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An investigation of the micro-variations of highly luminous OBA type stars. I (*)

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Summary. — *VBLUW* photometry of eight OB type stars of high luminosity ($M_{\rm bol} < -7$) is presented. This is the first paper of a series dealing with the search for possible micro variations in the brightness and colours of highly luminous OBA type stars.
This paper discusses the standard deviations, the mean errors and the variations in the photometric parameters relative to the comparison stars. The mean errors of the nightly averages of these relative brightnesses and colours amount to $\leqslant \pm 0^{\rm m}.002$. All program stars appear to be variable in brightness, ranging from about $0^{\rm m}.01$ to $0^{\rm m}.1$ with time-scales of days or weeks. One star HD 37022 (O7.0 V) shows a secular increase in brightness by $\sim 0^{\rm m}.012$ within an interval of ~ 2 yr. The fact that some stars exhibit much larger standard deviations in the colour index *B-U* than one would expect for a constant colour, suggests that temperature and/or density variations occur on or close to the surfaces of these stars in a time scale of days or shorter.

Key words : early type stars — supergiants — variable stars — photometry.

1. Introduction.

In 1980 a survey was started to investigate the photometric stability of OBA type stars of high luminosity (see the Introduction of the paper in the Main Journal, van Genderen 1985, hereafter called Paper II). The luminosity classes of the stars are I and II with a few of class V. The absolute bolometric magnitude $M_{\rm bol} < -7$.

The desired mean error for the nightly averages (abbreviated *NA*), in the sense program star minus comparison star, was of the order of $\pm 0^{\rm m}.002$ or smaller for the brightness and the colour indices. This put high demands not only on the selection of the comparison stars, but also on the observing technique. Our technique thus differs from that of the Geneva group, which does not use comparison stars for the study of micro variability, but only standard stars (Rufener and Bartholdi, 1982; Burki, 1984 and references therein). The comparison stars should be of luminosity class V to III and of lower absolute magnitudes than those of the program stars. The reason is that according to the results of the large photometric program of e.g. Maeder and Rufener (1972) and Burki (1978), the micro-variability strongly decreases with the luminosity. Nevertheless several small groups of low luminosity B type stars are now known, showing periodic or quasi-periodic light variations. Their periods are of the order of a day and the amplitudes are in the range $\leqslant 0^{\rm m}.1$ (Waelkens and Rufener, 1983). Thus one should always be cautious Spectral types of the comparison stars should preferably be late B or early A and their apparent magnitude $\lesssim 9$. Furthermore, they should not be located more than a few degrees from the program stars, in order to minimize the differential extinction corrections. Sky background measurements should always be taken at the same position, and standard stars should be measured frequently throughout the night. In our survey most of these requirements could be met.

2. The observations and reductions.

The observations were made with the 90 cm Dutch Light Collector stationed at the ESO, La Silla. This telescope is equipped with the five-colour simultaneous *VBLUW* photometer of Walraven. Descriptions of the photometer and the photometric system are given by Walraven and Walraven (1960), Rijf *et al.* (1969) and Lub and Pel (1977).

A number of OBA type stars of high luminosity were selected of which eight of them will be discussed in the present paper and in Paper II. Nearby comparison stars were also selected; they are listed in table I.

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As a rule each program star was measured eight times alternated with the comparison star. Sky backgrounds preceded and ended the cycle, with a third one in the middle of the sequence. They were always linearly interpolated in order to correct for a changing sky brightness during moon nights. The sky positions were always the same and usually close to the program stars. That this demand is necessary, considering the highly desired accuracy, is clear from the differences in the photometric data of the comparison star HD 93596, which has been used for two different program stars (table I).

A standard diaphragm of 16″ aperture was always used. The integration time per measurement amounted, depending on the visual brightness, to 2^5 or 2^6 s. During each night a large number of standard stars were measured in small groups of about 6 stars and spaced by ~ 2h, in order to obtain reliable calibration constants, extinction coefficients and corrections for zero point drifts of the photometer. In this way brightnesses V and colour indices V-B, B-U, U-W and B-L, with standard errors of $\lesssim \pm 0.0040$ and $\lesssim \pm 0.0020$ (equivalent to $\lesssim \pm 0^m_.010$ and $\lesssim \pm 0^m_.005$), respectively, could be obtained for comparison and program stars. The computer program for these reductions was written by J. Lub.

