Astron. Astrophys. 349, 537–545 (1999)

ASTRONOMY
AND
ASTROPHYSICS

Light variations of massive stars (α Cygni variables)*

XVII. The LMC supergiants R 74 (LBV), R 78, HD 34664 = S 22 (B[e]/LBV), R 84 and R 116 (LBV?)

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Received 21 April 1999 / Accepted 3 June 1999

Abstract. Multi-colour photometry (Walraven system) of five super- and hypergiants in the LMC, viz. R 74, R 78, HD 34664, R 84 and R 116, is searched for variability and periods, and discussed. Apart from R 84, of which the claimed variability in the past must be due to a number of faint field stars at the edge of the apertures, all are variable.

R 74 and HD 34664 are weak-active LBVs with superimposed microvariations. HD 34664 is the second known B[e] star which is also an LBV. The first reported one is R 4 in the SMC. This could alter some views on the evolutionary history of B[e] stars and LBVs.

R 78 is an α Cyg variable, but presumably no LBV. R 116 appears to be a close counterpart of the galactic ex-/dormant LBV ζ^1 Sco, also showing an intricate α Cyg-type multi-period microvariability.

Key words: stars: individual: R 116 = HDE 269700; R 74 = HDE 268939; R 78 = HDE 269050; R 84 = HDE 269227; S 22 = HD 34664 – galaxies: Magellanic Clouds

1. Introduction

This seventeenth paper on the photometric variability of α Cyg variables needs no extensive introduction considering the attention we paid to the one in paper fifteen of this series (van Genderen et al. 1998a). In the discussion of paper sixteen (van Genderen et al. 1998b) we paid attention to various competing models on the instability of α Cyg variables, including the important, but small subclass of S Dor variables, or Luminous Blue Variables (LBVs).

In the present paper we discuss $VBLUW$ photometry (Walraven system) of five other α Cyg variables: all emission-line supergiants in the LMC among which two LBVs, one ex-/dormant LBV, one normal α Cyg variable (non-LBV) and an object which likely is constant.

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* Based on observations obtained at the European Southern Observatory at La Silla, Chile

** Belgian Fund for Scientific Research (FWO)

Table 1. Aperture used (Ap, in arcsec) and the average standard deviation (σ) per data point (in units of 0.001 log intensity) for the five programme stars. In the text we refer to Ap = 11.6, 16.5 and 21.5 as apertures no. 3, 4 and 5, respectively

Star	Ap	V	$V-B$	$B-U$	$U-W$	$B-L$
R 74	16.5	3	3	4	8	4
R 78	16.5	4	4	5	10	5
HD 34664	16.5	4	4	6	11	6
R 84	11.6	7	5	7	14	6
	16.5	11	5	6	10	5
	21.5	20	8	7	16	7
R 116	16.5	3	3	3	5	3

2. Observations and reductions

The five objects were observed with the 90-cm Dutch telescope equipped with the simultaneous $VBLUW$ photometer, at the ESO, Chile. Further particulars on the observing procedure can be found in the previous papers of this series. Observations were made for R 74 and R 78 from 1988 to 1990, for HD 34664 = S 22 from 1982 to 1986 (scattered observations) and from 1987 to 1990, for R 84 from 1988 to 1991 and for R 116 from 1989 to 1990. The effective wavelengths and the band widths of the five channels are given by de Ruyter & Lub (1986). The L band (3837 Å) contains the Balmer limit, the U band (3623 Å) contains the Balmer jump and lies largely at its short-wavelength side, while the W band (3235 Å) lies in the Balmer continuum. The photometric data in the $VBLUW$ system are given in log intensity scale.

Table 1 lists the programme stars as observed in the $VBLUW$ system, the aperture used and average standard deviation (σ) per datapoint relative to the common comparison star HD 33486 (B9, $7\overset{\mathrm{m}}{.}9$), all in log intensity scale. Average mean errors are of course smaller, in these cases by about a factor two to three.

Since R 84 lies in a very crowded field (the OB association LH39, Sect. 3.4), the star was observed with three different apertures. Even with the smallest one, the photometry appeared

Table 2. The average photometric parameters of the common comparison star and the five programme stars (in log intensity scale for the $VBLUW$ system and in magnitudes for the transformed UBV parameters [with subscript J]). N is the number of measurements

		Sp	V	$V-B$	$B-U$	$U-W$	$B-L$	V_J	$(B-V)_J$	N
	HD 33486	B9 V	-0.390	-0.010	0.330	0.078	0.112	7.86	-0.04	
R 74	HDE 268939	B Ie[2]	-1.668	0.041	-0.036	0.074	-0.009	11.05	0.09	76
R 78	HDE 269050	B0 Ia[2]	-1.923	-0.012	-0.052	-0.003	-0.022	11.69	-0.04	83
S 22	HD 34664	B[e]0–0.5[3]	-1.980	0.104	0.084	0.047	0.095	11.83	0.25	152
R 84[1]	HDE 269227	WN9[4]	-2.082	0.052	-0.045	-0.010	-0.017	12.09	0.12	46
			-2.032	0.060	-0.040	-0.018	-0.014	11.97	0.14	37
			-1.970	0.056	-0.035	-0.020	-0.013	11.81	0.13	30
R 116	HDE 269700	B1.5 Iaeq[2]	-1.475	0.017	-0.043	0.021	-0.015	10.57	0.03	90

Notes: [1] Photometric parameters for the three apertures used separately: $11.''6$ (no. 3), $16.''5$ (no. 4) and $21.''5$ (no. 5), respectively
[2] Feast et al. (1960)
[3] Zickgraf et al. (1996a)
[4] Crowther et al. (1995)

to be contaminated by faint cluster members. In Sect. 3.4 the V and B will be corrected for these stars.

Table 2 lists the photometric results for the common comparison star and the five programme stars. The photometric parameters V and $B-V$ of the UBV system (with subscript J) were transformed with the aid of formulae given by Pel (1987), see van Genderen et al. (1992). The average photometric parameters of R 84 are listed for the three apertures separately, including the faint cluster members.

