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VBLUW photometry of Magellanic Cloud super- and hypergiants, made in 1977 up to 1979 (*)

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Summary. — *VBLUW* photometry (Walraven system) of SMC and LMC super- and hypergiants (= super-supergiants) is presented. The observations have been made in 1977 up to 1979. The values for V and B-V of the *UBV* system (with subscript J) are also given. A short discussion is given on the stability of the photometric parameters within the last 10 to 25 y by comparing stars in common with other authors.

Key words : supergiants — photometry — Magellanic Clouds.

1. **Introduction.** — *VBLUW* photometry (Walraven system) of bright stars in the Magellanic Clouds has been made by van Genderen (1970, 1973 : LMC) and Walraven and Walraven (1977 : SMC and LMC). To study the variability of four hypergiants (= super-supergiants : $M_v \lesssim -8$) in the LMC in detail, long time baseline *VBLUW* photometry has been made of four specimen (van Genderen, 1979a, b).

This paper contains new photometry of super- and hypergiants in both Clouds which has been made from 1977 up to 1979. The sample given here has some overlap with the previous studies.

2. **The observations and reductions.** — The observations have been made with the 90-cm light collector equipped with the simultaneous *VBLUW* photometer of Walraven. The 1977/1978 observations have been made when the telescope was still at the Leiden Southern Station in South-Africa (SAAO annex), those of 1979 at the ESO after the move to Chile.

A description of the photometer and the photometric system has been given by Walraven and Walraven (1960), Rijf *et al.* (1969) and Lub and Pel (1978).

In 1977/1978 the program stars were measured relative to the following comparison stars : HD 3719 for the SMC stars and HD 39844 for the LMC stars. Both are standards of the *VBLUW* system. In 1979 a different comparison star was used in the LMC viz. HD 33486 taken from van Genderen (1979a). The diaphragm aperture for the 1977/1978 observations was usually 23″ while that for the 1979 observations was 15″. The sky brightnesses were taken nearby the program stars. Corrections for differential extinction were applied with standard extinction coefficients. As in the normal practice in the *VBLUW* system, brightness and colours are expressed in the ^{10}log of the intensity.

Since the photometric system has slightly changed after the move to Chile, all 1979 observations are transformed to the 1970/1978 system using transformation formulae of Pel (1980). The corrections are generally not more than 0.01 (in log intensity scale).

The V-B colour index can be transformed into the equivalent B-V colour index of the *UBV* system (denoted with a subscript J) by table 7 in Walraven *et al.* (1964) and revised with the aid of formulae given by Lub and Pel (1977). The V_J (the V magnitude of the *UBV* system) can be transformed from V using the formula of Pel (1976). More details on dates and the number of observations are given in the explanation of tables I and II.

Tables I and II tabulate the SMC and LMC stars respectively. To make the photometric data of stars in common with previous *VBLUW* studies made *before* 1970 (see Sect. 1) comparable with those presented here, a slight revision should be made according to the formulae of Lub and Pel (1977) for V, V-B and U-W. Because the passband W (3255 A) has apart from the brightest stars, very low readings, the U-W colour index could not always be given.

The photometric accuracy expressed by the standard deviation is as follows :

for stars with $V_J < 11^m.8$:

(*) The observations have been partly made at the ESO, La Silla, Chile.

in V, ± 0.005 ; in V-B, ± 0.007 ; in B-U, ± 0.015 ; in B-L, ± 0.014

for stars with $12^m.8 > V_J > 11^m.8$:

in V, ± 0.020 ; in V-B, ± 0.012 ; in B-U, ± 0.035 ; in B-L, ± 0.023

for stars with $V_J > 12^m.8$:

in V, ± 0.023 ; in V-B, ± 0.015 ; in B-U, ± 0.060 ; in B-L, ± 0.035.

The standard deviation in U-W is difficult to determine, in view of the small numbers of available measurements, but it may amount up to ± 0.1. The 1979 observations, which have been made with an improved equipment and more sensitive photoelectric cells, have smaller standard deviations by a factor two for V up to a factor ten for U-W.