Table I lists the photometric and spectroscopic data of the comparison stars. The *VBLUW* photometric data are given in log intensity scale. The V and B-V of the Johnson *UBV* system (with subscript J) are in magnitude scale. V_J is transformed from the equivalent V of the *VBLUW* system with the aid of a relation given by Pel (1983). $(B\text{-}V)_J$ is transformed from the equivalent V-B of the *VBLUW* system with the aid of a calibration determined by Lub (1982). The standard deviations (*s.d.*) and the total number (n) of the nightly averages (*NA*) are also listed in table I and discussed in section 3. The internal *s.d.* for one *NA* is defined by :

$$s.d. = \sqrt{\frac{\sum_{i=1}^{n} (m_i - \overline{m})^2}{n-1}}$$

in which $\overline{m} = \sum m_i/n$ is the mean log intensity. The internal mean error (*m.e.*) is thus $s.d./\sqrt{n}$.

Table II lists the *NA* of the brightness differences in the sense program star minus comparison star for V (called ΔV) and for the colour indices (called $\Delta(V\text{-}B)$, $\Delta(B\text{-}U)$, $\Delta(U\text{-}W)$ and $\Delta(B\text{-}L)$). The latter are tabulated only if they clearly show variations. This is adopted to be the case if one or more of the colour curves in the phase diagrams (Paper II), also show a cyclic variation. If no such variation is present, only the averages (relative to the comparison star) are listed in table III, below the colour indices (which are on the natural *VBLUW* system) together with the *s.d.* of these relative colour indices. Only HD 62150 (B3/5 Iab) and HD 96248 (B1 Iab) were found to have two colour curves showing clearly a cyclic variation. The colour curves are also represented in table III by an average value and their *s.d.*'s are bracketed if extrema are obviously present. The column for V lists the average brightness with respect to the standard stars and their *s.d.*'s.

The average *m.e.* in the *NA* of the ΔV values appears to amount to $\pm$ 0.0004 with a spread of $-$ 0.0002 and $+$ 0.0003. Thus, the desired accuracy (Sect. 1) of $\leqslant 0^m_.002$ has been reached indeed. The average *m.e.*'s in the *NA* of the relative colour indices ($\Delta(V\text{-}B)$ etc.) appear to amount to $\pm$ 0.0003 with a spread of $-$ 0.0001 and $+$ 0.0004. The *m.e.* in $\Delta(V\text{-}B)$ is usually smallest and in $\Delta(U\text{-}W)$ largest.

The Julian Dates given in three decimals in table II refer to the middle of the measuring sequence. It was not considered necessary to derive a heliocentric correction.

Sometimes the series of observations was repeated once or more times in the same night (marked in table II by an asterisk). In most cases the differences between the averages were of the size of the just quoted *m.e.* An exception for example is HD 96248, which showed at JD 2445011 a total increase in its brightness by 0.0024 during subsequent series.

3. The stability of the comparison stars and the variability of the program stars.

Figure 1 shows the trend of the standard deviations (in log intensity scale) of V and the colour indices of the comparison stars as a function of the visual brightness V_J (in magnitude scale). HD numbers and spectral types are indicated. HD 93596 is plotted twice because it has been used separately for two different program stars, often during the same nights. The double circles will be explained later.

It appears from figure 1 that especially the *s.d.* for V are sensitive to the brightness : they range from $\pm$ 0.0040 for $V_J \sim 9^m$ to $\pm$ 0.0025 for $V_J \sim 5^m$. This variation is only partly governed by the photon statistic, therefore the stars are still too bright, so the fluctuations in the extinction and the atmospheric scintillation are the main cause. The *s.d.* for the colour indices are twice as small. Within certain limits this diagram indicates how stable the comparison stars are. Thus, strictly speaking, we are not sure that the comparison stars are constant in V within a limit somewhat smaller than 0.0025-0.0040 (or equivalently $0^m_.006$-$0^m_.010$). However, it can be shown that the scatter around the mean light curves, exhibited by most of the program stars is largely intrinsic (see Paper II). Thus it is unlikely that the comparison stars are variable with a range that large.

Figures 2 and 3 show the *NA* of ΔV of two program stars HD 76556 (O5.5 VNF) and HDE 305523 (O9 II), respectively, as a function of the date. Smooth curves have been sketched through the *NA* to indicate the timescales and amplitudes of the fluctuations. The derived *maximum m.e.* of the *NA* (0.0007, Sect. 2) has been indicated by bars at the left top. The variations are clearly at least four times larger, namely $\pm$ 0.0030. Since the program stars, because of their much higher luminosity, are supposed to be the ones which are variable they must be the main cause of the variations.