The differential intensities and colours relative to the comparison star will be published in a forthcoming paper in the Journal of Astronomical Data, together with data for other α Cyg variables (including LBVs).

3. The light- and colour curves, the period analysis

All figures depicting the $VBLUW$ light- and colour curves are in log intensity scale and the error bars represent twice the mean error. The curves sketched have the purpose to help the eye see the variations clearly. Due to the stochastic-noise component and the numerous gaps in the curves, even polynomial fits, are not always ideal; since they cannot make allowance for the fact that most data points should lie within their errors from the polynomial curve. This is clearly demonstrated by a number of such fits by van Genderen et al. (1998b), especially Figs. 3, 4 and 9.

3.1. R 74 = HDE 268939, B Ie

R 74 was suspected to be photometrically variable and to be an LBV candidate by Stahl et al. (1984) based on a compilation of photometric parameters from the literature between 1969 and 1984. The maximum light amplitude amounted to $0\overset{m}{.}25$. This amplitude, confirmed by the photometry of the present paper, is higher than for normal α Cyg variables of the same spectral type (see Fig. 13 in van Genderen et al. 1992). Stahl et al. (1985) classified the star as late B, in contrast with Shore & Sanduleak (1984) who suggested B1.5 based on UV resonance lines. Feast et al. (1960) kept it "neutral" at B Ie.

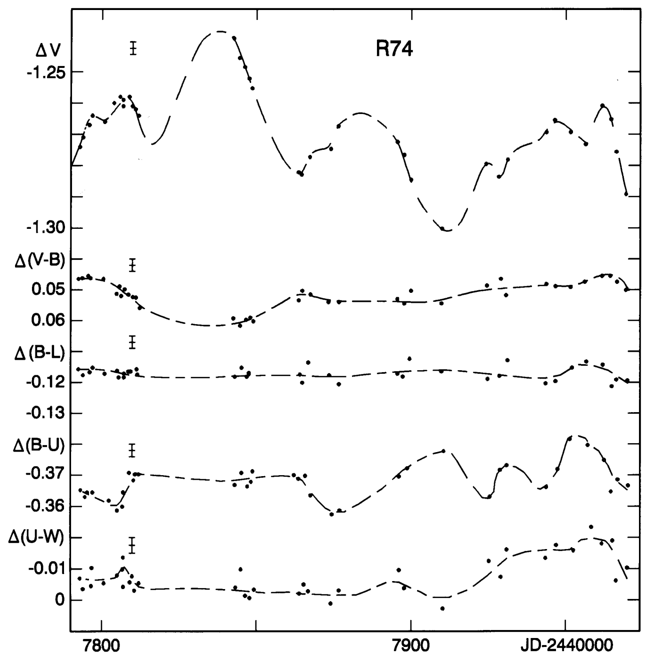

Fig. 1. A portion of the light- and colour curves of R 74 relative to the comparison star in log intensity scale. Bright and blue are up

Fig. 1 shows a representative part of the light- and colour curves with four consecutive cycles with a time scale of about 40 d. Often, the colours $V-B$ and $B-U$ tend to be redder at phases different from the light minima, which is together with the relative large amplitudes (also in $U-W$, viz. $\sim 0\overset{m}{.}05$, thus, about half of the amplitude in V), abnormal for ordinary α Cyg variables.

Fig. 2 shows a peculiar cycle of R 74 in the five passbands. Evidently, the light behaviour between 5500 Å and 3200 Å is strongly wavelength dependent, pointing at a complicated depth dependent oscillation pattern of a star with extended outer layers.

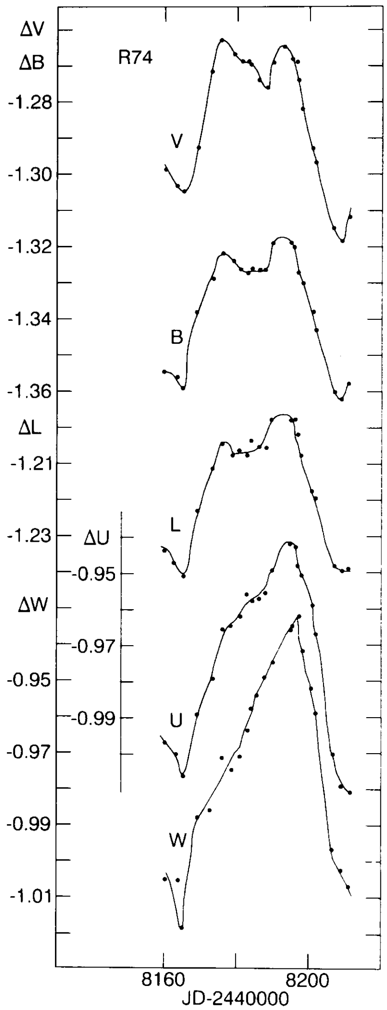

Fig. 2. The five light curves of a peculiar cycle of R 74 in 1990 relative to the comparison star. Bright is up

A Fourier analysis in the frequency domain 0–0.07 cd^{-1}, yields a best period: 42.1 d. The phase diagrams for 42.1 d of the colour curves $B-U$ and $B-L$ are not in phase with that of the light curve: they are reddest halfway the descending branch. This period is too long for an early B-type α Cyg type variable. A mid-B spectral type would fit better assuming $\log L/L_{\odot} \sim 5.46$ which is based on $\mathrm{E}(B-V)_J \sim 0.15$ (derived from the two-colour diagrams) and a distance modulus 18.6 (see its position with respect to the P = constant lines in the theoretical HR-diagram, Fig. 8 in van Genderen & Sterken 1996).

It is not impossible that a longer oscillation, responsible for the $0.^{\mathrm{m}}25$ light range, is present in our data set. It could then represent an S Dor cycle of the order of a year or so. However, due to our short time sequence of 2 y, this is uncertain. Nevertheless, from the evidences presented by other photometric characteristics together with the spectroscopic considerations, we conclude that R 74 must be considered as an LBV, albeit a weak-active one.

