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# A photometric study of the G0-4 Ia$^+$ hypergiant HD 96918 (V382 Carinae)*

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**Abstract.** Using a photometric method we derive $T_{\rm eff}$, log $g$ and E(B-V) for the star HD 96918 and also for 35 supergiants of similar spectral class. For HD 96918 we found $T_{\rm eff} = 5200 \pm 200$ K and log $g$ [cm s$^{-2}$]$= 0.0 \pm 0.5$. The comparison of the results indicates that HD 96918 is really a hypergiant with a spectral class around G0-G4. We also estimate the distance of HD 96918 using the kinematic and reddening methods, and by comparing its $T_{\rm eff}$ and log $g$ with evolutionary calculation. We consistently find a distance of $2.7 \pm 1.0$ kpc which implies log $L/L_\odot = 5.5 \pm 0.4$. A most probable mass for the star is $20 \pm 10\,M_\odot$.

**Key words:** spectrophotometry – stars: supergiant – stars: atmospheres of – stars: classification – stars: individual HD 96918

## 1. Introduction

Initially, all supergiants were classified in luminosity classes Ib and Ia. In 1956, Feast & Thackeray added another sub-class: that of the "super-supergiants", originally consisting of the four reddest of the brightest stars in the Large Magellanic Cloud. These are of luminosity class 0 (zero) but were later also called Ia-0 or Ia$^+$. At present, stars of this type are called hypergiants.

Only a few hypergiants are found in the Galaxy. Most of them have spectral types F-G (yellow hypergiants). Knowledge of these stars will help to understand better the evolution of the most massive stars and also to understand the cause(s) of instability of the stars near the so-called Humphreys-Davidson limit. HD 96918 (=V382 Car) is a hypergiant which has a spectral type similar to that of $\rho$ Cas (HD 224014), HR 8752, IRC +10420 and HR 5171A. In spite of this, it is more stable than the others (cf. Table 1). So a verification on luminosity and spectral type of this star is very useful for further research.

A simple and accurate photometric method for measuring stellar radii and $T_{\rm eff}$ has already been developed by Gray (1967, 1968). A similar method has also been used by Blackwell & Shallis (1977) to measure stellar angular diameters. In this paper, using a photometry fitting technique, we derive the atmospheric parameters $T_{\rm eff}$, log $g$ for the hypergiant HD 96918 and, for comparison, also for 35 supergiant stars in the range of spectral classes between F5 and G8. We also try to estimate the distance of the galactic hypergiant HD 96918 by using the kinematic and reddening methods, and by comparing the derived $T_{\rm eff}$ and log $g$ with evolutionary calculations. Finally, we derive the stellar radius and mass for HD 96918 from the estimated distance and from evolutionary models of Maeder (1990).

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*Partly based on observations collected at the ESO, La Silla, Chile

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## 2. Photometric data

The spectral type of HD 96918 (=V382 Car) is given as G0 Ia$^+$ (Bidelman 1954, Malaroda 1975), G2 Ia (Houk & Cowley 1975) or G4 Ia$^+$ (Hoffleit 1982). This star is classified as a variable star (Nicolet 1978), although Fernie (1976) did not find any evidence for variations from 6 nights of observation. Stift (1979) observed a systematic brightening of $0^m\!.03$ in V over a month. We (HN) have observed the star in the Walraven and ESO JHKLM system at ESO, La Silla in May 1987. We (J.P. de Jong at our request) also have the Walraven data observed in March 1990. By comparing our data with those obtained by Walraven & Walraven (1977), Pel (1976), Epchtein et al. (1985), Van Genderen et al. (1986) and by using the above information, we conclude that the star seems only slightly variable with a maximum range of $\sim 0^m\!.05$ (cf. Table 1). Therefore, it is possible for us to select most of the published photometric data for determining the spectral energy distribution. For a consistent analysis of the whole set of photometric data in terms of atmospheric model parameters, we use exclusively data for the same phase of stellar variability; or at least data for which the $V_w$-values are equal within the range of photometric errors. Other references for the photometric data are given in Table 2.

