries of the W Serpentis type. The light variations are complex and without an a priori knowledge of the orbital period, photometric observations can hardly be properly phased. Hvar observations span 3 years (1976 – 1978) and consist of 38 *UBV* measurements. The orbital light curve is peculiar but stable (Pavlovski et al. 1979). Even, when compared to previous photometric measurements by Hill et al. (1976), no pronounced changes in the shape of the light curve were noticed as could be expected for such an “active” binary.

HD 187811 (12 Vul):

Variability on a time scale of days (0^m1 within 20 days) was reported by Percy et al. (1988b). Short term variability was detected by Percy & Attard (1992) in the range of 0^m01 – 0^m03 . Variability was also found by Alvarez & Schuster (1981) and Schuster & Guichard (1984). Limited Hvar observations did not reveal light variations.

HD 189687 (V1746 Cyg, 25 Cyg):

Photometric observations of this star were described by Percy & Lane (1977), Percy et al. (1981) and Percy et al. (1988b). Comparing these studies one can conclude that if the star were variable at all, it would have a very small amplitude (0^m01) and would vary on a time scale of hours. The star was observed at Hvar since 1985 in three seasons. Neither rapid nor slow variations above the detection threshold were found, although some suspicion of variations with a very small amplitude remains.

HD 191610 (V1624 Cyg, 28 Cyg):

Light variability was first detected by Gies & Percy (1977). Since then, the star attracted attention of several photometrists. Rapid variations were confirmed by Percy & Lane (1977), Spear et al. (1981) who reported a periodicity of about 0^d7 , Percy et al. (1981), Schuster & Guichard (1984) and by Adelman (1992). Peters &

Fig. 11. Light and colour variations of 28 Cyg

Penrod (1988) obtained simultaneous IUE and ground-based spectral observations. They confirmed conspicuous mass-loss activity and moving sub-features in the optical line profiles. They interpreted the observed effects as NRP with a low-order mode $l = 2$ and a period of 0^d68 , and a high-order mode $l = 10$ with a period of 0^d13 . Pavlovski & Ružić (1990) analyzed Hvar measurements obtained during the same season as the Peters & Penrod (1988) data. Light variations with an amplitude of 0^m08 in *V* could be reconciled with either a 0^d68 period (sinusoidal light curve) or a 1^d36 period (a double-wave light curve). However, the authors concluded that the scatter around the mean curve was much larger than the observational errors. Using a Fourier decomposition, they were able to model the observed variations by a sum of four sinusoids with different periods. Ružić et al. (1994) attempted to analyze all available photometric data on this star. They tentatively concluded that the variations are either controlled by two principal periods, 0^d690 and 11^d1 or that regular variations are being disturbed by some stochastic process. The light amplitude varies from season to season. Bossi et al. (1993) found several different periods in the line-profile variations of He I $\lambda 6678$ Å and H α , including those reported by Peters & Penrod, and by Pavlovski & Ružić. Recently, Hahula & Gies (1994) analyzed series of observations of He I $\lambda 4921$ Å line and found a single-periodic variation with a period of 0^d64 . They attributed the variation to an $m = -2$ NRP mode. Early Hvar observations of this star suffered from the fact

that (at that time unknown) variable, V1644 Cyg = 29 Cyg (HD 192640) was originally used as the comparison. During the final reduction, differential magnitudes were derived relative to many different, accidentally observed comparison stars and are not, therefore, particularly suitable for analyses of low-amplitude changes. All reliable photometric observations obtained at Hvar are shown in Fig. 11.

HD 192044 (20 Vul):

The star was monitored by Percy et al. (1988b). No variations above the detection threshold were found at Hvar (Fig. 12).

Fig. 12. Photometry for 20 Vul, 25 Vul, QR Vul, and their check star 18 Vul, respectively

HD 192685 (QR Vul, HR 7739):

This star served as the comparison star for both 20 and 25 Vul, but was found to vary in light and emission strength (Pavlovski & Božić 1982; Harmanec et al. 1982b; Barker 1982). Sudden brightening, accompanied by a steep increase of the $H\alpha$ emission, reddening of the $B - V$, and blueing of the $U - B$ indices was described in detail by Pavlovski et al. (1983). Slight variations on long and short-term scales were reported by Percy et al. (1988b) and Percy & Attard (1992). Hvar photometry (Fig. 12) did not reveal secular changes, but variations on shorter time scales are obvious.