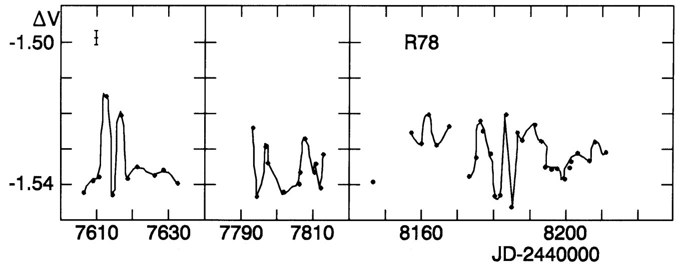

Fig. 3. Characteristic portion of the light variations of R 78 relative to the comparison star

3.2. *R 78 = HDE 269050,* B0 Ia

R 78 was suspected to be photometrically variable by Stahl et al. (1984) based on a compilation of photometric parameters from the literature between 1960 and 1983. The maximum light amplitude amounted to $0.^{\mathrm{m}}19$, which is twice the amplitude exhibited by our data set during the two years of monitoring. It appears that this large range is only based on the observation by Ardeberg et al. (1972), V_J = 11.54, made somewhere between 1968 and 1971), while the other observations from the literature hover around V_J = 11.69 with a maximum light amplitude of $0.^{\mathrm{m}}08$, which equals the one in our data set. If one would be tempted to consider the value of Ardeberg et al. (1972) as an outlier, then, there is still the remark by Feast et al. (1960) that: "V and B of R 78 show extreme ranges of $0.^{\mathrm{m}}15$ and $0.^{\mathrm{m}}14$, respectively". It is a pity that no further details are presented on these observations.

Fig. 3 shows a characteristic portion of the light curve (without colour curves because of their small ranges). The light variations look erratic with a total amplitude of $0.^{\mathrm{m}}08$ and a time scale of a few days. Considering this maximum light amplitude (MLA = 0.032 in $\log$ intensity scale, see Fig. 13 in van Genderen et al. 1992), the star is a normal early type α Cyg variable and no (weak-active) LBV.

The period search of the light curve (V) was carried out using Fourier analysis in the frequency domain 0.20–0.40 cd^{-1}. The amplitude spectrum shows a concentration of highest peaks in the domain 0.25–0.29 cd^{-1}. The four highest peaks of this group correspond with P = 3.6–3.86 d.

The suspected high MLA for R 78 ($\sim 0.^{\mathrm{m}}2$, see the beginning of this section) is for α Cyg variables of this early spectral type often an indication that the star also belongs to the LBV class (see Fig. 13 in van Genderen et al. 1992). The lack of significant colour variations does not favour such a classification, although, the high temperature ($\sim$ 26 000 K) could also be the reason. Since further firm proof of a relative high light amplitude is lacking, we consider R 78 tentatively as a non-LBV.

3.3. *HD 34664 = S 22,* B[e]0–0.5

HD 34664 is one of the few luminous stars which are supposed to represent edge-on cases of B[e] supergiants for which a two-component stellar wind model has been suggested (Zickgraf et al. 1985, 1986, 1996a). Friedjung & Muratorio (1980) were

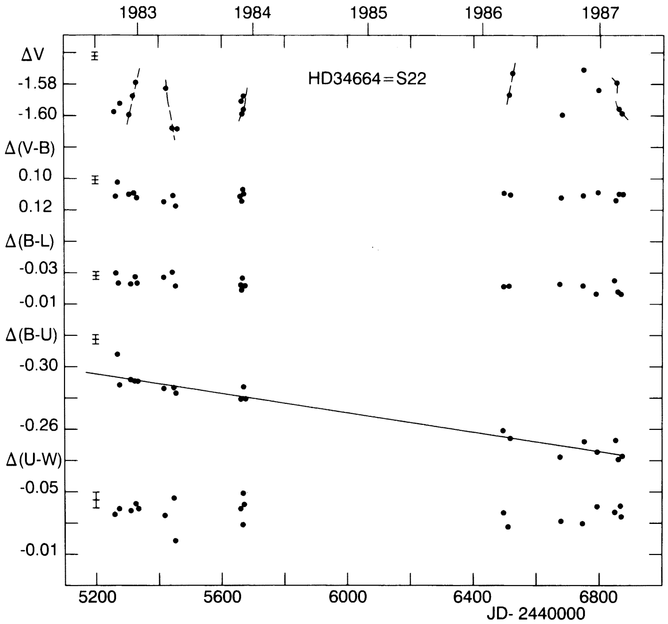

Fig. 4. Light and colour curves of HD 34664 = S 22 relative to the comparison star in the time interval 1982–1987. Bright and blue are up. The dashed line in the $B-U$ curve illustrates the long-term trend due to the decrease of the brightness in U. The dates mark the beginning of the year

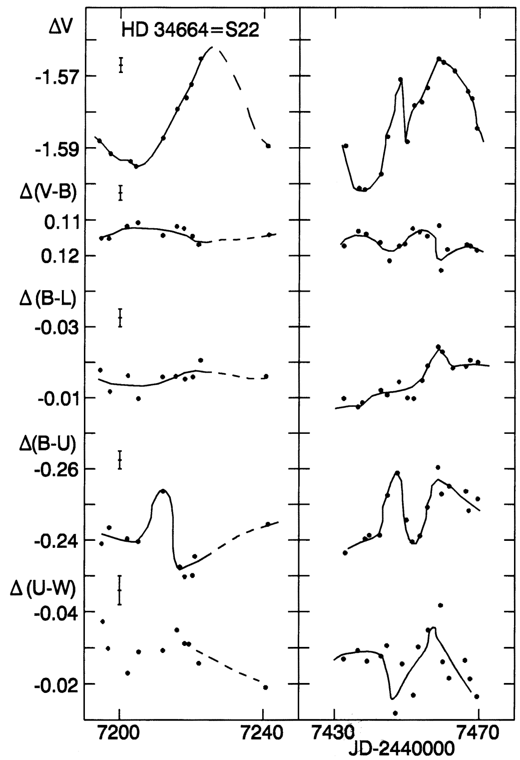

Fig. 5. A portion of the light- and colour curves of HD 34664 = S 22 relative to the comparison star in 1988. Bright and blue are up

the first who suggested the presence of such a disk-like structure around HD 34664. Far UV spectroscopy was used to try to unravel the complex gaseous environment of HD 34664 (Bensammar et al. 1983; Muratorio & Friedjung 1988). The last mentioned authors also found spectroscopic similarities with LBVs, especially with η Car. It has an almost pure emission spectrum in the optical and the UV spectrum appears to be crowded with FeII absorption components.