3. **The photometrical stability of the investigated stars.** — The V_J and $(B\text{-}V)_J$ values of all stars listed here were compared with the data given by other authors to check the long term photometrical stability within an interval of 10 up to 25 y. For the SMC the following lists were consulted : Feast *et al.* (1960), Wesselink (1962), Dachs (1970) and Walraven and Walraven (1977), for the LMC : Feast *et al.* (1960), Wesselink (1962), Woolley (1963), Bok *et al.* (1966), Mendoza (1970), van Genderen (1970, 1973), Ardeberg *et al.* (1972), Brunet *et al.* (1973). Isserstedt (1975), Walraven and Walraven (1977), Ardeberg and Maurice (1977), and Rousseau *et al.* (1978).

Total ranges in V_J and $(B\text{-}V)_J$ were determined and the number of stars counted having ranges of 0.00 up to 0.03, 0.04 up to 0.07, 0.08 up to 0.11 and > 0.11 mag. The result is shown in table III. It is difficult to say how large the influence of errors in the photometry is on the reliability of this statistic, it should however be kept in mind. If one assumes that ranges larger than 0.04 mag in V_J indicate a possible real variability, then 67 % of the SMC and 69 % of the LMC stars make a chance to be slightly variable.

In the SMC the stars with AV numbers 88, 159, 199, 417 and further R 40 (= HD 6884) show a total range between 0.21 and 0.15 mag in V_J, but apart from the last specimen the number of available observations is only two or three. The total range of R 45 (= HD 7583) is 0.09 mag in V_J. R 40 as well as R 45 are also suspected of variability by Ardeberg and Maurice (1979). All the stars quoted above are marked by « v ? » in the column « Rem » in table I.

The LMC stars with a total range in $V_J > 0.04$ mag based on *at least four* observations are marked by « v ? » in the column « Rem » in table II. The largest range in V_J is 0.12 mag for HDE 269723 (= R 117) a G2 Ia type star. However a very faint star is present near the edge of the 23″ diaphragm, so this object may be partly the cause.

Thus the conclusion is that within two decennia none of the investigated stars show light variations of 0.5 up to 2 mag similar to the LMC hypergiants HD 35343 (= S Dor = R 88), HDE 269006 (= R 71) and HDE 268757 (= R 59), they rather are of the type of HD 33579 (R 76) (van Genderen, 1979b). Apparently the extreme unstable ones are the very few exceptions.

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TABLE I. — *SMC super- and hypergiants observed from 1977 up to 1979.*

No			Sp	V	V-B	B-U	U-W	B-L	V_J	$(B-V)_J$	Rem.
				(log intensity)					(mag)		
AV	HD	WW									
79			F2	-2.716	.085	.420		.106	13.65	0.21	77/78
88			F2	-2.427	.061	.376		.070	12.93	0.14	77/78,v?
107			F5	-2.704	.101	.489		.139	13.62	0.25	77/78
121			G0	-1.804	.301	.521		.279	11.34	0.73	77/78
127			F2	-2.240	.109	.522		.128	12.46	0.27	77/78
134			F2	-2.353	.066	.466		.091	12.75	0.16	77/78
140		116	F2	-2.014	.201	.496		.208	11.88	0.49	77/78
142			F5	-2.390	.104	.510		.128	12.83	0.25	77/78
159			F2	-2.616	.117	.488		.181	13.39	0.29	77/78,v?
167			F2	-2.867	.109	.426		.173	14.02	0.27	77/78
174			A7	-2.238	.099	.502		.139	12.45	0.24	77/78
197		142	F5	-2.002	.176	.484		.192	11.85	0.43	77/78
198			F5	-2.580	.176	.491		.191	13.30	0.43	77/78
199			A5	-2.560	.071	.276		.084	13.26	0.17	77/78 db.$\Delta m \sim 0^m.5$,v?
269		182	A5	-1.821	.065	.412		.084	11.42	0.15	77/78
305			F5	-2.360	.085	.458		.145	12.76	0.21	77/78
310		202	F0	-1.910	.126	.516		.139	11.63	0.31	77/78 R26
323			F2	-2.561	.108	.460		.164	13.26	0.26	77/78
369		250	G0	-1.659	.249	.485		.218	10.98	0.61	77/78
401			F2	-2.552	.077	.609		.126	13.24	0.18	77/78 db. $\Delta m \sim 2^m$
415	6884	266	B8Ie	-1.473	.056	.071	.125	.017	10.55	0.13	16/10/79 v? R40
				-1.458	.056	.072	.125	.016	10.51	0.13	31/10/79
417			F5:	-2.774	.157	.476		.194	13.78	0.39	77/78,v?
434			F5	-2.340	.157	.470		.197	12.70	0.39	77/78
473			F5	-2.403	.255	.486		.220	12.84	0.62	77/78
475	7583	314	AoIae	-1.334	.069	.187	.176	.038	10.20	0.16	79,v?,R45