HD 193237 (P Cyg):

Historical observations of this luminous blue variable star can be found in Lamers & de Groot (1992). The 1985 and 1986 Hvar observations were incorporated into the

study by Percy et al. (1988a). They found irregular variations up to $0^m.2$ on time scales ranging from a few days to a few months.

HD 193911 (25 Vul):

No report of light variability was found. Hvar observations show this star to be non-variable (cf. Table 1 and Fig. 12, respectively).

HD 194335 (HR 7807):

This relatively bright Be star has been almost neglected by photometrists. Our data which cover 3 consecutive observing seasons clearly revealed light variations on a short-term scale (Fig. 13).

Fig. 13. Light variations of HR 7807

Fig. 14. Light and colour variations of 55 Cyg

HD 195554 (MWC 637):

No report of variability was found and no changes in the emission strength between 1953 and 1975 are reported in Atlas. This star was observed at Hvar since 1980 and seems to be constant at our detection threshold.

Fig. 15. Light and colour variations of 8 Lac

HD 198478 (V1661 Cyg, 55 Cyg):

Percy et al. (1988b) report small photometric variations on a time scale of weeks to months. Apparently there were no short-term variations. On the other hand, Percy & Welch (1983) present indications of shorter changes on a time scale of 5 to 10 d. Rufener & Bartholdi (1982) list this star among microvariables. Hvar observations (cf. Fig. 14) show significant changes on a time scale of days, with a possible pseudoperiod of $45^{\text{d}}.284$.

HD 199478 (HR 8020):

Summary of observations of this star in 1986 and 1987 was given by Percy et al. (1988b). Slight variations on a time scale of days to months can be deduced from their data.

HD 200120 (V832 Cyg, 59 Cyg):

This bright and frequently observed Be star is a member of the Cyg OB7 association and the brightest component of a multiple system of stars. It is characterized by variable emission lines and a temporary shell of hydrogen, helium and ionized metals and by variable mass-loss (studied intensively in UV superionized lines, e.g. Doazan et al. 1989 and references therein). For a long time, it has been known as a light variable. Lynds (1959b) reported a steady decline of brightness by $0^{\text{m}}.1$ during five months in 1958. Large changes in V ($\geq 0^{\text{m}}.4$) and in the near IR was observed in 1977–1979 by Schuster & Alvarez (1983). Rapid variations on a time scale of days were reported by Percy et al. (1988b) and Hadrava et al. (1989).

Fig. 16. Phase diagram of V360 Lac in the V passband folded with a period of $10^{\text{d}}.0854$ for the Hvar observations

HD 200310 (V1931 Cyg, 60 Cyg):

Light variations were found by Harmanec et al. (1986). They found a possible period of $2^{\text{d}}.48$, which was consistent with the published radial velocity variations, and suggested that the star was a spectroscopic binary. Percy et al. (1988b) confirmed that the star varies on a time-scale of days, but their data did not support the $2^{\text{d}}.48$ period. Rapid line-profile variations were detected by Koubský et al. (1995).

HD 201733 (MWC 363):

A summary of observations of this star in 1986 and 1987 was given by Percy et al. (1988b). Slight variations on a time scale of days to months can be derived from their monitoring. Alvarez & Schuster (1981) list this star as possibly variable.

HD 203467 (6 Cep):

We are not aware of any report of light variations. No convincing evidence of light variations was found from one season of monitoring at Hvar.

HD 214168 (8 Lac):

Alvarez & Schuster (1981) and Schuster & Guichard (1984) list this star as possibly variable in their 13-colour photometry of Be stars. Hvar measurements are shown in Fig. 15. No secular changes were found but some light variability may be suspected from the rms errors listed in Table 1.

HD 216057 (MWC 393):

This is a relatively little-studied Be star. Photometric observations were presented by Alvarez & Schuster (1981) and Schuster & Guichard (1984). They found no evidence of light variability. No evidence of light variations was found during 7 seasons of observations at Hvar.

Fig. 17. Photometric variability of EW Lac

HD 216200 (V360 Lac, 14 Lac):

Walker (1952) discovered variability of 14 Lac with an amplitude of a few 0^m01 . Hill et al. (1976) confirmed the light variability and concluded that 14 Lac is an ellipsoidal variable with a period near 20 days. Mantegazza (1980), clearly unaware of these previous results, found evidence of Balmer emission and reported light variations with a possible (pseudo)-periodicity of about 5 days. This fact prompted Morris (1985) to reject the star from his list of ellipsoidal variables. Hvar observations extend over 8 seasons. Period analysis of combined Hvar and MtKobau observations yield a period of $P = 10^d0854$, similar to that found by Hill from radial velocities (see Richardson 1977). Phase diagram of the light and colour variations is shown in Fig. 16. A detailed analysis of the combined photometric and spectroscopic data has been carried out by Hill et al. (1997).