## 3. Determination of $T_{\rm eff}$, log$g$ and E(B-V)

The $T_{\rm eff}$ and log $g$-values are determined by using a '$\chi$-square' method which is explained below. For each band in every used photometric system, we calculate the theoretical transmitted flux ($F^{\rm th}$) with :

$$F^{\rm th} = \pi \int_0^\infty F_\lambda S_\lambda d\lambda \, , \qquad (1)$$

**Table 1.** Comparison of the photometric data of HD 96918

| | WALRAVEN (log intensity scale) | | | | | UBV* (mag) | |
|---|---|---|---|---|---|---|---|
| | $V_W$ | $(V-B)_W$ | B-U | U-W | B-L | $V_J$ | $(B-V)_J$ |
| Walraven & Walraven, 1977 (observed in 1960-1963)** | 1.155 | 0.578 | | 0.514 | | 3.93 | 1.23 |
| Pel, 1976 (observed in 1970-1971)** | 1.155 | 0.586 | 0.677 | 0.505 | 0.516 | 3.95 | 1.25 |
| Van Genderen et al., 1986 (observed in 1982) | 1.159±0.005 | 0.573±0.002 | 0.637±0.002 | 0.502±0.004 | 0.496±0.002 | 3.93±0.01 | 1.22±0.01 |
| Our data (1987) | 1.140±0.053 | 0.549±0.053 | 0.654±0.002 | 0.504±0.002 | 0.504±0.002 | 3.99±0.13 | 1.18±0.13 |
| Our data (1990) | 1.176±0.002 | 0.576±0.002 | 0.656±0.002 | 0.493±0.002 | 0.520±0.002 | 3.90±0.01 | 1.23±0.01 |

| | ESO JHKLM (mag) | | | | |
|---|---|---|---|---|---|
| | J | H | K | L | M |
| Our data (1987) | 2.10±0.03 | 1.73±0.02 | 1.54±0.20 | 1.34±0.01 | 1.19±0.06 |
| Epchtein et al. (1985) | 2.12 | 1.77 | 1.57 | 1.37 | 1.15 |

*$V_J$ and $(B-V)_J$ in UBV system were derived from the Walraven data using the transformation formulae of Pel (1987)

**transformed to the photometric system of the years 1980-1990, with the aid of the transformation formulae of Pel (1987).

where $F_\lambda$ are theoretical fluxes from the new model atmospheres (solar abundance) calculated by Kurucz (1990) and $S_\lambda$ is the transmission function of the relevant photometric filter. The '$\chi$-square' value is defined by :

$$\chi = \frac{\sqrt{\sum_i [\log F_i^{\rm obs} - (\log F_i^{\rm th} - C)]^2}}{n}, \quad (2)$$

where $F_i^{\rm obs}$ is the observed flux for all of the photometric data within the wavelength normalization range (300 nm to 3000 nm), corrected for the average interstellar extinction ($R = A_v/E(B-V) = 3.1$) from Savage & Mathis (1979). $n$ is the number of data. $C$ is a normalization factor which depends on the angular diameter of the star, introduced in order to have a good fit between the observed flux and the theoretical flux. It is calculated using :

$$C = \frac{\sum_i [\log F_i^{\rm th} - \log F_i^{\rm obs}]}{n}. \quad (3)$$

Note that the $\chi$-values defined here should not be confused with the conventional $\chi^2$. The $\chi$-values are calculated for many combinations of $T_{\rm eff}$, $\log g$ and E(B-V); in which the range of $T_{\rm eff}$ is taken from 3500 K to 8500 K with steps of 250 K, the range of E(B-V) is 0 to 1 with steps of 0.01 and the range of $\log g$ is 0 (for $T_{\rm eff} \leq 6000$ K) to 5 with steps of 0.5. Note that the new model atmospheres of Kurucz (1990) have a grid of $\Delta T_{\rm eff} = 250$ K, which is smaller than the grid of his older models (Kurucz 1979). The results for $T_{\rm eff} = 5250$ K are illustrated in Fig. 1.

In this figure the lowest $\chi$ is found at the bottom of the diagram, viz. for $\log g = 0$ and E(B-V)=0.25, which indicates a best fit. In Fig. 2, we show the spectral energy distribution of HD 96918 for three different values of $T_{\rm eff}$. From these figures, we estimate that the $T_{\rm eff}$ of this star is in the range of 5000-5250 K. The next lower $T_{\rm eff}$ of the Kurucz model, $T_{\rm eff} = 4750$ K, gives too high fluxes for the near infrared part of the spectrum as compared to the observed fluxes.

