
Further \textit{VBLUW} Photometry of the S Doradus Type Variables S Dor and HDE 269006 in the LMC and a Discussion on Their Temperatures\textsuperscript{*}

A.M. van Genderen

Leiden Observatory, Postbus 9513, NL-2300 RA Leiden, The Netherlands

Received February 24, accepted April 6, 1982

Summary. New \textit{VBLUW} photometry of the S Dor type variables S Dor and HDE 269006 in the LMC made in 1979 and 1981 are discussed. S Dor has reached the lowest brightness in 1981 of the last 8 yr, but it is still far from the minimum. HDE 269006 was at minimum brightness. Temperatures are estimated for the central star and the envelope by fitting black body energy distributions to the \textit{VBLUW} energy distributions. The agreement with spectroscopic results is satisfactorily, although \(T_{\text{eff}}\) for the central star of S Dor, 0.7 mag below the maximum, seems to be much higher than for an early A type star as proposed by some spectroscopists for the maximum. Although there are no direct proofs of a variable central star, such a possibility should not be excluded.

Some basic properties of the shell of HDE 269006 are estimated.

Key words: \textit{VBLUW} photometry – variable stars – supergiants – S Dor – HDE 269006

1. Introduction

The S Dor type variables S Dor and HDE 269006 in the Large Magellanic Cloud (LMC) were systematically observed for several years in the \textit{VBLUW} system (van Genderen 1979a, b, hereafter called Papers I and II, respectively). Both stars are redder and cooler during maximum brightness than during the minimum. The explanation for this reverse correlation between brightness and temperature is presumably the result of changing envelope properties: in maximum the stars are surrounded by a relative dense cool shell, which dissipates after some years (Martini, 1969; Thackeray, 1974; Paper II). It is however still uncertain whether the star stays physically the same during the ejection of the shell.

Recent IUE satellite spectroscopy supports the view that the shell is at least largely responsible for the optical changes (Wolf et al., 1980, 1981). In the first paper S Dor was observed not long after the start of the decline to minimum brightness. According to Wolf et al. the continuum energy distribution can be reasonably explained by the superposition of the radiation of an early A type photosphere of \(T_{\text{eff}} \sim 8000–9000\) K surrounded by a hotter shell of \(\sim 10,000\) K giving rise to a Balmer continuum radiation. Martini (1969) classified the star in the minimum phase of 1946 as B 8. HDE 269006 discussed in the second paper was observed during the minimum (when the shell has the least influence on the total photometric appearance). The central star is an early B type supergiant with \(T_{\text{eff}} \sim 13,600\) K surrounded by a cool shell of \(\sim 6000\) K.

2. The Observations

The new observations were made with the same telescope and the same Walraven \textit{VBLUW} photometer as the observations described in Papers I and II, but now at the ESO, Chile. References describing the system can be found there in as well as the description of the transformation to the \textit{UBV} system. Small

<table>
<thead>
<tr>
<th>Date</th>
<th>J.D.</th>
<th>Star</th>
<th>(V)</th>
<th>(V-B)</th>
<th>(B-L)</th>
<th>(B-U)</th>
<th>(U-W)</th>
<th>(V_f)</th>
<th>((B-V)_f)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17/18–10–79</td>
<td>244000</td>
<td>S Dor</td>
<td>−1.113</td>
<td>0.064</td>
<td>0.006</td>
<td>−0.058</td>
<td>0.033</td>
<td>9.65</td>
<td>0.152</td>
</tr>
<tr>
<td>20/21–11–79</td>
<td>4198.8</td>
<td></td>
<td>−1.210</td>
<td>0.006</td>
<td>−0.013</td>
<td>−0.011</td>
<td>0.024</td>
<td>9.90</td>
<td>−0.004</td>
</tr>
<tr>
<td>14/15–11–81</td>
<td>4923.8</td>
<td></td>
<td>−1.211</td>
<td>0.007</td>
<td>−0.013</td>
<td>−0.018</td>
<td>0.018</td>
<td>9.90</td>
<td>−0.003</td>
</tr>
<tr>
<td>15/16–11–81</td>
<td>4924.8</td>
<td></td>
<td>−1.210</td>
<td>0.008</td>
<td>−0.011</td>
<td>−0.013</td>
<td>0.028</td>
<td>9.90</td>
<td>−0.002</td>
</tr>
<tr>
<td>16/17–11–81</td>
<td>4925.8</td>
<td></td>
<td>−1.209</td>
<td>0.008</td>
<td>−0.010</td>
<td>−0.008</td>
<td>0.031</td>
<td>9.90</td>
<td>−0.002</td>
</tr>
<tr>
<td>17/18–10–79</td>
<td>4164.8</td>
<td>HDE 269006</td>
<td>−1.603</td>
<td>0.012</td>
<td>−0.009</td>
<td>−0.029</td>
<td>0.030</td>
<td>10.88</td>
<td>0.011</td>
</tr>
<tr>
<td>20/21–11–79</td>
<td>4198.8</td>
<td></td>
<td>−1.592</td>
<td>0.012</td>
<td>−0.009</td>
<td>−0.029</td>
<td>0.030</td>
<td>10.85</td>
<td>0.011</td>
</tr>
</tbody>
</table>