HD 217050 (EW Lac):

This often studied Be star has exhibited a strong shell spectrum since 1940. Its light variations were discovered by Walker (1953). He was able to reconcile “periods” in the range of $0^d7 - 0^d8$ in some series of observations, but no apparent periodicity was present in other epochs. Lester (1975) confirmed the variations with a characteristic cycle of $\approx 0^d7$ from his *uvby* observations. Harmanec et al. (1979) demonstrated the presence of long-term light variations between 1972 and 1978. Percy (1981a) found periods of either 0^d725 or 0^d418 from his 1980 observations but expressed doubts about the presence of a real periodicity. Similar periods were found by several authors: 0^d72 (Pavlovski 1983, 1987), 0^d75 (Iliev et al. 1984), 0^d716 (Stagg et al. 1988). Pavlovski (1983) pointed out the double-wave character of the light curve. Later, he derived a multifrequency fit with 3 periods of 0^d364 , 0^d784 and 0^d619 (Pavlovski 1987).

Fig. 18. Colour behaviour of long-term changes in EW Lac

The star shows conspicuous spectroscopic variations on the same time scale. Multifrequency analysis of He I 6678 Å line profiles and equivalent width (Floquet et al. 1992) and of rapid V/R variations of the H γ line (Pavlovski & Schneider 1990) led to periods close to those derived by Pavlovski (also, Pavlovski et al. 1993a) from the light variations and a longer one, 2^d.22. Results of the above mentioned multifrequency analysis for the shorter periods have been interpreted as nonradial pulsations while the longer period was suggested to be due to inhomogeneities slightly above the photosphere. Hvar photometric measurements of EW Lac are displayed in Fig. 17. Both long-term and rapid variations are obvious. Full *UBV* amplitudes of the long-term changes exceed the amplitudes of the rapid light variations, and amount to 0^m.35, 0^m.35, and 0^m.65 in *V*, *B*, and *U* passbands, respectively. Seasonal changes of the amplitudes of the short-term variations, first observed for *o* And (see below), are clearly seen in Fig. 17. Colour changes are also significant (Fig. 18) and the star becomes redder when brighter in both *B* – *V* and *U* – *B* indices. However, changes in the *U* – *B* are not linear and their maximum does not coincide with the brightness extremum. This effect was also found for several other Be stars by Dachs et al. (1988) who interpreted it as due to selective contributions of circumstellar envelope and underlying stellar photosphere in the course of significant changes of the envelope structure.

HD 217543 (MWC 395):

Schuster & Alvarez (1981) listed HD 217543 as a variable star. Jerzykiewicz (1993) confirmed its variability with an amplitude of 0^m.018 without giving details. Our observations clearly indicate variability – see the rms errors in Table 1 and Fig. 19, respectively.

Fig. 19. Photometric observations of HD 217543 (MWC 395)

HD 217675 (o And, 1 And):

McAlister et al. (1983) have confirmed that *o* And is a speckle interferometric triple star. Later Harmanec et al. (1987a) and Hill et al. (1988, 1989) have shown that *o* And is a quadruple system. The Be variable is the brightest component *o* And A. At a distance of about 0^{''}.3, *o* And B apparently revolves in a common orbit with A – its estimated orbital period being well over 100 years. Component B itself is a double-line spectroscopic binary with a period of 33^d.08 composed of two B6–B8 stars. There is a faint fourth component *a* at a distance of some 0^{''}.05. If this component is also gravitationally bound to A, the expected orbital period is about 10 years. Since the beginning of this century several transitions B–Be–Be shell and vice versa of *o* And A were reported. Since 1918, *o* And has been known to show rapid photometric variability (Guthnick 1918). The photometric history of the star has been summarized by Harmanec (1983b). Harmanec (1984b) suggested that the available photometric observations could be explained as superposition of a long-term variation with an amplitude of 0^m.1 in *B* and *V* and a short-term periodic variation of 1^d.571272. The 1.571-day curve has a double-wave character and is secularly changing both in amplitude and shape. These variations are connected to the long-term photometric and spectral changes. Harmanec (1984b) also suggested that the long-term cycle (photometry and reappearance of shell lines) is 8.5 years long and might correspond to the period of the system *o* And Aa. The presence of the 1.571-day modulation in the light of *o* And was confirmed by Harmanec et al. (1987b) and during two international campaigns – Stagg

Fig. 20. Photometric behaviour of *o* And

et al. (1988) and Sareyan et al. (1992). Figures 20 and 21 show the light and colour changes, respectively, observed at Hvar between 1973 and 1990. Long-term variations with peak-to-peak amplitudes of $0^m.23$ in V , and up to $0^m.33$ in U are well seen. Also, significant colour changes occurred over the same cycle of about 8–9 years, in good agreement with Harmanec’s (1984b) result.