Zickgraf et al.'s (1986) compilation of photometric data from literature between 1957 and 1984, show variations up to $0\overset{\mathrm{m}}{.}13$, but no long-term variations (years). Smaller light variations during short monitoring runs (weeks) were considered as not real, which was likely a too pessimistic point of view, as will be shown below.

Fig. 4 shows the very first portion of the light- and colour curves for the interval end of 1982 – early 1987. In V the star shows microvariations up to $0\overset{\mathrm{m}}{.}1$ (0.04 $\log$ intensity scale). The curves sketched here and there are only a help for the eye. Surprising is a long-term reddening in all colours, especially in $B-U$ amounting to $0\overset{\mathrm{m}}{.}1$ indicated by the straight line.

Figs. 5 and 6 show two typical portions of the light- and colour curves in 1988 and in the interval 1989–1990, respectively, (Fig. 6 without $U-W$). Individual cycles show a large variety, which is normal for α Cyg variables. The maximum light amplitude ($0\overset{\mathrm{m}}{.}14$) is relatively high as well as the intrinsic spread in the colour curves with respect to similar variables of the same spectral type (B0–0.5), see Fig. 13 in van Genderen et al. 1992). Also the time scale of the cycles (40 d–50 d) is too long, which would be normal for late B-types. If the spectral type would be correct, one would expect a time scale in the order of a week or so (see Fig. 8 in van Genderen & Sterken 1996).

The amplitudes of the colour variations are also deviating: relatively large, and in $B-U$ and $U-W$ nearly as large as in V. The colours in most of the cycles tend to become redder in the maxima, while normally one expects them to become bluer. The same type of deviating correlation shows the weak-active LBV R 74 discussed in Sect. 3.1.

The spectral classification and the temperature determination of HD 34664 are very controversial. Muratorio & Friedjung (1988) suggested $T_{\rm eff}$ = 15 000 K which implicates a $\sim$ B4-type star. Zickgraf et al. (1986, 1996a) classified the star as B0–0.5, implicating $T_{\rm eff} \sim$ 24 000 K, while the physics of the disk wind suggests a late-B type, or early-A type star, implicating $T_{\rm eff} \sim$ 11 000 K. The photometric characteristics discussed above fit the latter temperature much better.

Fig. 7 shows the light- and colour curves of HD 34664 of the complete data set 1982–1990, but now based on averages of sub-sets. The use of it is two-fold: it illustrates the relatively large size of the colour variation just mentioned with respect to that in V (defined as a "standard deviation" and represented by the bars) and it shows a surprising long-term cycle. (No bar has been given to the data point of the sub-set JD 244 7609–JD 244 7611, because of its low number of observations (6)). Evidently, the average size of the oscillations in each sub-set did not change significantly during this long-term cycle.

The amplitude of this cycle amounting to 7 y, is very small: amounting to $0\overset{\mathrm{m}}{.}04$ in V, exhibiting a reddening in all colours at

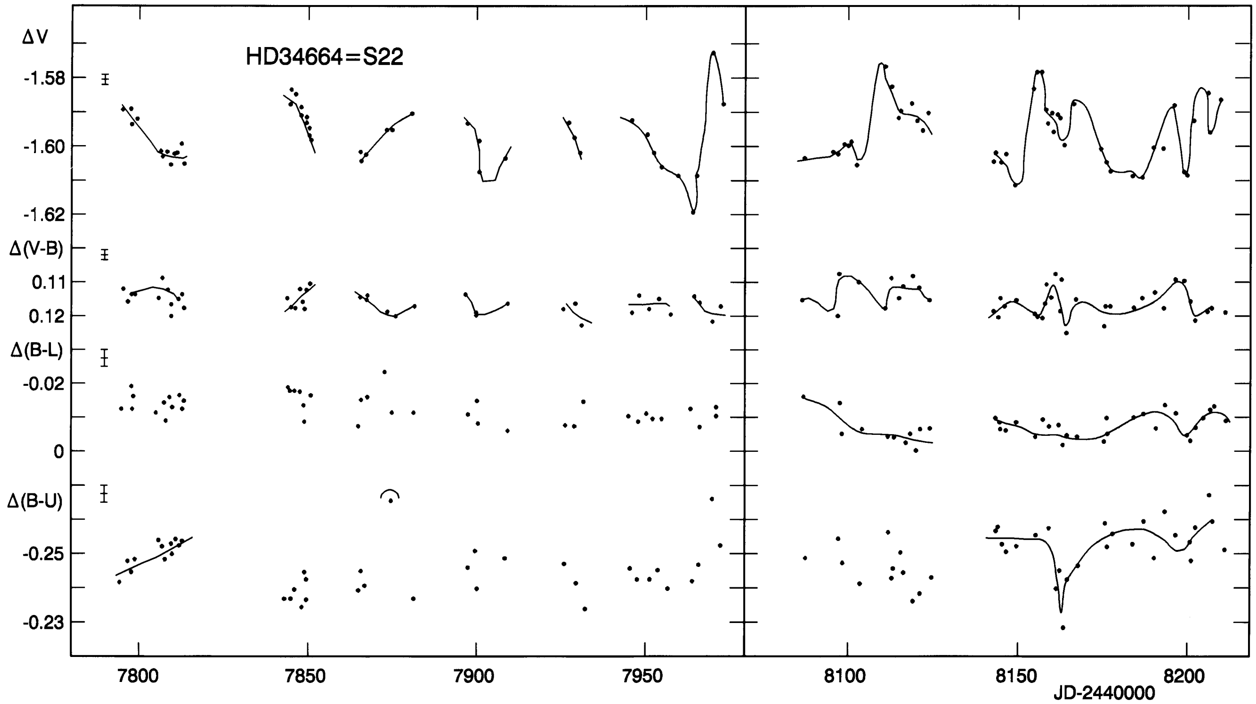

Fig. 6. A portion of the light- and colour curves of HD 34664 = S 22 relative to the comparison star in 1989–1990. Bright and blue are up

light maximum: $0\overset{m}{.}01$ in $V-B$, $0\overset{m}{.}02$ in $B-L$, $0\overset{m}{.}11$ in $B-U$ and $0\overset{m}{.}025$ in $U-W$. The reverse is the case when the star turns fainter, with the exception of $B-L$, where a reddening trend persists.