Figure 4 shows the *NA* of ΔV of the program star HD 93205 (O3 V). It should be noted that the same comparison star as for HDE 305523 has been used in figure 3. Most of the *NA* of both program stars have thus been obtained in the same nights (March 1982 and February 1983). A close inspection of the fluctuations in these nights in common, shows that no correlation exists.

The *s.d.* of the scatter of V of the program stars (*V is directly obtained from a comparison with the standard stars*, thus similar to the comparison stars), were also determined.

For four of the program stars, HD 57061 (O9 I), HD 62150 (B3/5 Iab), HD 96248 (B1 Iab) and HD 105056 (O9.7 IaeN), the light variations are so large that they are definitely real : they range from 0.0200 up to 0.0500 (Paper II). A fifth star HD 37022 (O7.0 V), shows an *s.d.* only slightly larger than the expected average *s.d.* (Sect. 2), because it does show a slow secular increase in brightness during ~ 2 yr of observing by ~ 0.0050 in V and a secular change in the colours by ~ 0.0010 (Fig. 5). Thus a discussion of the *s.d.* of these five stars has little sense.

Three stars remain, which were already discussed before, namely HD 76556 (O5.5 VNF), HD 93205 (O3 V) and HDE 305523 (O9 II). Since their maximum fluctuations in ΔV are small (namely ± 0.0030 for the first and third star and ± 0.0045 for the second one), it is of interest to plot the *s.d.* of the scatter in the V values, directly obtained from a comparison with the standard stars, in figure 1 also. They are represented by double circles. A line connects them with their respective comparison stars. HD numbers are indicated.

It is evident that in view of its visual brightness V_J, HD 93205 shows a larger *s.d.* than we expect from a non-variable star (as the plotted comparison stars are supposed to be). The *s.d.*'s of HD 76556 and HDE 305523 do not differ much from those of the comparison stars. This must be considered as accidental in view of the spread in the *s.d.*'s of the comparison stars. Besides, their amplitudes of variation are small, indeed, but real (Paper II).

It is not the purpose of this paper to discuss the real variations of the program stars into detail. Nevertheless it is important to discuss here the scatter in the average NA of the *relative* colour indices. This is particularly true if the colour curves do not show clear extrema, which is the case for most of the colour curves.

Table III lists the average relative colour indices for all colour curves and their *s.d.*'s. It is obvious that mutually large differences exist between these *s.d.*'s, despite the small *m.e.* in the individual NA, which for most of them is only ± 0.0003 with a maximum range to a larger *m.e.* of at most + 0.0007 (Sect. 2).

It is also obvious from table III that HD 37022 (V) is a star of which the *s.d.*'s are of the above mentioned value, although we had expected them to be smaller since the star is very bright. However, this can be explained by its slow secular variation (Fig. 5). HD 105056 (Ia) and HD 57061 (I) for example, show *s.d.*'s much larger than these values, especially in $\Delta(B\text{-}U)$. It is also important to note that the *s.d.*'s in $\Delta(B\text{-}U)$ are often of the same size as those for $\Delta(U\text{-}W)$, despite the fact that the W passband has the lowest intensity. Since the U band lies in the Balmer continuum at the short wavelength side of the Balmer-jump, these large *s.d.*'s suggest temperature and/or density variations on or close to the stellar photosphere on a time scale of days.

It is possible to check mathematically whether the *s.d.*'s in the $\overline{NA}$ (that is the average of all NA) are caused by systematic effects (variability of a star), or whether it is compatible with the *m.e.* in the individual NA. Let the weights of the individual NA be :

$$W_i = \frac{1}{\mu_i^2}$$

in which μ_i is the *m.e.* of the NA of the colour indices designated by X_i. Then the value for $\overline{NA}$ (listed in table III) is :

$$\overline{X} = \frac{\sum_i W_i X_i}{\sum_i W_i}$$

in which the weight of $\overline{X} = \sum_i W_i$.

If the deviations of X_i from $\overline{X}$ are :

$$\Delta_i = X_i - \overline{X}$$

then the *m.e.* of the unit weight is :

$$\mu_{w=1} = \sqrt{\frac{\sum_i W_i \Delta_i^2}{n-1}}$$

which should be equal to 1 if no systematic effects are present; in other words if the star is constant in the colour index X. Consequently, the *s.d.* of $\overline{NA}$ can only be attributed to the *m.e.* of all individual NA. If $\mu_{w=1} > 1$, in particular if it is $\gg 1$, the colour index is variable. This appeared to be often the case and is confirmed in Paper II, where even with no cyclic variation, relatively large daily fluctuations are present. These fluctuations are obviously real in view of the fact that mutual correlations exist.