For obtaining the most probable values of $T_{\rm eff}$, $\log g$, E(B-V) and $C$, about 10 combinations were selected that yielded the smallest $\chi$-values (derived with Eq. 2 above), and from these we took a weighted average according to :

$$T_\circ = \frac{\sum_i T_i \frac{1}{\chi_i}}{\sum_i \frac{1}{\chi_i}}, \quad (4)$$

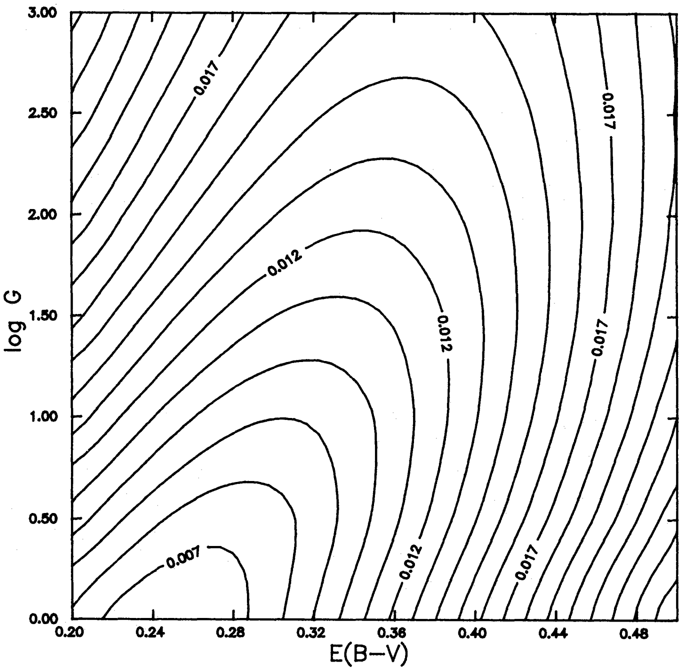


**Fig. 1.** Contours of $\chi$-values which represent the fitting quality between the observed and theoretical fluxes for several combinations of $\log g$ and E(B-V). These contours are calculated for $T_{\rm eff} = 5250$ K

and mutatis mutandis for $\log g$, E(B-V) and $C$. This is done mainly because only discrete steps of model atmospheres are used. The approach outlined here should give correct data in case the values of the unknown parameters follow a gaussian distribution. For a non-gaussian distribution of data, i.e. in the case where the real $\log g$ is equal to 0 while our data only give $\chi$-values for model atmospheres with $\log g \geq 0$, an additional correction to the results may be made by visually examining the data. For HD 96918 (cf. Fig. 1), it seems that the most probable of $\log g$ is less than 0. But the lowest value of $\chi = 0.007$ (log intensity scale), which corresponds to 0.018 mag, is already fairly low as compared to the accuracy of the observation (cf. Table 1). We conclude that the most probable value of $\log g$ is not far from 0, although it can be less than 0. This is confirmed below by a different treatment.

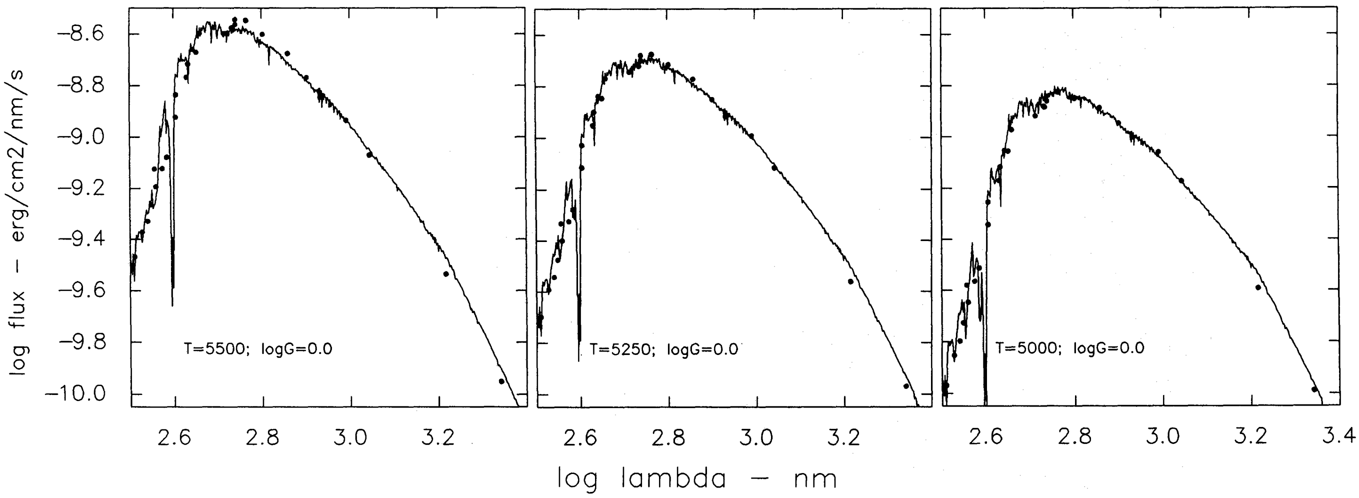


**Fig. 2.** The spectral energy distribution of HD 96918 for three different temperatures: 5500, 5250 and 5000 K

The 'error' is estimated by using a Taylor's first order expansion series, which is explained in the following. The *expected* deviation between the observed flux ($\log F_i^{obs}$) and the normalized theoretical flux ($\log F_i^{th} - C$) for each bandwidth is 0. Hence for each bandwidth we can write :