Photometric variations by more than one magnitude in the optical, happening somewhere between 1983 and 1990 were claimed by Shore (1990, 1992) based on IUE FES measurements. Probably there is something wrong with these optical data, since according to our photometric runs 1982–1983 and 1986–1990 such a large excursion did not occur, unless it happened accidentally in a gap between our sub-sets and that it lasted much shorter than 2 y.

Further, he claimed that in April 1990 the far UV brightness (<1600 Å) dropped by a factor of two compared to 1983, and he suggested that this was due to the increase of mass-loss rate somewhere between 1983 and 1990. This suggestion was substantiated by the optical linear spectropolarimetry by Schulte-Ladbeck & Clayton (1993), who found an increased polarization in November 1991 compared to that in late 1989.

The above mentioned drop in the far-UV by a factor of two is substantiated by the drop in our near-UV passbands, although not so much: $\sim$ 10%. The total continuum changes from minimum to maximum light amounted to (negative means brighter, positive means fainter): in V: $-0\overset{m}{.}04$, in B: $-0\overset{m}{.}03$, in L (Balmer limit): $-0\overset{m}{.}01$, in U (Balmer jump): $0\overset{m}{.}08$ and in W (Balmer continuum): $0\overset{m}{.}11$.

Considering all the evidence discussed above, we conclude that HD 34664 is not only a B[e] star, but also a very weak-active LBV, showing an S Dor (SD) phase between 1982 and 1990 (during such a phase, radius and temperature slowly vary while the luminosity often stays more or less constant). Suggestions that HD 34664 could be related to the LBVs were already made by Muratorio & Friedjung (1988). See Sect. 4.3 for a discussion on this double membership.

A period search of the V data was carried out using Fourier analysis in the frequency domain 0–0.05 cd^{-1}, often the V data were corrected for the contribution of the long-term SD phase (Fig. 7). The amplitude spectrum shows a dominant peak at 0.02117 cd^{-1} corresponding to P = 47.2 d and amplitude A = $0\overset{m}{.}0088$. Prewhitening with this frequency did not reveal any significant secondary frequencies. The phase diagram of the colour curve $V-B$ shows a small intrinsic scatter and a clear significant phase dependency in the sense the brighter the star, the redder the colour (by more than $0\overset{m}{.}01$). This is abnormal for α Cyg-type microvariations of normal α Cyg variables and of LBVs near minimum light, but normal for the so-called "100-d"-type microvariations of LBVs near maximum light and of which the temperatures lie between say 10 000 K and 15 000 K (van Genderen et al. 1997b). It should be noted that the latter type of microvariation can have a time scale as low as $\sim$ 50 d. (We showed above that the quasi-period for HD 34664 amounts to 47.2 d). These two types of microvariations must be caused by different instability mechanisms. The above mentioned colour behaviour supports the stellar temperature of Muratorio & Friedjung (1988) ($\sim$ 15 000 K).

The intrinsic scatter in $B-U$ and $U-W$ is considerable and more than twice that in $V-B$, indicating that there is a strong intrinsic noise in the UV radiation (up to $0\overset{m}{.}1$). That is the reason why no phase dependent behaviour was detectable in the phase diagrams of these colour indices.

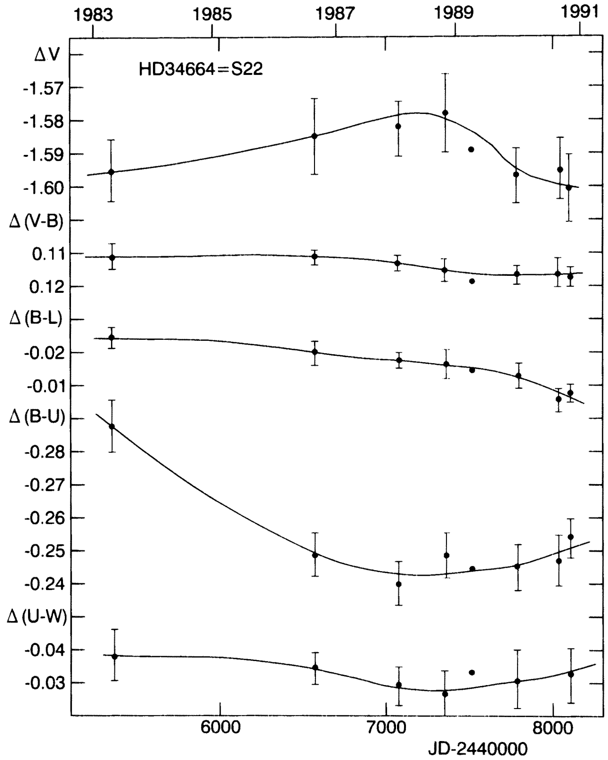

Fig. 7. Light- and colour curves of HD 34664 = S 22 relative to the comparison star for the total time interval 1982–1990, but now based on averages of sub-sets of observations. The "error" bars represent the "standard deviation" caused by the microvariations. The dates mark the beginning of the year

3.4. *R 84 = HDE 269227,* WN9

R 84 is a most spectacular emission-line star (Stahl et al. 1985) and the central and reddest star of the LMC OB-association LH 39 (Heydari-Malayeri et al. 1997, hereafter called HM). The spectrum also shows features of a late type supergiant companion, spectroscopically detected by Cowley & Hutchings (1978).