4. Conclusions.

We have shown that the nightly averages (NA) of brightnesses and colour indices relative to the comparison stars have mean errors of the order of $\leqslant \pm$ 0.0007 or equivalently $\leqslant \pm$ 0^{m}002.

The size of the visual brightness variations can be summarized as follows :

— four program stars show, on time scales of days or weeks, intrinsic variations ranging from 0.0200 up to 0.0500 which can be easily seen by eye inspection. These stars are : HD 57061 (O9 I), HD 62150 (B3/5 Iab), HD 96248 (B1 Iab) and HD 105056 (O9.7 IaeN).

— three stars HD 76556 (O5.5 VNF), HD 93205 (O3 V) and HD 305523 (O9 II) presumably show intrinsic variations between 0.0050 and 0.0070, on time scales of days or shorter;

— one star, HD 37022 (O7.0 V), presumably shows no intrinsic variations on such a short timescale, but rather a secular increase in the visual brightness by ~ 0.0050 within ~ 2 yr (the comparison star is constant, it is a standard star of the *VBLUW* system and has been used for many years).

The variations of the colour indices can be summarized as follows : for some stars (such as HD 57061 (O9 I), HD 62150 (B3/5 Iab), HD 96248 (B1 Iab) and HD 105056 (O9.7 IaeN)), the colour indices clearly vary, since the *s.d.*'s of the average colour indices (thus of $\overline{NA}$) are larger by a factor 2 to 4 than the *s.d.*'s of the individual NA. Especially ($B\text{-}U$) shows this effect, suggesting that the Balmer continuum and/or the size of the Balmer-jump varies by temperature and/or density variations near the surfaces of these stars on time scales of days or shorter.

The secular colour variations of HD 37022 are ~0.0010 in *V-B* (bluer), *B-U* (redder) and *B-L* (redder). *U-W* is approximately constant. Consequently, the brightnesses in the ultraviolet passbands *L*, *U* and *W* increase slower than that in *B* and are roughly equal to that in *V*.

It is of interest to mention here some results of the last Geneva catalogue according to Rufener (priv. comm.). The *s.d.*'s for six stars of our sample confirm that they are variable. HD 76556 was not registered as such for the time being and HDE 305523 was not measured.

All these variations will be discussed and investigated in more detail in Paper II.

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TABLE I. — *Photometric and spectroscopic data of the comparison stars. (The indicated errors are standard deviations).*

HD	Sp	n	V	V-B (log intensity)	B-U (log intensity)	U-W	B-L	V_J (mag)	$(B-V)_J$ (mag)	comparison star of HD/HDE
36512	B0V[1]	35	0.9083 ± 26	-0.0933 ± 12	-0.0887 ± 14	-0.0470 ± 18	-0.0496 ± 11	4.627 ± 7	-0.265 ± 3	37022
58612	B9(III)[1]	20	0.4383 ± 21	-0.0374 ± 10	0.2381 ± 16	0.0627 ± 16	0.0505 ± 17	5.797 ± 5	-0.110 ± 3	57061
67162	A0IV/V[4]	45	-0.5430 ± 32	0.0056 ± 11	0.3001 ± 13	0.0641 ± 17	0.1261 ± 16	8.246 ± 8	-0.010 ± 3	62150
75212	B8/9V[3]	24	-0.6071 ± 35	-0.0232 ± 17	0.2741 ± 15	0.0576 ± 18	0.0899 ± 13	8.409 ± 9	-0.080 ± 4	76556
93596	B5III[2]	21	-0.7585 ± 47	-0.0239 ± 16	0.1933 ± 14	0.0350 ± 17	0.0576 ± 13	8.788 ± 12	-0.082 ± 4	93205
		22	-0.7561 ± 45	-0.0231 ± 18	0.1904 ± 11	0.0376 ± 16	0.0562 ± 11	8.782 ± 11	-0.080 ± 5	305523
97223	B3V[2]	16	-0.7388 ± 32	0.0346 ± 22	0.1775 ± 18	0.0588 ± 16	0.0515 ± 13	8.733 ± 8	0.060 ± 6	96248
102207	A1V[2]	18	-0.9381 ± 42	0.0767 ± 16	0.4759 ± 11	0.1423 ± 21	0.1995 ± 10	9.225 ± 10	0.165 ± 4	105056

[1] Spectral type according to the HD catalogue, luminosity class according to our photometry
[2] Spectral type and luminosity class according to Houk and Cowley (1975)
[3] Spectral type and luminosity class according to Houk (1978)
[4] Spectral type and luminosity class according to Houk (1982)