HD 218393 (KX And):

A comprehensive review of the observational history of this star was given by Štefl et al. (1991). Light and colour variations of the star were discovered by Harmanec et al. (1977b). Štefl et al. (1991) showed that the light and colour variations are consistent with the period of $38^d.919$ derived from the RV variations. The variations are the most conspicuous in the U magnitude and in the $U - B$ but their amplitude varies significantly from cycle to cycle. Low-amplitude light variations on a time scale of about half a day were reported by Stagg et al. (1988) and further studied by Pavlovski & Ružić (1989). The conclusion of Štefl et al. (1991) that the $38^d.9$ -period reflects the orbital motion in an interacting binary system was confirmed by

Floquet & Hubert (1991) and Floquet et al. (1995). They discovered a K-type secondary in the near-IR region and derived half of its RV curve. The orbital light variations are not caused by stellar eclipses. The rapid light variations may be a result of processes in the accretion stream or in the region of its interaction with the disk.

Fig. 21. Color variations in long-term cycle of *o* And

Fig. 22. Photometry of KY And

HD 218674 (KY And):

Earlier photometric and spectral studies of KY And were summarized by Pavlovski & Ružić (1988). They analyzed rapid light variations observed in 1988 at Hvar but failed to find any strict periodicity. They suggested that variations of the star may be multiperiodic, with a dominant period of $0^d.75$. Also Stagg et al. (1988) were unable to reconcile the rapid changes of KY And, observed during the multi-site observing campaign in 1983 with a single periodic process. Recently, Hahula & Gies (1994) analyzed a series of observations of He I $\lambda 4921$ Å line-profile and found periodic variations with a single period of $0^d.79$ which they attributed to low-order NRP mode with $m = -2$. Hvar photometric data are displayed in Fig. 22. Light variations are rapid and have a large amplitude.

HD 224559 (LQ And, MWC 407):

The light variability of HD 224559 was discovered by Provin (1953). Percy (1983) derived a sinusoidal light curve of LQ And with a period of $0^d.307$ and an amplitude of $0^m.03$ in *ubvy*. Harmanec (1984a) argued that Percy's observations could be better represented by a double-wave light curve, with a twice as long period of $0^d.62$. The ambi-

guity in the light-curve shape and period was not settled with new observations obtained during three intercontinental campaigns (Stagg et al. 1988; Sareyan et al. 1988; Harmanec et al. 1991). Only Matthews et al. (1991) resolved it finally in favour of Harmanec's longer period. Moreover, they concluded that LQ And might also be a spectroscopic binary with a period over 7 d.

HD 225094 (V639 Cas, MWC 408):

Hill et al. (1976) list this star as a possible irregular variable. Guinan et al. (1982) confirmed that the star varied on a time scale of several days with a full amplitude of about $0^m.1$. They could not exclude that the variations were in fact periodic, with a possible period of about 2 days or shorter. Our limited data seem to indicate some variability, too.

4. Conclusion

During almost twenty years of the photometric monitoring, 13 848 *UBV* measurements of 76 bright Be stars of all luminosity classes were secured at the Hvar Observatory. For 46 of them, the time coverage was sufficient enough

to permit more detailed studies on the incidence and time scales of the light and colour variability. The results are summarized in Table 4 in which Be stars are divided into early- and late-B types. Light variations on both, long and short time scales are frequent among early Be stars, in contrast to late-type Be stars. In several known spectroscopic binaries we succeeded to demonstrate the presence of phase-locked light variations related to their binary nature (KX And, LQ And, RX Cas, V1507 Cyg, CX Dra, V360 Lac, ϕ Per, ζ Tau).

Sudden brightenings, on a time scale of a few days, were detected for σ Cas and QR Vul.

In addition, 9648 *UBV* measurements of 48 check stars of, mostly, early spectral types were collected in the present long-term observing project.

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