\* Observations were made at the ESO, Chile

© European Southern Observatory • Provided by the NASA Astrophysics Data System
Fig. 1. The two-colour diagrams for S Dor (similar to Fig. 5 of Paper II). The new observations of 1979 and 1981 are represented by plus signs. The evolution of the colours of the first measurement of 1979 to the second of 1979 is indicated by an arrow. The colours in 1981 are practically equal to the last one. The black body temperatures are indicated at the top.

Fig. 2. The two colour diagram for HDE 269006 (similar to Fig. 8 of Paper II). The new observations of 1979 are represented by plus signs.
changes in the photometric system were eliminated by transformation formulae provided by Pel (1980), so that the observations presented here are comparable to those of Papers I and II. The star HD 33486 (Paper I) has been used as a comparison star for both variables. Table I tabulates the observations. S Dor appears to be in a declining phase, although the brightness in 1979 and 1981 is the same and HDE 269006 is in a minimum phase. The new observations of the colours are plotted in Figs. 1 and 2 together with the previous observations of Papers I and II. The short arrow in Fig. 1 connecting the plus signs, indicates the evolution of the colours from the first measurement in 1979 up to the second in 1979 (with an interval of one month only!). The colours in 1981 are practically equal to the last one. However, small variations are present in the observations of S Dor in the three consecutive nights of November 1981, made by J. Meijer. The variations are the largest in the ultra violet (of the order of 0.02 to 0.03 mag). The colours of HDE 269006 in the 1979 minimum are practically equal to those of the minimum of 20 yr before observed by Walraven and Walraven (1977).

3. The Temperature of S Dor

Wolf et al. (1980) discussed IUE satellite low resolution spectrograms (1150 ≤ λ ≤ 3100 Å) obtained on June 12th 1978, a few months after the last observations of Papers I and II, when the star had reached maximum brightness (see their Fig. 5). According to Wolf et al., the observed continuum distribution of S Dor near maximum can be explained by a superposition of the radiation of an A2-A5 type supergiant photosphere of $T_{\text{eff}} = 8000-9000$ K and a surrounding hotter expanding shell of ~10,000 K giving rise to a Balmer continuum radiation and consequently an ultra violet excess compared to normal A type supergiants. If one assumes that the central star does not change much during the process of changing mass loss [so far the possibility of a varying central star has never been discussed] this spectral classification is in disagreement with that of Martini (1969) viz. B 8, which is based on spectra from the 1946 minimum.

To investigate this matter further we tried to derive temperatures in those parts of the light curve which according to the colours simulate more or less black body radiators (see Fig. 1).

At first a reddening correction should be applied. Similar to Wolf et al. we adopted $E_{V-B}=0.05$ mag (or $E_{V-U}=0.02$). In Paper II a larger value was used, but it seems now to be too high.

Figure 3 depicts the flux $F_{\lambda}$ (erg cm$^{-2}$ s$^{-1}$ A$^{-1}$) as a function of $\lambda$ A. A part of the IUE energy distribution is shown (for $\lambda$ ≤ 3100 Å) and the $UBV$ fluxes according to Wolf et al. The $V$, $B$, $U$ and $W$ data were transformed into fluxes by calibration constants given by Lub et al. (1979). The calibration constant for $L$ is given by Lub (1980).

The fluxes at three occasions during the two maxima of 1974/1975, and 1978 were taken together (the small dots in Fig. 3). In $W$ one observation was omitted because of an abnormal high reading (Paper II and broken arrows in Fig. 1, third panel). The extrapolation of the IUE energy distribution up to our $W$ passband fits satisfactorily.