TABLE III. — *Photometric and spectroscopic data on the program stars. Second row of the V column gives the standard deviation. Second row of the colour indices gives the colour indices relative to the comparison star with the standard deviation (see Sect. 2).*

HD/HDE	Sp	Cluster	V	V-B Δ(V-B) (log intensity)	B-U Δ(B-U) (log intensity)	U-W Δ(U-W)	B-L Δ(B-L)	V_J (mag)	$(B-V)_J$ (mag)	HR No/Name
37022	O6ep[5] O7.0V[4]	OriOB1	0.7199 ± 27	-0.022 0.0716 ± 5	-0.046 0.0431 ± 6	-0.024 0.0234 ± 4	-0.021 0.0288 ± 6	5.09	-0.09	1895/41 θ^1Ori
57061	g+O9.5[3] O9I[5]	NGC2362	0.9923 ± 82	-0.052 -0.0143 ± 9	-0.076 -0.3145 ± 12	-0.029 -0.0918 ± 8	-0.041 -0.0910 ± 11	4.42	-0.16	2782/30 τCMa
62150	B3/5Iab[6]	NGC2439	-0.3280 ± 94	0.201 0.1958 (± 10)	0.179 -0.1209 (± 28)	0.147 0.0827 ± 18	0.077 0.0486 ± 13	7.69	0.45	
76556	O6[1] O5.5VN(f)[4]	VelaOB1	-0.5321 ± 34	0.179 0.2023 ± 4	0.056 -0.2176 ± 8	0.086 0.0280 ± 10	0.050 -0.0396 ± 9	8.20	0.38	
93205	dO3[3] O3V[4]	Tr. 16	-0.3477 ± 50	0.036 0.0596 ± 4	-0.042 -0.2356 ± 9	0.001 -0.0338 ± 9	-0.012 -0.0693 ± 7	7.76	0.05	
96248	B1Iab[2]	CarOB2	0.1210 ± 92	0.104 0.0698 ± 12	0.033 -0.1447 (± 20)	0.058 -0.0011 ± 11	0.016 -0.0347 (± 9)	6.58	0.22	
105056	O9/B0Ia[2] O9.7IaeN[4]		-0.2028 ± 116	0.037 -0.0398 ± 12	-0.032 -0.5080 ± 17	0.011 -0.1312 ± 19	-0.009 -0.2088 ± 8	7.39	0.05	
305523	O9II[4]	Coll. 228	-0.6512 ± 42	0.074 0.0971 ± 5	-0.004 -0.1946 ± 9	0.018 -0.0191 ± 9	0.007 -0.0488 ± 8	8.51	0.14	

[1] Houk (1978)
[2] Houk and Cowley (1975)
[3] IUE Low Dispersion Spectra (1984)
[4] Cruz-Gonzalez et al. (1974)
[5] Kennedy and Buscombe (1974)
[6] Houk (1982)

TABLE II. — *The nightly averages (NA) of the program stars relative to the comparison stars (ΔD = J.D. − 2440000).*

HD 37022 ΔD	ΔV
4545.861	-.1911
4546.861	-.1919
4561.819	-.1916
4565.743	-.1912
4566.736	-.1910
4568.760	-.1916
4569.736	-.1915
4660.549	-.1896
4676.542	-.1884
4677.597	-.1907
4678.528	-.1898
4679.521	-.1896
4680.521	-.1888
4681.514	-.1899
4682.521	-.1896
4683.549	-.1901
4952.628	-.1873
4954.708	-.1872
4959.792	-.1876
4975.566	-.1873
4976.580	-.1879
4977.573	-.1881
5311.781	-.1866
5331.615	-.1864
5333.607	-.1857
5370.604	-.1863
5381.583	-.1863
5382.583	-.1883
5383.580	-.1866
5384.583	-.1868
5385.583	-.1857
5386.590	-.1860
5387.583	-.1861
5389.583	-.1857
5390.573	-.1869

HD 76556 ΔD	ΔV
4659.708	.0773
4665.698	.0735
4667.705	.0755
4668.750	.0746
4678.740	.0726
4970.802	.0742
4972.788	.0765
4974.833	.0750
4975.750	.0731
4978.799	.0750
5031.580	.0750
5031.760	.0760
5032.625	.0734
5033.608	.0782
5034.635	.0773
5036.670	.0731
5037.677	.0736
5038.660	.0750
5043.583*	.0758*
5043.719*	.0786*
5366.890	.0778
5370.740	.0728
5375.708	.0748
5376.708	.0765
5380.701	.0721
5381.708	.0724
5382.715	.0764
5383.705	.0734
5384.705	.0746
5385.715	.0765
5386.701	.0771
5387.708	.0776
5388.705	.0784