Explanation of table I (SMC)

No : first column : numbers according to Azzopardi and Vigneau (1975) ; second column : HD numbers ; third column : numbers according to Walraven and Walraven (1977, *VBLUW* photometry).

Sp : spectral classification according to Azzopardi and Vigneau (1975) apart from HD 6884 and HD 7583 which are taken from Feast *et al.* (1960).

V, V-B, B-U, U-W and *B-L* : photometric parameters of the 1970/1978 *VBLUW* system in log int. scale averaged over two or three observations.

V_J, $(B-V)_J$: photometric parameters of the *UBV* system (in mag) transformed from the equivalent *V* and *V-B* values (see text).

Rem : 77/78 : observations made from August 1977 up to January 1978 ; 79 : observations made in October 1979 ; 16/10/79, etc. : more precise data for a star suspected of a variability on a short time scale (one observation only). Remarks concerning duplicity (db) according to Azzopardi and Vigneau (1975). Radcliffe numbers if present (R). Stars marked with v ? may be variable according to the criteria explained in section 3.

TABLE II. — *LMC super- and hypergiants observed from 1977 up to 1979.*

HD/HDE	No. FD/A.etal	R	WW	vG	Sp.	V	V-B	B-U	U-W	B-L	V_J	$(B-V)_J$	Rem.
							(log intensity)				(mag)		
	G79				F0Ia	-1.886	.079	.439		.108	11.58	0.18	77/78
32034	G80	62	19		B9Iae	-1.116	.042	.059	.090	.012	9.66	0.09	17/10/79 | v?
						-1.149	.045	.057	.101	.012	9.74	0.10	20/11/79 |
268687	G28				F6Ia	-1.566	.209	.421	.06	.185	10.76	0.50	77/78, v?
268819	G91				F6Ia	-1.284	.206	.519	.30	.207	10.05	0.49	77/78
268822	C12				F6Ia	-1.552	.229	.496	.42	.231	10.72	0.56	77/78
269110	G222				G0.Ia	-1.582	.382	.549		.365	10.74	0.88	77/78
269128	G226	81	55		B2.5Ieq	-1.453	.013	-.019	.035	-.009-	10.50	0.01	18/10/79 | v?
						-1.416	.016	-.020	.034	-.006	10.41	0.02	20/11/79 |
269154	G234B				F6Ia	-1.436	.187	.277	.01	.155	10.43	0.44	77/78, 2 faint stars in diaf. v?
269236	G247				F2Ia	-1.719	.121	.393		.113	11.15	0.29	77/78
269355	G258				F8Ia	-1.738	.183	.531		.210	11.19	0.43	77/78
	G274				F6:Ia	-2.157	.211	.459		.205	12.23	0.50	77/78
269542	G296				F6Ia	-1.245	.137	.279	.18	.115	9.96	0.32	77/78, db, v?
269546	C41	103	86		B5Ia	-1.214	.005	-.013	.020	-.011	9.91	-0.08	79 WW 85 ≠ HDE 269546 but = HDE 269541, WW 86 ≠ 36521 but = HDE 269546
269594	G312		96	13	F8Ia	-1.474	.233	.491	.30	.243	10.52	0.55	77/78, v?
	G317				F2Ia	-1.828	.149	.537		.168	11.42	0.35	77/78
269661	G346	111	106		A0Iaoe	-1.407	.059	.102	.099	.026	10.38	0.14	79, v?
269662		110			B9Ieq	-1.351	.100	.217	.214	.060	10.24	0.24	79, WW 105 wrong identif?
269697	G352		107	24	F6Ia	-1.397	.169	.522	.51	.181	10.34	0.40	77/78, v?
269700	G361	116			B1Iae	-1.470	.014	-.046	.015	-.020	10.55	0.02	79