R 84 has been reclassified by Crowther et al. (1995) from Ofpe/WN9 to WN9, and could be a "quiescent" (or dormant) LBV according to e.g. Bohannan & Walborn (1989), or according to our nomenclature: an ex-/dormant LBV (Sterken et al. 1997). After all, it is unknown whether the star will ever return to the active state if it was an LBV in the past.

Some spectroscopic variability has been reported by Stahl et al. (1985). The IR fluxes are dominated by an M-type supergiant (M4 according to Stahl et al. 1985, M2 Ib according to HM). However, it is uncertain whether it physically belongs to R 84 (HM).

A photometric variability for R 84 up to $0\overset{\mathrm{m}}{.}3$, has been claimed by Stahl et al. (1985) based on a compilation of photometry from literature between 1960 and 1984. Therefore, they argued that the star is likely closely related to LBVs. According to a deconvolutioned R image of the field using NTT+SUSI by HM, roughly 30 fainter cluster members (14^{m}–19^{m}), lie within $11''$ from R 84. Thus, aperture photometry, even with the smallest diaphragm, will always be hampered by stars lying near the edge of the aperture. In addition, the size of the aperture influences the number of stars included. Therefore, the reported variability may be at least partly spurious, a concern also expressed by HM.

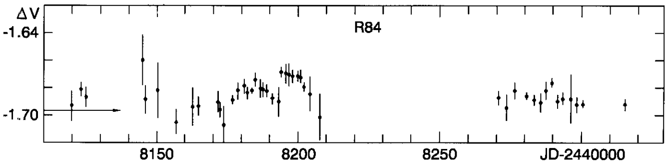

Fig. 8. The brightness of R 84 relative to the comparison star as measured with the smallest aperture (no. 3). Bright is up. The bars represent standard deviations. The arrow at the left indicates the relative brightness transformed from the genuine brightness (V_J = 12.10) determined by Heydari-Malayeri et al. 1997

Table 1 lists the average standard deviations which appear to increase with increasing aperture, especially in V. Apparently, relatively bright cluster members are situated close to the edge of the larger apertures. Table 2 lists the average photometric parameters of R 84 for each aperture separately. As expected, the brightness (V_J) increases with increasing aperture, viz. from $12\overset{\mathrm{m}}{.}09$ to $11\overset{\mathrm{m}}{.}81$, i.e. by $0\overset{\mathrm{m}}{.}3$. The influence on the colour indices is much smaller because there is not much difference between the colours of R 84 and the cluster stars.

Fig. 8 shows the nightly averages as a function of Julian date for the smallest aperture (no. 3) only (made in 1990–1991). The bars represent the standard deviation which are smaller than for the larger apertures. The average brightness for the large apertures nos. 4 and 5 is 0.05 and 0.11 (in log intensity scale, or $0\overset{\mathrm{m}}{.}12$ and $0\overset{\mathrm{m}}{.}3$) higher, respectively). The genuine undisturbed brightness of R 84 (including the red companion) as determined by HM on the CCD frames appeared to be equal at three occasions (in 1988, 1990 and 1991), viz. V_J = 12.10 and is indicated in Fig. 8 by the horizontal arrow.

The observed scatter showed by our data points, including those made with apertures nos. 4 and 5, is most likely caused by faint stars near the edge of the apertures. One would be tempted to conclude from Fig. 8 that e.g. the wavy pattern between JD 244 8170 and JD 244 8220 represents a stellar variability with a time scale of $\sim$ 20 d and an amplitude of $\sim 0\overset{\mathrm{m}}{.}03$ log intensity scale (or $\sim 0\overset{\mathrm{m}}{.}08$). However, a time scale of this order is quite unlikely for such a hot star. Thus, we conclude that R 84 was constant in the interval 1988–1991.

In order to find the genuine values for V_J and B_J (and $(B-V)_J$) and to compare them with those of HM, we subtracted from each of the three "aperture averages" all field stars present in the apertures. HM give a list of the V_J and B_J magnitudes and with the aid of their Fig. 2, it was quite easy to find corrected V_J and $(B-V)_J$ values for R 84. The result is as follows:

aperture no. 3: 12.18 and 0.14,
aperture no. 4: 12.08 and 0.06,
aperture no. 5: 12.08.

No proper $(B-V)_J$ could be derived, because no B_J has been given for the relatively bright star no. 34. The average magnitude for R 84 V_J = 12.11 compares very well with that of

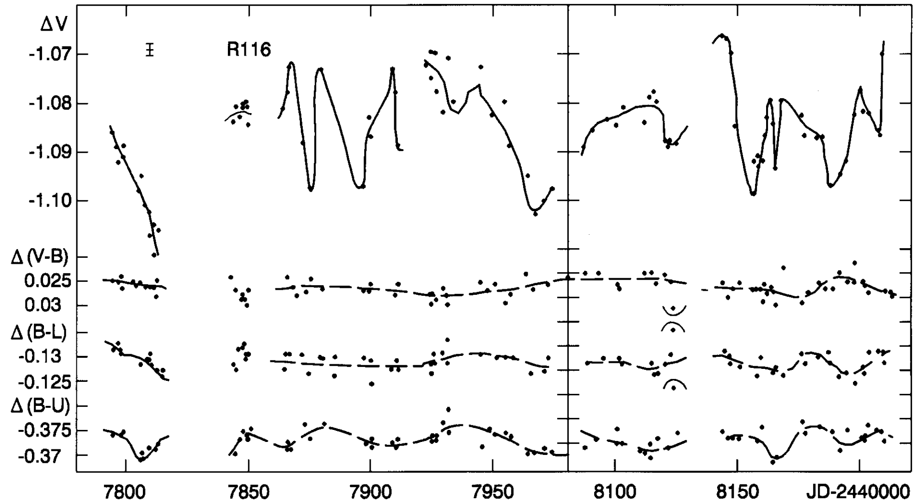

Fig. 9. The light- and colour curves of R 116 relative to the comparison star. Bright and blue are up

HM: 12.10, and the average colour $(B-V)_J$ = 0.09 is somewhat too blue compared to that of HM: 0.16.