HD 105056 ΔD	ΔV
5365.844	.7174
5366.851	.7316
5369.833	.7405
5370.837	.7378
5372.805	.7338
5374.840	.7611
5375.844	.7241
5377.809	.7385
5378.819	.7421
5379.826	.7340
5380.813	.7267
5381.823	.7534
5383.819	.7424
5384.813	.7280
5385.823	.7405
5386.813	.7234
5387.819	.7174
5388.813	.7428

HDE 305523 ΔD	ΔV
5031.792	.1076
5032.667*	.1055*
5032.813*	.1054*
5033.823	.1054
5034.681	.1038
5035.847	.1046
5037.771	.1031
5366.830	.1055
5369.809	.1030
5370.823	.1049
5372.771	.1051
5374.819	.1036
5376.774	.1033
5378.799	.1071
5379.806	.1047
5380.785	.1035
5381.764	.1049
5382.830	.1069
5383.802	.1061
5384.792	.1057
5385.806	.1052
5386.795	.1037
5387.802	.1054
5388.792	.1043
5423.719	.1036
5424.698	.1050
5426.663	.1017
5429.597	.1036
5449.632	.1077
5450.635	.1070

HD 57061 ΔD	ΔV
4567.833	.5601
4654.733	.5409
4655.611	.5592
4657.674	.5586
4676.608	.5482
4677.740	.5483
4682.691	.5608
4950.774	.5520
4952.736	.5483
5333.792	.5587
5366.712	.5610
5367.708	.5473
5370.694	.5537
5376.667	.5472
5380.649	.5589
5381.632	.5465
5382.667	.5588
5383.660	.5411
5384.656	.5628
5385.670	.5535
5386.663	.5613
5387.663	.5627
5388.660	.5529

HD 93205 ΔD	ΔV
5012.771*	.4101*
5012.795*	.4106*
5012.813*	.4090*
5012.830*	.4098*
5013.708*	.4152*
5013.729*	.4147*
5014.708	.4087
5015.806	.4113
5016.722	.4087
5020.726	.4107
5031.656	.4125
5032.607	.4073
5033.719	.4104
5034.771	.4107
5035.802	.4096
5036.646	.4102
5037.823	.4134
5038.819	.4060
5366.813	.4069
5367.764	.4106
5370.806	.4097
5372.750	.4125
5374.770	.4080
5376.757	.4118
5380.736	.4127
5381.743	.4092
5382.809	.4115
5383.774	.4093
5384.743	.4147
5385.753	.4104
5386.743	.4119
5387.750	.4106
5388.750	.4119