$$-\Delta F_i = \frac{\partial \Delta F_i}{\partial \log T_{eff}} d \log T_{eff} + \frac{\partial \Delta F_i}{\partial \log g} d \log g + \frac{\partial \Delta F_i}{\partial E(B-V)} dE(B-V), \quad (5)$$

where $\Delta F_i$ is the *calculated* deviation between the observed flux and the normalized theoretical flux. From *n observed fluxes* ($n \geq 3$) we can obtain values of $d \log T_{eff}$, $d \log g$ and $dE(B\text{-}V)$ by solving *n equations* (5). The error of $C$ is estimated directly from a derivation of Eq. 3. The final results for HD 96918 are : $T_{eff} = 5200 \pm 200$ K, $\log g$ [cm s$^{-2}$]$= 0.0 \pm 0.5$, E(B-V)$= 0.27 \pm 0.07$. Using the resulting value of $C$, we calculate the angular diameter of the star using :

$$L = 4\pi R_\star^2 \left(\pi \int F_\lambda d\lambda\right) = 4\pi d_\star^2 \left(\int F^{obs} d\lambda\right), \quad (6)$$

where $L$ is the luminosity of the star; $F_\lambda$ is the flux at the surface of the star, which is the same as the Kurucz fluxes; $R_\star$ is the radius of the star; $d_\star$ is the distance and $F^{obs}$ is the flux of the star which is observed on earth, corrected for interstellar extinction. The shapes of $F_\lambda$ and $F^{obs}$ are identical, with $\pi F_\lambda / F^{obs} = 10^C$ (Eqs. 1 & 2). Thus the angular diameter of the star is :

$$\phi = 2.06265\, 10^8\ (2\ 10^{-0.5\,C}) \text{ milliarcsec}. \quad (7)$$

For the calculated angular diameter of HD 96918 we find $2.49 \pm 0.15$ milliarcsec.

## 4. The distance

The distance of HD 96918 (l=290°.01, b=1°.29) is not well known. The star is located in the direction of the Car OB2 association; however, the line-of-sight to the star is almost tangential to the Carina spiral arm. Hence, the luminous stars in this area have a large range of possible distances. Usually the distance is taken as 1.2 kpc (Goniadzki 1972) or 1.8 kpc (Humphreys 1972). These distances were calculated assuming that the absolute luminosity and the intrinsic color index B-V are known (photometric distance). Different assumptions of the intrinsic color index B-V used by these authors might explain the difference in the distances obtained. This method is not reliable for hypergiants, since only a few of the relevant data of these stars are known and there are no reliable $M_v$ versus spectral type or $(B\text{-}V)_\circ$ versus spectral type scales for hypergiants. We therefore tried to determine the distance to this star in three independent ways

### 4.1. The kinematic distance

The kinematic distance of an object can be determined from its velocity due to the differential rotation of the Galaxy. The radial velocity of HD 96918 is variable (Wright 1907). A mean velocity of $+5.5$ km s$^{-1}$ was determined by the Cape observers (Hough 1928), and of $+5.6 \pm 0.5$ km s$^{-1}$ by Balona (1982) from 49 observations. Using $+5.6$ km s$^{-1}$ as the velocity for HD 96918, its velocity with respect to the local standard of rest is $-5.2$ km s$^{-1}$. Dubath et al. (1988) have derived a second order expansion of the standard equation for circular rotation, which is important for a distant star. Using their result with $R_\circ = 8.5$ kpc, A = 16.0 km sec$^{-1}$ kpc$^{-1}$ and $A_2 = -0.7$ km sec$^{-1}$ kpc$^{-1}$, we obtain two solutions for the distance: 0.5 kpc and 5.3 kpc. Note that in the fourth quadrant of the galactic plane, a negative velocity means that the object is inside the solar orbit; hence it is quite possible to find two distances. Non-circular motions of about $5 - 10$ km s$^{-1}$ are common for the extreme Pop I objects that define the spiral arms (Humphreys et al. 1989). In view of this fact, the possible range of the kinematic distances for the star are : $0.5^{+1.8}_{-0.5}$ or 0 - 2.3 kpc and $5.3^{+1.0}_{-1.8}$ or 3.5 - 6.3 kpc.