Only in the $V-B/B-L$ and $V-B/B-U$ diagrams of Fig. 1, the colours for the maximum lie close to or on the black body line [also after the small reddening correction]. In the $V-B/U-W$ diagram, too much absorption lines in $W$ cause the large distance to the black body line. Therefore only the fluxes in $V$, $B$, $L$, and $U$ fit a black body energy distribution for $T_{\text{eff}} = 10,000 ± 500$ K. This tempera-

![Fig. 3. The continuum energy distribution of S Dor according to the $VBLUW$ fluxes at the maximum of 1974/1975 and 1978 and at two occasions during the decline of 1979 (dots, plus signs and circles, respectively). The $UBV$ observations (crosses, Wolf et al., 1980) were also made during the decline, but in 1978. A part of the IUE satellite fluxes are also taken from Wolf et al. (1980)](image-url)
ture can be expected since the shell (of which $T_{\text{eff}} \sim 10,000$ K according to Wolf et al.) is at its maximum power and if it dominates the central star.

However, the spectral classifications made at earlier maxima indicate for the total appearance of the object a type A2–A5 (Wesselink, 1956; Martini, 1969; Thackeray, 1974), which mean $T_{\text{eff}} = 8000-9000$ K. Then our temperature would be too high. Wolf et al. arrived at a more detailed description of the continuum energy distribution not long after the last recorded maximum of 1978. The observed energy distribution namely is explained by a superposition of an early A type supergiant photosphere and a surrounding hotter envelope producing Balmer continuum radiation. Consequently, one expects that then a temperature determination, based on a fit of observed and black body energy distribution, should amount to say 9000 to 10,000 K, which it does, at least within the range of the estimated uncertainty. The spectral classification of the object as a whole by Wesselink, Martini and Thackeray, pointing also into the direction of an early A type spectrum, should then mean that the central star dominates the shell as far as the spectrum is concerned.

One expects that the more the shell dissipates into space during the brightness decrease, the more important the contribution of the central A type star on the observed energy distribution should become. Thus the temperature should drop, assuming that the star does not change. However, according to observations made further down the descending branch, the temperature appears to rise as will be clear from the following discussion. The $B_J$ and $V_J$ data ($UBV$ system: large crosses in Fig. 3) at June 12, 1978, obtained when the decline of the brightness had started, still fit a temperature of $\sim 10,000$ K. The $U_J$ flux dropped however more than the $B_J$ and $V_J$ fluxes. At October 18, 1979 (plus signs) the visual brightness has dropped by $\sim 0.45$ mag. A black body energy distribution for $T_{\text{eff}} \sim 12,000 \pm 500$ K fits the $V$, $B$, and $L$ fluxes best, while $U$ clearly shows an excess relative to $B$ (see the position in the $V$–$B$/B–$U$ diagram of Fig. 1, which is above the black body line). The flux in $W$ increased relatively to $U$, so that it shows a larger excess relative to $B$ (probably the absorption lines decreased in strength because the shell decreased in density). A month later, at November 21, 1979 (circles in Fig. 3), the visual brightness has dropped by $\sim 0.7$ mag ($V_J \sim 9.9$) and the corresponding black body temperature is $\sim 14,000 \pm 1000$ K.

This tendency strongly suggest that the central star is much hotter than an early A type star.

Support for higher temperatures at lower brightnesses in the past comes from the 1968/1969 observations of Alexander and Thackeray (1971) when $V_J \sim 10.2$ (see Fig. 4, Paper II) and $(B-V)_{0.4} \sim -0.08$ corresponding with $T_{\text{eff}} \sim 12,000$ K.

To explain the contradiction between the A type classifications near maximum and the obvious higher temperatures at lower brightnesses, we have two possibilities for the explanation: 1. The star is of type B (late) and not variable. In maximum we see the combination of a dominating envelope cooler than 10,000 K and a photospheric continuum of the B type star. The A type spectrum should then be an artifact of the envelope. 2. The envelope near maximum has a temperature of $\sim 10,000$ K and the star is variable in the sense that it becomes hotter if the mass loss drops. Then also the envelope density decreases and its contribution to the total brightness drops. If the mass loss increases we get the opposite.

Fig. 4. The continuum energy distribution of HDE 269006 according to the $VBLUV$ fluxes at the maximum of 1974/1975 and the minimum of 1979 (dots). The $UBV$ and IUE satellite fluxes are taken from Wolf et al. (1981) (crosses and circles, respectively)
effects. Thus mass loss and variability of the central star should then be connected. A radius change could then be also one of the accompanying effects. However no theoretical evolutionary models of hot stars with $M \sim 40 M_\odot$ predict any instability of this kind so far. Apennzeller (1970) studied the evolution of a main sequence star of $130 M_\odot$ and did find it vibrationally unstable. Further study is clearly required.