3.5. R 116 = HDE 269 700, B1.5 Iaeq

R 116 is an emission-line star and according to Code & Houck (1958) as luminous as the galactic hypergiant ζ^1 Sco ($\mathrm{B1.5\,Ia^+}$), but slightly cooler and therefore they classified it as $\mathrm{B2\,Ia^+}$. Appenzeller & Wolf (1979) remarked that the for reddening corrected UV spectrum of ζ^1 Sco is almost identical to the IUE spectrum of R 116 (of which the interstellar reddening is small) and both have also nearly identical luminosities (Sect. 4.5). According to Sterken & Wolf (1978) the mass losses are nearly identical as well. Also Hutchings (1980) made a study of the stellar winds of some Magellanic Cloud objects including R 116.

The photometric compilation of Thackeray (1974) revealed that R 116 was brighter in the 19th century by $\sim 0\overset{\text{m}}{.}5$ and gradually became fainter during the first half of the 20th century. The photometry by Code & Houck (1958), presumably made in 1955, fits in the gradual decline: V_J = 10.23 and $(B-V)_J$ = -0.03, but is not listed in Thackeray's (1974) Table 4. After 1960 and up to 1990 the star stayed apparently stable, at least with respect to long-term variations: the brightness hovered around V_J = 10.55. This conclusion is based on the photometry by Feast et al. (1960), Mendoza (1970), Appenzeller (1972), Ardeberg et al. (1972), van Genderen et al. (1982), Stahl et al. (1985) and the present paper.

Fig. 9 shows the light- and colour curves for our complete data set (with omission of the $U-W$ curve). The time scale of the microvariations is of the order of a few weeks and the maximum light amplitude amounts to $0\overset{\text{m}}{.}11$. Both are typical for an early B-type hypergiant/α Cyg variable (see Fig. 13 in van Genderen et al. 1992 and Fig. 8 in van Genderen and Sterken 1996). The size of the intrinsic variations in the colour indices is also normal.

A comparison of the photometric characteristics and variability of R 116 with those of ζ^1 Sco is of high interest in view of the spectral similarities. Like R 116, ζ^1 Sco was brighter in the past (and better documented) by not less than 2^{m} around 1750 (Sterken et al. 1997). Gradually, ζ^1 Sco became fainter, and at times with fluctuations, until 1900 when it reached the present day magnitude. Since 1982 the star was photometrically monitored in various photometric systems until 1995, revealing amongst others a multi-periodic character (Sterken et al. 1997) with a strong stochastic noise component. Periods (a few weeks) and amplitudes are comparable to those of R 116. The mean photometric parameters of R 116 are, apart from a difference in interstellar reddening, very close to those of ζ^1 Sco.

The period search of the V data of R 116 was carried out using Fourier analysis in the frequency domain 0–0.10 $\mathrm{cd^{-1}}$. The amplitude spectrum of R 116 is much less convincing than that of ζ^1 Sco (Figs. 3 and 4 in Sterken et al. 1997) where at least two significant periods could be identified: 26 d and 32 d and some others which were also present in the spectroscopic variations investigated by Rivinius et al. (1997). The amplitude spectrum of R 116 shows several peaks with amplitudes $A > 0\overset{\text{m}}{.}005$ with more or less equal significance. The relative low numbers of observations (compared to that for ζ^1 Sco) will be partially responsible for this unsatisfactory solution. Yet, it is noteworthy that there are a few striking coincidences with the peaks in the amplitude spectrum of ζ^1 Sco (Figs. 3 and 4 in Sterken et al. 1997), although most of them are only local peaks. Four peaks of R 116 lie at frequencies (with the corresponding frequencies of ζ^1 Sco bracketed): 0.031 (0.031 = f_1), 0.037 (0.038, a local peak), 0.046 (0.046, a local peak) and 0.063 (0.0625, a local peak). The last mentioned frequency of R 116 (P = 15.9 d) also corresponds with the Hα-emission variability of ζ^1 Sco which lies between 14 d and 16 d (Rivinius et al. 1997).

The three other peaks of R 116 at 0.005, 0.011 and 0.014 $\mathrm{cd^{-1}}$, corresponding with 200 d, 90 d and 71 d, cannot hardly be considered as realistic, in view of the fact that our observations only comprise two runs of 160 d and 100 d, respectively, and 110 d apart (Fig. 9).

We conclude that R 116 looks also in photometric sense similar to ζ^1 Sco, an ex-/dormant LBV (Sterken et al. 1997).

4. Discussion and conclusions

We have investigated the photometric characteristics of five LMC super-/hypergiants. All are emission-line objects. R 74 and HD 34664 are, at least at present, low-amplitude LBVs (thus, showing very low-amplitude S Dor phases or cycles), for which we introduce the name "weak-active" LBVs (amplitudes $<0\overset{m}{.}5$), as opposed to the "strong-active" LBVs (amplitudes $>0\overset{m}{.}5$, like AG Car, S Dor, etc.).

R 78 is presumably a non-LBV, thus, possibly a normal α Cyg variable, R 116 is likely an ex-/dormant LBV and R 84 is likely constant, at least within the interval 1988–1991.

4.1. R 74 = HDE 268939

The quasi-period of the microvariations amounts to 42.0 d and is too long for an early B-type α Cyg variable. A mid-B spectral type would fit much better. The maximum light amplitude of the microvariations is too large for a normal α Cyg variable and the colour behaviour (often red in the maxima and blue in the minima) is also abnormal. The presence of a weak-active S Dor cycle is not excluded.

All these peculiarities suggest that R 74 is likely an LBV, albeit a weak-active one. There are a number of photometric similarities with e.g. R 99 (Ofpe/WN9) and R 123 (B pec) (van Genderen et al. 1998a), R 85 (B5 Iae) (van Genderen et al. 1998b) and HD 34664 (Sect. 4.3 of the present paper).

4.2. R 78 = HDE 269050

This B0 Ia supergiant may have shown a weak emission in Hβ when observed by Feast et al. (1960). Considering the relatively high maximum light amplitude for the micovariations, the star could be an LBV, but this is based on one deviating magnitude only. During our photometric run (1988–1990), the star behaved as a normal α Cyg variable, but with a multi-periodic character.