### 4.2. The reddening-distance method

We have collected E(B-V) data from the literature for about 40 stars located within 0.5° of HD 96918. Note that the extinction in the area around the star is nearly homogeneous, as can be seen in a picture taken from the ESO sky survey. Most of the selected stars are main sequence stars; a few of them are giants. We calculated the photometric distances for these stars using the luminosity calibration and intrinsic color indices from Schmidt-Kaler (1982) and assuming $R = 3.1$. Figure 3 shows the variation of E(B-V) with distance for these stars. From this figure, while using for HD 96918 the extinction value E(B-V) = $0.27 \pm 0.07$ mag, one derives a distance of $2.4 \pm 0.9$ kpc.

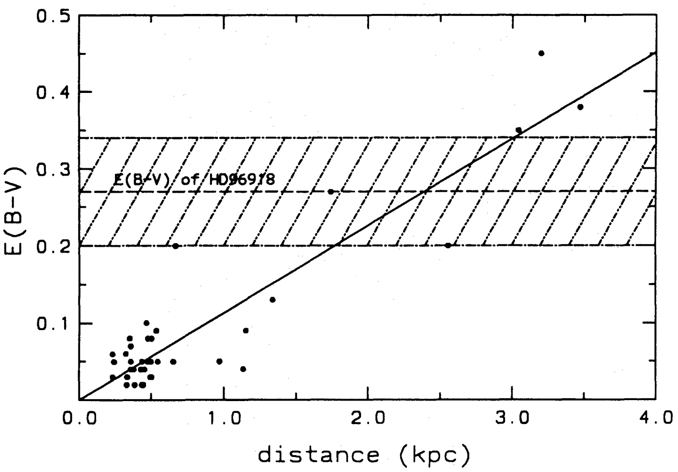


**Fig. 3.** The relationship between E(B-V) and distance for stars around HD 96918.

### *4.3. Distance from atmospheric model parameters and evolutionary model*

The relation between luminosity and effective temperature can be written as :

$$\log \frac{L}{L_\odot} = 4 \log \frac{T_{\rm eff}}{T_\odot} + 4.44 - \log g + \log \frac{M}{M_\odot}. \quad (8)$$

Using the adopted $T_{\rm eff} = 5200$ K and $\log g = 0$, we obtain a relation between luminosity and mass for HD 96918. This relation is shown by a dashed line in Fig. 4.

From a grid of stellar evolution calculations by Maeder (1990), we obtain another relation between luminosity and mass for stars with $T_{\rm eff} = 5200$ K and solar abundance (cf. solid lines in Fig. 4). Combining this with Eq. 8, as shown in Fig. 4, we can estimate the most probable luminosity for the star. In this figure, the dotted line is an extrapolation of the luminosity-mass relation for stars evolving blueward. This dotted line would be the locus of stars with initial mass around $20\,M_\odot$ which are evolving blueward. However, according to Maeder (1990), stars with initial mass around $20\,M_\odot$ and solar abundance will not evolve blueward, which reduces the reliability of the extrapolation. Another line, the dashed-dotted line, is the extrapolation of the luminosity-mass relation for stars evolving redward. This extrapolation also meets with difficulties because it is above the Humphreys-Davidson limit which is the observed upper luminosity limit of stellar existence.

From Fig. 4 we find that the star has a $\log L/L_\odot = 5.4$ and a mass $M = 14\,M_\odot$ if it is evolving blueward. Using the $\log g = 0$ implies a radius $R = 600\,R_\odot$. From the angular diameter 2.49 milliarcsec found in Sect. 3, we obtain a distance 2.2 kpc. If the star is evolving redward, we obtain a $\log L/L_\odot = 5.8$, a mass $M = 42\,M_\odot$, a radius $R = 1100\,R_\odot$ and a distance 4.1 kpc. The reliability of these two results is less because of the use of the extrapolation line as explained in the above paragraph. The two choices between redward and blueward evolution can further be tested with abundance studies, since the star is expected to have an N-rich atmosphere after the red supergiant phase (Maeder, 1986).

The conclusion of this section is that using the atmospheric model data together with the evolutionary models of Maeder (1990), this star has a most probable luminosity $\log L/L_\odot = 5.6 \pm 0.3$, a mass $M = 28 \pm 12\,M_\odot$, a radius $R = 800 \pm 300\,R_\odot$ and a distance of $3.0 \pm 1.1$ kpc. A photospheric abundance analysis may result in a reduction of the errors.