HD 62150 ΔD	ΔV	Δ(V−B)	Δ(B−U)	Δ(U−W)	Δ(B−L)
4654.792	.2336	.1974	-.1254	.0798	-.0466
4655.736	.2361	.1968	-.1254	.0816	-.0480
4657.760	.2282	.1970	-.1248	.0820	-.0475
4676.646	.1882	.1967	-.1097	.0874	-.0475
4682.757	.2177	.1971	-.1174	.0898	-.0429
4952.750	.2270	.1971	-.1224	.0835	-.0488
4954.712	.2144	.1966	-.1201	.0782	-.0489
4955.802	.2113	.1965	-.1237	.0838	-.0500
4959.823	.2357	.1969	-.1228	.0829	-.0499
4968.781	.2215	.1948	-.1214	.0830	-.0498
4969.813	.2263	.1961	-.1227	.0831	-.0498
4971.800	.2181	.1966	-.1221	.0827	-.0499
4972.764	.2193	.1949	-.1197	.0813	-.0492
4974.750	.2197	.1957	-.1222	.0847	-.0494
4977.688	.2181	.1958	-.1206	.0834	-.0492
4978.639	.2175	.1958	-.1196	.0840	-.0484
5015.635*	.2126	.1964	-.1184	.0812	-.0493
5015.653*	.2127	.1968	-.1194	.0837	-.0486
5015.670*	.2118	.1965	-.1203	.0825	-.0483
5015.722*	.2128	.1974	-.1205	.0842	-.0489
5015.740*	.2126	.1968	-.1205	.0831	-.0479
5016.618	.2074	.1978	-.1212	.0839	-.0495
5033.580	.2040	.1952	-.1197	.0831	-.0499
5034.607	.1971	.1954	-.1162	.0819	-.0495
5036.601	.2013	.1965	-.1207	.0854	-.0499
5037.635	.2043	.1963	-.1184	.0815	-.0501
5038.628	.2074	.1946	-.1198	.0823	-.0498
5043.531*	.2159	.1954	-.1228	.0827	-.0481
5043.646*	.2154	.1956	-.1232	.0827	-.0481
5314.785	.2165	.1955	-.1232	.0841	-.0497
5366.712	.2213	.1942	-.1178	.0815	-.0476
5367.698	.2193	.1944	-.1199	.0841	-.0481
5370.719	.2275	.1960	-.1207	.0821	-.0474
5376.688	.2273	.1953	-.1203	.0828	-.0484
5380.674	.2235	.1939	-.1206	.0816	-.0503
5381.688	.2215	.1958	-.1184	.0810	-.0481
5382.688	.2189	.1952	-.1220	.0826	-.0479
5383.681	.2217	.1952	-.1201	.0811	-.0483
5384.677	.2218	.1934	-.1181	.0830	-.0474
5385.691	.2143	.1943	-.1203	.0823	-.0486
5386.681	.2143	.1946	-.1211	.0823	-.0472
5387.688	.2149	.1953	-.1192	.0831	-.0474
5388.681	.2191	.1947	-.1181	.0834	-.0461
5426.635	.2176	.1960	-.1246	.0826	-.0492
5427.562	.2182	.1961	-.1233	.0829	-.0501
5428.656	.2292	.1954	-.1187	.0800	-.0477
5429.607	.2206	.1943	-.1194	.0811	-.0486
5446.604	.2263	.1968	-.1238	.0816	-.0496
5449.580	.2156	.1968	-.1269	.0814	-.0494
5450.573	.2221	.1958	-.1225	.0826	-.0476
5451.556	.2270	.1960	-.1252	.0803	-.0494

HD 96248 ΔD	ΔV	Δ(V−B)	Δ(B−U)	Δ(U−W)	Δ(B−L)
4665.750	.8765	.0699	-.1472	-.0002	-.0339
4666.733	.8718	.0721	-.1458	-.0016	-.0342
4668.854	.8734	.0709	-.1465	-.0006	-.0344
4679.844	.8549	.0722	-.1443	-.0008	-.0334
4680.778	.8493	.0702	-.1448	.0005	-.0346
5010.813	.8687	.0689	-.1459	-.0009	-.0348
5011.733*	.8659	.0687	-.1445	-.0023	-.0360
5011.774*	.8666	.0684	-.1446	-.0033	-.0357
5011.802*	.8674	.0686	-.1451	-.0019	-.0359
5011.833*	.8683	.0682	-.1450	-.0022	-.0356
5012.722	.8627	.0688	-.1437	-.0010	-.0339
5013.729	.8532	.0690	-.1409	-.0009	-.0340
5014.726	.8605	.0689	-.1423	-.0009	-.0336
5015.736	.8420	.0708	-.1442	-.0006	-.0351
5016.757	.8655	.0722	-.1455	.0011	-.0345
5020.701	.8721	.0691	-.1470	-.0005	-.0358
5022.851	.8650	.0704	-.1464	.0001	-.0362
5031.635	.8434	.0697	-.1399	.0002	-.0332
5032.688	.8529	.0700	-.1429	-.0018	-.0337
5033.625*	.8598	.0705	-.1422	-.0016	-.0347
5033.847*	.8601	.0704	-.1452	-.0036	-.0349
5034.757	.8654	.0687	-.1434	-.0027	-.0347
5035.656	.8717	.0693	-.1466	-.0004	-.0349
5037.722	.8691	.0695	-.1451	-.0009	-.0357
5038.802	.8689	.0702	-.1480	-.0005	-.0352

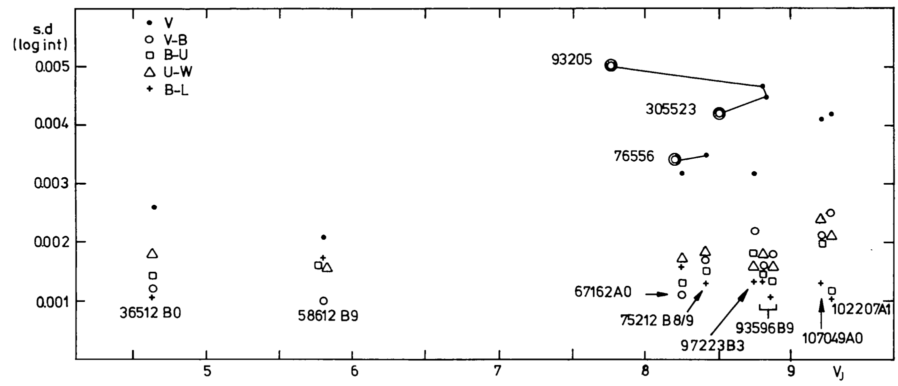

FIGURE 1. — The standard deviations (*s.d.*) in log intensity scale of the nightly averages (*NA*) of the comparison stars as a function of their brightnesses V_J (in magnitudes). HD numbers and spectral types are indicated. Also the standard deviations of three program stars are plotted (double circles, *V* only). They are connected with their respective comparison stars by a line.