4.3. HD 34664 = S 22

It appears from the literature that the spectral classification and the temperature determination of HD 34664 are very controversial. The photometric characteristics, such as the relatively large colour variations, the quasi-period of the light variations amounting to 47.2 d and the reddening of the $V - B$ colour index at maximum brightness, suggest a spectral type mid-, to late-B, corresponding with a temperature range from 10 000 K to 14 000 K.

HD 34664 showed surprisingly a clear, but very low-amplitude S Dor-cycle with a time scale of $\sim$ 7 y. At maximum light the amplitude amounted to $0\overset{m}{.}04$ in V, while the UV showed a dip amounting to $0\overset{m}{.}1$.

It is not unlikely that physical changes of the disk (making a small angle with the line of sight, Muratorio & Friedjung 1988), due to the increased mass-loss rate during our photometric run (Shore 1990, 1992; Schulte-Ladbeck & Clayton 1993), somehow contributed to the light- and colour variations. After all, a strong increase of the mass loss was reported by Shore (1990) in April 1990 (near the end of our photometric run at the right of Fig. 7, at $\sim$ JD 2447990) compared to 1981 (a year ahead our photometric run at the left of Fig. 4). The precise amount is unknown, as well as if any effect on the optical light should exist.

The weakness of the SD activity and the peculiar characteristics of the microvariations, make HD 34664 comparable to the weak-active LBVs and emission-line supergiants R 74 and those mentioned in Sect. 4.1. It should be noted that two of them (R 99 and R 123) presumably possess a gaseous disk also (Stahl & Wolf 1987).

HD 34664 appears to be the second B[e] star which is also an LBV. The first one is R 4 in the SMC (Zickgraf et al. 1996b). (It is noteworthy that this B[e]/LBV star possesses an A-type companion). These two B[e]/LBV stars seem to disprove the concept that B[e] stars cannot be post-RSG stars because of their high angular momentum (which is expected to get lost in the RSG phase, while LBVs are supposed to be post-RSG stars because of their abundances and circumstellar shells. According to Zickgraf et al. (1996b) the B[e]/LBV star in R 4 could be a post-RSG star because of its low mass. It is assumed that fast rotation makes from a B-type star a B[e] star by creating an asymmetric wind distribution and consequently a disk-like structure in the equatorial plane. Further, fast rotation is in the case of evolved massive stars also seen as obstructing LBV-instability (Conti 1997).

Obviously, HD 34664 and R 4 demonstrate that some of these views need to be altered unless HD 34664 regained by some reason angular momentum after the post-RSG phase in its blueward evolution just as has been suggested by Conti (1997) for R 4.

4.4. R 84 = HDE 269227

R 84 could be a "quiescent" (or dormant) LBV according to e.g. Bohannan & Walborn (1989), or according to our nomenclature: an ex-/dormant LBV (Sterken et al. 1997). An extensive discussion on previous studies (e.g. evolutionary status, photometry, etc.) on R 84 and the nearby stars is presented by HM. The supposed photometric variability (Stahl et al. 1984) is likely spurious and due to the many faint cluster member stars near the edge of the apertures used by various observers. We corrected for their effect and conclude that R 84 was most likely constant from 1988 up to 1991.

Schmutz et al. (1991) and Crowther et al. (1995) found that hydrogen is very depleted and that R 84 has lost about half of its mass, so that it is probably a post-RSG star, like most LBVs are supposed to be.

Yet, if the absence of any light variations is real, R 84 is now no α Cyg variable, nor an LBV.

4.5. R 116 = HDE 269700

The early-type (B1.5) emission-line star R 116 is known to show almost identical spectroscopic characteristics as ζ^1 Sco

= HD 152236. Our photometric study also reveals a number of striking similarities with ζ^1 Sco, especially with respect to the mean photometric parameters and the light variability. The long-term variation of R 116 ($\sim 0\overset{\mathrm{m}}{.}5$) classifies the star as an LBV, obviously representing an SD phase similar to that of ζ^1 Sco in the 18th and 19th century (Sterken et al. 1997) and to that of the at present strong-active LBVs like AG Car, S Dor, etc. (van Genderen et al. 1997a, 1997b).

Since mid-20th century R 116 is at minimum brightness showing α Cyg-type microvariations caused by an intricate multi-periodicity with time scales between 1 and 6 weeks (like ζ^1 Sco). No clear solution was found with the Fourier analysis. Yet there is a striking coincidence of a number of peaks in the amplitude spectrum with those of ζ^1 Sco.

Adopting E$(B-V)_J \sim$ 0.15 (from the postion in the two colour diagrams) and $T_{\rm eff} \sim$ 19 500 K, we find $M_{\rm bol} \sim$ -10.2, which also compares very well with that for ζ^1 Sco: $\sim$ -10.4.

Thus, it seems that one has found accidentally in the LMC a very close counterpart of the galactic ex-/dormant LBV ζ^1 Sco (Sterken et al. 1997), so that R 116 can also be considered as an ex-/dormant LBV.

Acknowledgements. We are much indebted to Dr. J. Lub, Mr. K. Weerstra and Mr. L. Maitimo, who were responsible for various parts of the automatic reduction. C.S. acknowledges a research grant from the Belgian Fund for Scientific Research (FWO). We like to acknowledge the following observers who made the observations (more or less in chronological order): W. van Driel, A.K. van den Boogaart, W. Tijdhof, H. Bovenschen, E.C. Engelsman, L. de Lange, J.J. Prein, F.W.M. Steeman, J. van Grunsven, M. Heemskerk, I. Wanders, I. Larsen, D. Heynderickx, Th. Augusteijn, R. Kalter, G. Hadiyanto-Nitihardjo, H. Greidanus, F.H.A. Robijn, R. van der Heiden, R.A. Reijns, R.S. le Poole, O.M. Kolkman, R.L.J. van der Meer, J.M. Smit, J.P. de Jong, F.J. Dessing, G.C. Fehmers, A.M. Janssens, M.J. Zijderveld, F.C. van den Bosch and M.A.W. Verheijen. We are indebted to Dr. O. Stahl, the referee, for his invaluable comments.

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