It is evident from Fig. 3 that the flux at longer wavelengths drops quicker than at shorter wavelengths, a fact already noticed in Paper II. The explanation may be that much of the input ultra violet radiation is converted by the shell into the visual continuum. As soon as the shell dissipates, the visual flux drops faster than the ultra violet flux. Also the finding that the central star is much hotter than a A type star provide further support to this bolometric flux redistribution model, since only then the variations of up to two mag in visual brightness by density variations of the envelope can be understood (Wolf, private communication).

4. The Temperature of HDE 269006

Wolf et al. (1981) discussed UVE satellite low resolution spectrograms $(1200 < \lambda < 1200 \text{~A})$ and ground based spectroscopy of HDE 269006 during minimum state. They derived for the minimum state (thus if the shell is optically thin) $T_{\text{eff}} \sim 13,600 \text{~K}$.

Similar to the previous section, we have plotted in Fig. 4 the fluxes $F_\lambda$ (erg cm$^{-2}$ s$^{-1}$ A$^{-1}$) as a function of $\lambda$ (A) for this star in maximum (VBLUEW data from Papers I and II) and in minimum (VBLUEW data from this paper, UBV and IUE satellite data from Wolf et al.'s paper).

The UBV fluxes (crosses) are from Wramdemark (1981: quoted by Wolf et al.) and the energy distribution including absorption and emission features (circles) are from Willis and Nandy's low resolution IUE spectrograms (1979; also quoted by Wolf et al.).

The reddening correction is according to Wolf et al. $E_{(B-V)} = 0.05 \text{~mag}$ ($E_{V,B} = 0.02$). (In Paper II a higher value was adopted, but that may be too high.)

All the fluxes of the minimum state of the star agree very well and fit a black body energy distribution of $T_{\text{eff}} = 14,000 \pm 500 \text{~K}$ in agreement with Wolf et al. According to the temperature scale of Lamers (1981) for O and B type stars, the spectral type should then be B3–B5. Feast et al. (1960) classified the star at the minimum of the 1950's as B2.5 type. The optical thin shell which is supposed to be now unimportant for the total brightness of the object, has according to Wolf et al. the surprising low temperature of 6000 K.

For the temperature determination of the maximum state we took the VBLUEW data of the 1974/1975 smoothed maximum read off for three different moments. A black body energy distribution for $T_{\text{eff}} = 11,000 \pm 500 \text{~K}$ is fitted to the $V$, $B$, $L$, and $U$ fluxes. In $W$ there are apparently too many absorption lines, similar to S Dor in maximum (also in Fig. 2 third panel, HDE 269006 deviates too much from the black body line). The so found temperature corresponds to a spectral type B8–B9 (Lamers, 1981), while Thackeray (1974) finds for the same maximum state, but from spectra taken in 1973, B9–A1. Both classifications agree reasonably well and support the temperature found above.

5. Discussion

The approximate temperature determinations obtained by the fitting procedure of a black body energy distribution to the VBLUEW fluxes gives reasonable results for both stars when compared with the spectroscopy.

The change in temperature between the two extremes of HDE 269006 is according to Sect. 4 $\sim 3000 \text{~K}$. This value is dependent on the adopted reddening (compare with the result of Paper II: $7500 \text{~K}$). Also the way in which $M_\text{bol}$ varies with log $T_{\text{eff}}$ (Fig. 10 in Paper II) is now different, both stars behave now dissimilar. We will not discuss this any further.

If the shell is largely responsible for the brightness increase, then the total mass loss of S Dor is larger than for HDE 269006. This is obvious to see since in the last deep minimum of 1964, S Dor was fainter by $\sim 0.5 \text{~mag}$, but in maximum $\sim 0.5 \text{~mag}$ brighter than HDE 269006 (see Figs. 4 and 7 of Paper II). Thus S Dor shows a total amplitude of light variation 1 mag larger than HDE 269006. It would be of great importance to have in future accurate mass loss data. Table 2 summarizes the most important characteristics of both stars in maximum and minimum (assuming $E_{(B-V)} = 0.05$ and $m-M = 18.6$).