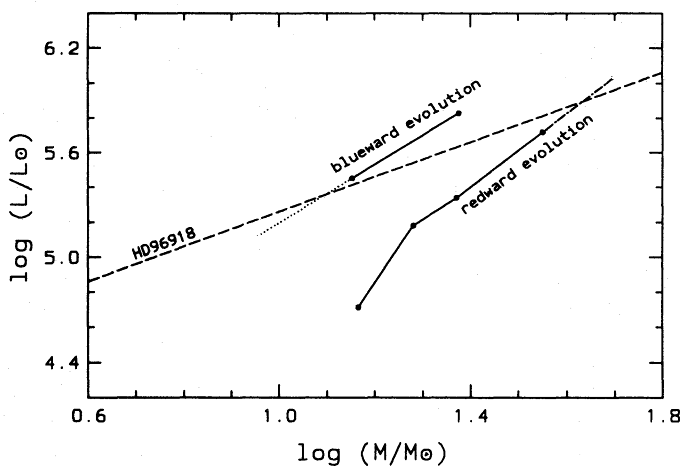


**Fig. 4.** The dashed line is the luminosity-mass relation for the adopted values $T_{\rm eff} = 5200$ K, $\log g = 0$ (cf. Eq. 8). The solid lines are the luminosity-mass relations from stellar evolution calculations by Maeder (1990) for stars with $T_{\rm eff} = 5200$ K. The upper solid line refers to stars evolving blueward and the lower solid line to stars evolving redward