269723	G367	117	110	27	G2Ia	-1.221	.426	.450	.32	.338	9.86	0.98	77/78 | faint star in diaf.
						-1.271	.463	.551	.321	.415	9.98	1.08	79 | v?
269781	C53	118	111		A0Iae	-1.203	.041	.084	.108	.016	9.87	0.09	79, v?
269809	G403			35	F0Ia	-1.981	.104	.516		.133	11.81	0.24	77/78
	G396				F0Ia:	-2.036	.136	.565		.165	11.94	0.32	77/78
269840	G405		114	36	F3Ia	-1.395	.167	.447	.27	.141	10.33	0.40	77/78, v?
269868	G406			41	F5:I	-2.200	.206	.541		.223	12.34	0.49	77/78, WW 113 wrong identif?
269879	G407				G2:Ia	-1.616	.454	.591		.427	10.84	1.04	77/78
269953	G423	150		43	C0Ia	-1.263	.355	.500	.42	.303	9.97	0.83	77/78 | close to emission nebula
						-1.258	.345	.555	.434	.316	9.96	0.83	79 | v?
	G429				F6Ia	-1.781	.265	.523		.257	11.28	0.63	77/78
	G439				F6Ia	-2.016	.233	.522		.251	11.88	0.55	77/78
270046	G454			50	G0Ia	-1.386	.381	.545	.44	.335	10.28	0.88	77/78, v?
270050	G443			51	F6Ia	-1.598	.155	.541	.37	.185	10.84	0.37	77/78
270111	G460			54	F8Ia	-1.360	.286	.531	.45	.294	10.23	0.68	77/78
	G495				F2:I	-2.434	.139	.507		.211	12.94	0.33	77/78
271018	C20				F6:Ia	-1.838	.230	.501		.240	11.43	0.55	77/78
271182	G266	92	70		F8Ia	-1.156	.291	.509	.41	.299	9.72	0.69	77/78 | v?
						-1.136	.280	.526	.39	.298	9.67	0.68	79 |

Explanation of table II (LMC)

No : first column : HD/HDE numbers ; second column : *G* numbers according to Fehrenbach and Duflot (1970) or *C* numbers according to Ardeberg *et al.* (1972) ; third column : numbers according to the Radcliffe observers Feast *et al.* (1960) ; fourth column : numbers according to Walraven and Walraven (1977, *VBLUW* photometry) ; fifth column : numbers according to van Genderen (1970, 1973, *VBLUW* photometry).

Sp : spectral classification mostly according to Ardeberg *et al.* (1972), in a few cases according to Brunet *et al.* (1973) or Feast *et al.* (1960).

V, V-B, B-U, U-W and *B-L :* photometric parameters of the 1970/1978 *VBLUW* system in log int. scale averaged over two or three observations.

V_J, $(B-V)_J$: photometric parameters of the *UBV* system transformed from the equivalent *V* and *V-B* values (see text).

Rem : 77/78 : observations made from November 1977 up to March 1978 ; 79 : observations made in October and November 1979 ; 17/10/79, etc. : more precise data for a star suspected of a variability on a short time scale (one observation only). Stars marked with v ? may be variable according to the criteria explained in section 3.

TABLE III. — *Statistic of stars showing total ranges in V_J and $(B-V)_J$ according to the following division.*

Total range (mag)	SMC V_J	SMC $(B-V)_J$	LMC V_J	LMC $(B-V)_J$
0.00 - 0.03	8	17	11	19
0.04 - 0.07	5	7	14	12
0.08 - 0.11	5	0	8	2
> 0.11	6	0	2	2
Total number	24		35	