In order to get a crude idea on some characteristics of the shell of HDE 269006 in the maximum state, we made the following scheme. We call the star in minimum (thus shell presumably of no influence on the total brightness): "s", the star in maximum (the star obscured by the shell plus the shell): "s + sh", the shell only: "sh". Possible intrinsic variations of the star were assumed to be negligible. The radius is computed with the formula:

$$
\log R/R_\odot = 8.48 - 0.2 M_\text{bol} - 2 \log T_{\text{eff}}
$$

and the luminosity with:

$$
\log L/L_\odot = \frac{M_\text{bol} - 4.75}{-2.5}.
$$

The bolometric correction B. C. has been taken from Brinks (1977). The absolute visual mag $M_\star$ has been computed using a distance modulus of 18.6 for the LMC.

$$
\begin{align*}
V_\lambda &= 10.74, \quad (B-V)_\lambda = -0.04 \\
T_{\text{eff}} &= 14,000 \text{~K}, \quad BC = -0.95 \\
M_\star &= -7.86, \quad M_\text{bol} = -8.81 \\
L/L_\odot &= 2.7 \times 10^5, \quad R/R_\odot = 89
\end{align*}
$$

$$
\begin{align*}
V_{\lambda} &= 9.64, \quad (B-V)_{\lambda} = 0.10 \\
T_{\text{eff}} &= 11,000 \text{~K}, \quad BC = -0.38 \\
M_\star &= -8.96, \quad M_\text{bol} = -9.34 \\
L/L_\odot &= 4.3 \times 10^5, \quad R/R_\odot = 184
\end{align*}
$$

The two extreme possibilities

$$
\begin{align*}
\delta &= s \quad (\text{shell does not obscures the star}) \\
\delta &= 0 \quad (\text{shell obscures the star completely})
\end{align*}
$$

Thus for $\delta$:

$$
\begin{align*}
V_{\lambda} &= 10.13, \quad (B-V)_{\lambda} = 0.19 \\
T_{\text{eff}} &= 9800 \text{~K}, \quad BC = -0.14 \\
M_\star &= -8.47, \quad M_\text{bol} = -8.61 \\
L/L_\odot &= 2.2 \times 10^5, \quad R/R_\odot = ?
\end{align*}
$$

The $UBV$ parameters for $\delta = s$ were obtained by subtracting $s$ from $\delta + sh$. The $T_{\text{eff}}$ follows then from the colour index, $B-V$.

As can be seen, the sum of $L/L_\odot$ of the star in min state $s$ and of the shell for $\delta = s$ (4.9 $\times 10^5$) is not exactly equal to $L/L_\odot$ of the star in max state $\delta + sh$ (4.3 $\times 10^5$) as it should be. This is caused by inconsistencies between the visual mag for min and max state (which are accurately known) and the accompanying temperatures which are less accurate. Thus also the B. C. have larger errors and
Table 2. Summary of a few data for the highest maximum and the lowest minimum of S Dor and HDE 269006

<table>
<thead>
<tr>
<th></th>
<th>S Dor</th>
<th>HDE 269006</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min 1978</td>
<td>Min 1979</td>
</tr>
<tr>
<td>$V_J$</td>
<td>9.2</td>
<td>9.8</td>
</tr>
<tr>
<td>$(B-V)_J$</td>
<td>0.2 &lt; 0?</td>
<td>0.2</td>
</tr>
<tr>
<td>$M_V$</td>
<td>-9.5</td>
<td>-8.8</td>
</tr>
<tr>
<td>$T_{\text{eff}}$</td>
<td>10,000 &gt; 14,000?</td>
<td>11,000 14,000</td>
</tr>
<tr>
<td>$M_{\text{bol}}$</td>
<td>-9.7 ?</td>
<td>-9.2 -8.8</td>
</tr>
<tr>
<td>log $L/L_\odot$</td>
<td>5.78</td>
<td>5.60 5.44</td>
</tr>
</tbody>
</table>

consequently, the limits for the parameters of the shell in maximum state are as follows:

$10.13 \geq V_J \geq 9.64$
$0.19 \geq (B-V)_J \geq 0.10$
$9800 \leq T_{\text{eff}} \leq 11,000$
$- 8.61 \geq M_{\text{bol}} \geq - 9.34$
$2.2 \times 10^5 \leq L/L_\odot \leq 4.3 \times 10^5$

$R/R_\odot \leq 184$ (? see further).

The value for the radius should be valid if the central star is invisible and then if it only refers to the ionized part of the shell. Since the star shines through the shell, otherwise we would not see P Cygni profiles, it cannot be used as an upper limit. It is therefore a meaningless number, also because of the fact that the central star may be variable (Sect. 3).