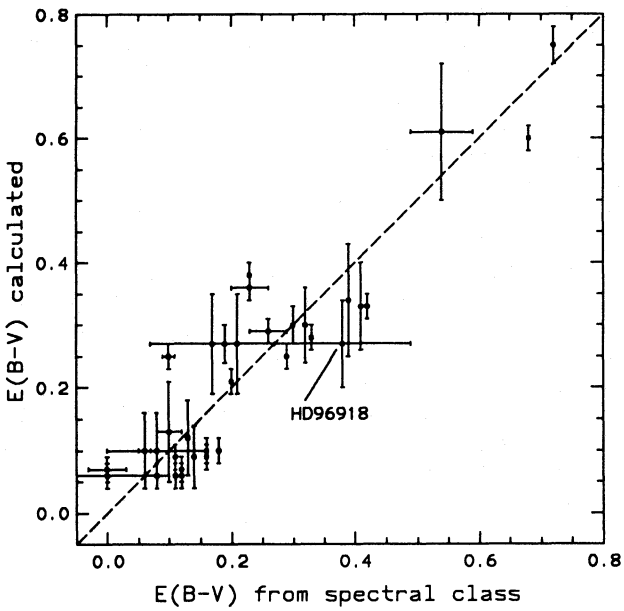


**Fig. 5.** Comparison of E(B-V)-values for stars studied here

**Table 2.** Stellar parameters derived from the photometric data

| Star | Sp. Type | $E_{(B-V)}$ | log $g$ [cm $s^{-1}$] | Temp. [Kelvin] | Ang. $\phi$ [milliarcsec] | ref. for photometric data |
|---|---|---|---|---|---|---|
| HD 4362 | G0 Ib | 0.28±0.02 | 0.9±0.4 | 5570±220 | 0.72±0.06 | 1,2,3,4 |
| HD 8890 | F7 Ib/II | 0.13±0.08 | 2.2±0.6 | 6500±590 | 3.09±0.30 | 1,5,6,7 |
| HD 11544 | G2 Ib | 0.30±0.03 | 0.3±0.4 | 5500±150 | 0.63±0.03 | 1,3,8 |
| HD 26630 | G0 Ib | 0.21±0.02 | 1.2±0.4 | 5630±270 | 1.79±0.15 | 1,2,3,4,5 |
| HD 39949 | G2 Ib/II | 0.29±0.02 | 0.5±0.3 | 5600±190 | 0.48±0.03 | 1,2 |
| HD 54605 | F8 Ia | 0.07±0.02 | 0.9±0.3 | 6050±150 | 3.50±0.07 | 1,5,6,7,10 |
| HD 57146 | G2 II | 0.10±0.02 | 1.4±0.3 | 5350±240 | 1.03±0.11 | 1,2,3,4,9,10 |
| HD 58526 | G0-3 Iab/Ib | 0.10±0.06 | 1.2±0.4 | 5500±150 | 0.70±0.06 | 1,2,3,4,9,10 |
| HD 59890 | G2 Iab/b | 0.10±0.06 | 1.0±0.3 | 5500±150 | 1.28±0.13 | 1,*,9,10 |
| HD 63700 | G6 Ia | 0.09±0.02 | 0.2±0.3 | 4950±150 | 3.13±0.10 | 1,5,6,7,10 |
| HD 67594 | G2 Ib | 0.09±0.02 | 1.0±0.3 | 5380±220 | 1.55±0.10 | 1,5,6,7,10 |
| HD 77912 | G8 Ib/II | 0.06±0.02 | 1.0±0.3 | 5180±190 | 1.50±0.11 | 1,5,6,7 |
| HD 96918 | G0-4 $Ia^+$ | 0.27±0.07 | 0.0±0.5 | 5200±200 | 2.49±0.15 | 1,2,5,9,10,12,13,14 |
| HD 101570 | G3 Ib | 0.38±0.02 | 0.9±0.3 | 5600±240 | 1.61±0.16 | 1,* |
| HD 114533 | G2 Ib | 0.27±0.08 | 1.3±0.3 | 5500±150 | 0.96±0.11 | 1,9 |
| HD 139915 | G0 Ib | 0.25±0.02 | 1.2±0.3 | 5500±150 | 0.70±0.03 | 1,*,9 |
| HD 146143 | F7 Ib | 0.30±0.06 | 1.6±0.3 | 6190±350 | 1.11±0.14 | 1,4,9,10 |
| HD 158476 | F8-G0 Ib | 0.27±0.08 | 1.6±0.3 | 6070±150 | 0.70±0.06 | 1,* |
| HD 159633 | G2 Ib | 0.34±0.09 | 0.7±0.3 | 5250±150 | 0.98±0.11 | 1,*,9 |
| HD 161664 | G3-G5 Ib | 0.61±0.11 | 0.8±0.8 | 5250±150 | 1.49±0.20 | 1,*,9,10 |
| HD 171635 | F7 Ib | 0.12±0.06 | 1.7±0.3 | 6330±150 | 0.88±0.07 | 1,*,4,5 |
| HD 180028 | F6 Ib | 0.33±0.02 | 1.9±0.7 | 6350±590 | 0.44±0.07 | 1,*,2,4 |
| HD 182296 | G3 Ib | 0.33±0.07 | 0.2±0.3 | 5250±150 | 0.68±0.07 | 1,*,2,4,9,10 |
| HD 185018 | G0 Ib/II | 0.09±0.05 | 2.0±0.3 | 5550±170 | 0.69±0.07 | 1,*,9 |
| HD 190323 | G0 Ia/Iab | 0.25±0.02 | 0.8±0.7 | 5880±300 | 0.49±0.04 | 1,2,4,9,10 |
| HD 192876A | G3 Ib | 0.10±0.02 | 1.2±0.3 | 5180±150 | 1.84±0.08 | 1,5,6,7 |
| HD 194093 | F8 Ib | 0.06±0.02 | 0.8±0.4 | 6050±150 | 2.87±0.06 | 1,5,6,7 |
| HD 195593 | F5 Iab | 0.60±0.02 | 1.7±0.3 | 6500±150 | 0.85±0.03 | 1,5,6,7 |
| HD 200102 | G1-2 Ib | 0.36±0.02 | 1.3±0.4 | 5770±150 | 0.66±0.03 | 1,* |
| HD 204022 | G0 Ib | 0.75±0.03 | 0.3±0.6 | 5650±310 | 0.85±0.10 | 1,2 |
| HD 204867 | G0 Ib | 0.06±0.02 | 1.1±0.3 | 5600±310 | 2.59±0.25 | 1,5,6,7,10 |
| HD 206859 | G5 Ib | 0.10±0.02 | 0.8±0.4 | 5050±150 | 1.93±0.07 | 1,5,6,7 |
| HD 209750 | G2 Ib | 0.06±0.02 | 0.7±0.3 | 5350±280 | 2.86±0.28 | 1,5,6,7,10 |
| HD 216206 | G4 Ib | 0.27±0.03 | 0.6±0.4 | 5410±150 | 0.84±0.04 | 1,2 |
| HD 222574 | G2 Ib/II | 0.07±0.02 | 1.6±0.3 | 5630±170 | 1.09±0.06 | 1,5,6,7 |

The spectral type are taken from Houk & Cowley 1975, Michigan Spectral Catalogue; Hoffleit 1982, The Bright Star Catalogue; or Strasbourg's database.