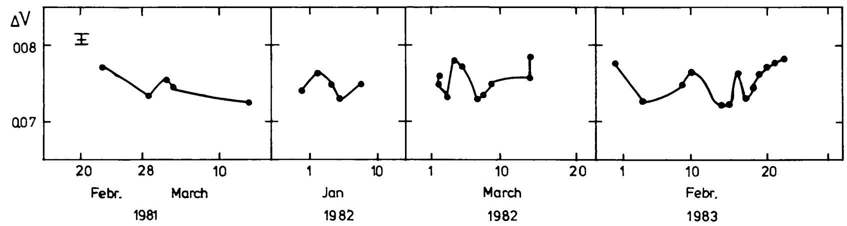

FIGURE 2. — The *NA* ΔV (in log intensity scale) of the program star HD 76556 (O5.5 VNF) as a function of the date. The error bar at the left top indicates the maximum mean error (*m.e.*) of $\pm$ 0.0007 in the *NA*.

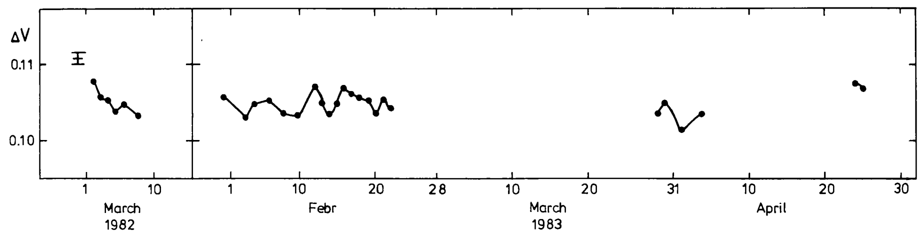

FIGURE 3. — Similar to figure 2, but now for the program star HDE 305523 (O9 II).

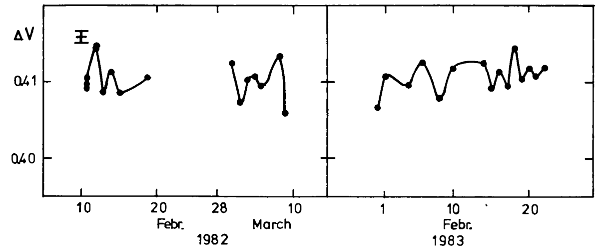

FIGURE 4. — Similar to figure 2,
but now for the program star HD 93205 (O3 V).

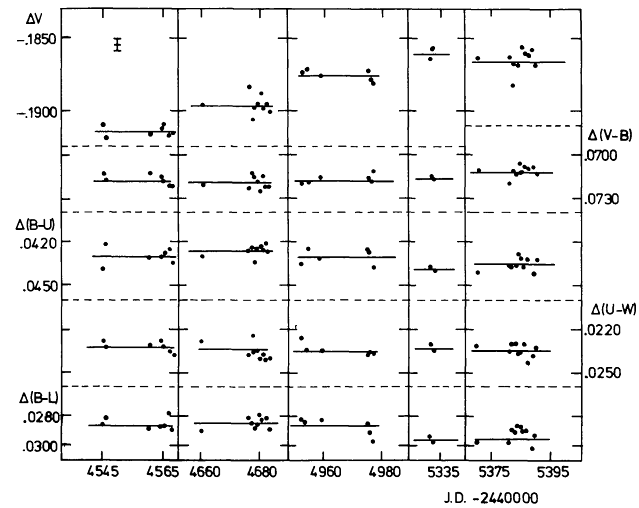

FIGURE 5. — The *NA* ΔV, $\Delta(V\text{-}B)$ etc. (in log intensity scale) of the program star HD 37022 (O7.0 V) as a function of the Julian Date. For each time interval the average level has been indicated by a short line. The error bar in the top left hand corner indicates an average *m.e.* of $\pm$ 0.0004 in the *NA*.