Since there is no sign of matter falling back (Martini, 1969) the neutral shell should extend much further, until it fades away in the interstellar medium. With an average expansion velocity of $59$ km s$^{-1}$ (Wolf et al.), the distance of the gas which escaped from the star at the start of the rising branch of the light curve, has

![Fig. 5. The theoretical HR diagram with S Dor, HDE 269006 and P Cyg. The dotted curves represent the contours of constant mass loss for galactic supergiants (in $M_\odot$ yr$^{-1}$) according to Hutchings (1976). The evolutionary tracks (for mass loss parameter $N = 100$) are according to de Loore et al. (1978). The remaining mass ($M_\odot$) is indicated along the tracks (upper number) as well as the age (10$^6$ yr) (lower number).](image-url)
A.M. van Genderen: VBLUW Photometry of S Dor and HDE 269006 and a Discussion on Their Temperatures

reached a distance of \( \sim 10^8 R_\odot \) after 4 yr (the duration of the rising branch). In this context it would be of importance to compute how far from the photosphere the gas is ionized, the so called Strömgren sphere. This is at present impossible, since we do not know for example the mass loss variation with time, the velocity- and electron density distribution.

We can conclude from the list given above, that even if the central star is variable, the contribution of the shell of S Doradus type variables to the total appearance of these objects is considerable. In maximum the shell of HDE 269006 is somewhere between 0.6 and 1.1 mag brighter in the visual than the central star in minimum. It illustrates that one should be careful with the interpretation of the central stars like our two program stars, η Car, P Cyg etc. One should first try to disentangle the influences of the central star and the envelope with the aid of spectroscopy and multicolour photometry made at minimum (envelope negligible) and maximum (envelope at full power).

Estimates on the mass loss for HDE 269006 are given by Wolf et al. which will be compared with the empirical formula of Lamers (1981) and the observations of other hot supergiants of Hutchings (1976). In minimum the mass loss according to Wolf et al. is \( \dot{M} = 3 \times 10^{-7} M_\odot \text{yr}^{-1} \), but they add that this value is very uncertain. Assuming that the minimum state is a normal situation for the central star, we find with the aid of Lamers' empirical formula:

\[ \dot{M} = 6 \times 10^{-6} \text{ (for a mass loss parameter } N = 300) \text{ and } 4.5 \times 10^{-6} M_\odot \text{yr}^{-1} (N = 100). \]

L and R which have to be substituted in the formula are given above, while the mass is deduced from the luminosity, adopting the models of the Loore et al. (1978): \( \dot{M} = 22 M_\odot (N = 300) \text{ and } \dot{M} = 30 M_\odot (N = 100) \). Thus the empirical value is 20 times higher than the estimated value of Wolf et al.

The mass loss in maximum state is derived from the infrared excess and according to Wolf et al.: \( \dot{M} = 5 \times 10^{-5} M_\odot \text{yr}^{-1} \). Thus an increase by a factor 10 when compared with the empirical value (assuming that this one can be more trusted) for the minimum state.

Figure 5 shows the theoretical HR diagram with the dotted curves representing the contours of constant mass loss for galactic supergiants from Hutchings (1976). The spectral type - \( T_{\text{eff}} \) calibration is taken from Lamers (1981). The diagram also shows the evolutionary tracks for initial masses of 50, 40, and 30 \( M_\odot \) for a mass loss \( N = 100 \) (moderate mass loss), which according to de Loore et al. (1977) and Lamers et al. (1980) is the best choice for normal stars. The numbers along the tracks are the remaining mass of the star (upper number) and the age in \( 10^6 \) yr (lower number). S Dor (max), HDE 269006 (max and min) are plotted. The numbers close to it represent the mass loss rates. P Cyg is also plotted. It showed in the past large magnitude variations (de Groot, 1969) and is now somewhere between maximum and minimum brightness. The indicated mass loss is according to Lamers (1981).

The empirical mass loss for HDE 269006 in minimum fits the Hutchings contours satisfactorily while the observed mass loss in maximum (Wolf et al.) is too high by a factor 7. If the latter is correct, this may be the reason why the star is abnormal compared to other luminous stars.

It would be of great interest to have observations of S Dor in minimum, which may reached in this decennium.

Acknowledgements. I am much indebted to F. van Leeuwen, P. Alphenaar and J. Meijer for some additional observations and the referee, Dr. B. Wolf for valuable comments.

References


Brinks, E.: 1977, Internal report