Reference for the photometric data:

⋆. UBV Johnson; average value from several literature sources taken from Strasbourg's database
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14. Humphreys et al. 1971, ApJ Letter 167, 35

## 5. Conclusion and discussion

Three approaches have been made to estimate the distance of HD 96918. From the differential rotation of the Galaxy and the radial velocity of the star, we found two distances: $0.5^{+1.8}_{-0.5}$ kpc and $5.3^{+1.0}_{-1.8}$ kpc; from the extinction $2.4 \pm 0.9$ kpc and from the combination of the atmospheric and evolutionary models $3.0 \pm 1.1$ kpc. From these results, we come to the conclusion that this star is most probably at a distance of $2.7 \pm 1.0$ kpc. This implies a radius $R = 700 \pm 250\, R_\odot$; using $T_{\rm eff} = 5200 \pm 200$ K we obtain a luminosity $\log L/L_\odot = 5.5 \pm 0.4$ and using $\log g = 0.0 \pm 0.5$ a mass $M = 20 \pm 10\, M_\odot$. From the evolutionary calculation, these values correspond to an initial mass of $M = 31 \pm 10\, M_\odot$ if the star is evolving blueward or an initial mass of $M = 26 \pm 10\, M_\odot$ if the star is evolving redward. The IRAS data show only a small infrared excess, which indicates that the lower initial mass is more probable. With the distance, the visual magnitude $m_v = 3.91$, E(B-V) $= 0.27$ and $R = 3.1$ we find the absolute visual magnitude $M_v = -9.0$.

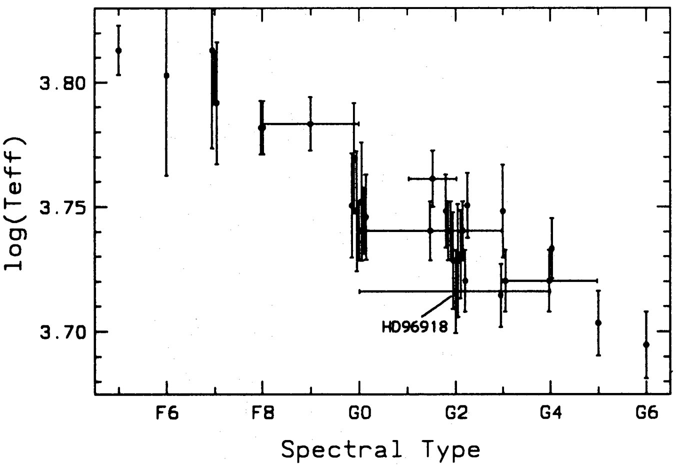


**Fig. 6.** $T_{\rm eff}$ vs. spectral type for stars studied here

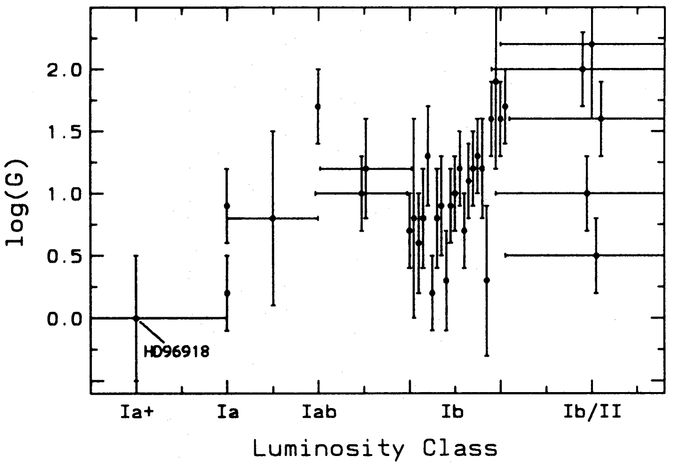


**Fig. 7.** $\log g$ vs. luminosity class for stars studied here

Using the photometric method, as explained in Sect. 2, we also obtained atmospheric parameters $T_{\rm eff}$ and $\log g$ values for 35 supergiants in the spectral range F5-G8. The results are given in Table 2. This Table also contains the calculated E(B-V) values. We also derived E(B-V) values for all stars in Table 2 directly from the information on their spectral classes, the observed (B-V) values and the $(B-V)_o$ vs. spectral types calibration of Schmidt-Kaler (1982). We could verify that our calculated E(B-V) values are in reasonable agreement with the derived E(B-V) values from their spectral classes as can be seen in Fig 5. Note that the error bar in the x-axis is only due to uncertainties in the spectral class of a star.

By examining the relation between $T_{\rm eff}$ vs. spectral type in Fig. 6 and $\log g$ vs. luminosity class in Fig. 7, we come to the conclusion that indeed HD 96918 has the characteristics of a hypergiant because of its low $\log g$. Note that most of the other supergiants in Figs. 6 & 7 have the luminosity class Ib. The spectral type G0-G4 is also very reasonable since we expect that hypergiants have a lower temperature as compared to supergiants of the same spectral class.

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