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The very massive star HDE 269676 and its components

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Abstract. We show that one of the most luminous stars of the Large Magellanic Cloud (LMC), HDE 269676, is in fact a massive star cluster. On the basis of observations with the ESO New Technology Telescope (NTT) we classify the main components of the cluster and show that there are several O type stars in HDE 269676 instead of the one or two previously known. This is interesting for the initial mass function in the LMC and implies that the number of O type stars in the LMC is generally underestimated. The most massive star of the system being about a factor three less luminous than previously estimated is a supergiant O5f with a zero age main sequence mass of $\sim 80\,M_{\odot}$.

Key words: galaxies: Magellanic Clouds – stars: early-type – stars: mass of – stars: spectral classification

1. Introduction

Recently we have presented evidence against the existence of stars with masses higher than $\sim 100\,M_{\odot}$ in the Magellanic Clouds (Heydari-Malayeri et al. 1988, 1989; Heydari-Malayeri & Hutsemékers 1991). This is very important for the question of the upper mass limit which is one of the fundamental problems of astrophysics. In the present paper, we deal not only with the multiplicity of another very massive star (VMS) in the Large Magellanic Cloud (LMC), but we also analyze the nature of the component stars. In the above-mentioned papers we have argued, on the basis of $B-V$ colors, that the main components of VMSs are of type O. Here we present spectroscopic results confirming this conclusion which is particularly important for the initial mass function (IMF).

HDE 269676, identified also as R 113 (Feast et al. 1960) and Sk $-71°45$ (Sanduleak 1969), was considered to be one of the most luminous and hence most massive stars in the LMC. HDE 269676 was classified O4–5 III (f) by Walborn (1977). The reported V magnitude of 10.9 (Lucke 1972) indicates a mass far above $120\,M_{\odot}$ for HDE 269676. Due to its high luminosity, this object has been a good target for several *IUE* programs concerning, e.g., the investigation of mass loss from hot stars and also the velocity components of the interstellar medium in the LMC (Gondhalekar et al. 1980; Hutchings 1980a, b; Macchetto et al. 1980).

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2. Observations

2.1. Imaging

The images of HDE 269676 were obtained using the ESO New Technology Telescope (NTT) on January 11, 1990 equipped with the ESO Faint Object Spectrograph and Camera (EFOSC2). The detector was a Tektronix CCD chip, 520×520 pixels, each pixel $27\,\mu m^2$ ($0\farcs21$ on the sky). Broad band B, V and R images were taken with good seeings of $0\farcs92$, $0\farcs84$, and $0\farcs79$ FWHM respectively (Fig. 1).

The images were restored using a deconvolution code kindly provided by Marc Remy. The point spread function (PSF) was defined by the bright stellar images on the same frame. This PSF was used to deconvolve the images on the basis of a maximum entropy method (Skilling & Bryan 1984) which proved to give very reliable results. Part of the original image showing HDE 269676 is presented in Fig. 2a, while the processed image is displayed in Fig. 2b.

2.2. Spectroscopy

The NTT equipped with EFOSC2 was also used on March 15, 1990 in order to take spectra of the various components of HDE 269676. The CCD detector was a Thomson chip of 1024×1024 pixels, each pixel $19\,\mu m$ ($0\farcs15$ on the sky). The dispersion of the grism was 101 Å mm^{-1}, and the resolution 13 Å; the spectrum ranging from 3669 Å to 5450 Å. The slit width was $0\farcs74$. Exposure times were 10 or 15 min.

3. Some data

HDE 269676 lies $\sim 2°$ due south of 30 Dor region, $\sim 35''$ east of the H II region N 206A (Henize 1956) or NGC 2018 (Fig. 1). The only photoelectric UBV observations reported for HDE 269676 are those of Macchetto et al. (1980) who, using the ESO 50 cm telescope and a $15''$-diameter aperture, obtained $V=11.51$, $B-V=-0.19$ and $U-B=-0.91$. A color excess of $E(B-V)=+0.11$ can be derived for the star using the intrinsic value of $(B-V)=-0.30$ for O type stars (Conti et al. 1986). This corresponds to a visual extinction of $A_V=0.34$ mag. The other photometric results given in Table 1 are based on photographic techniques.

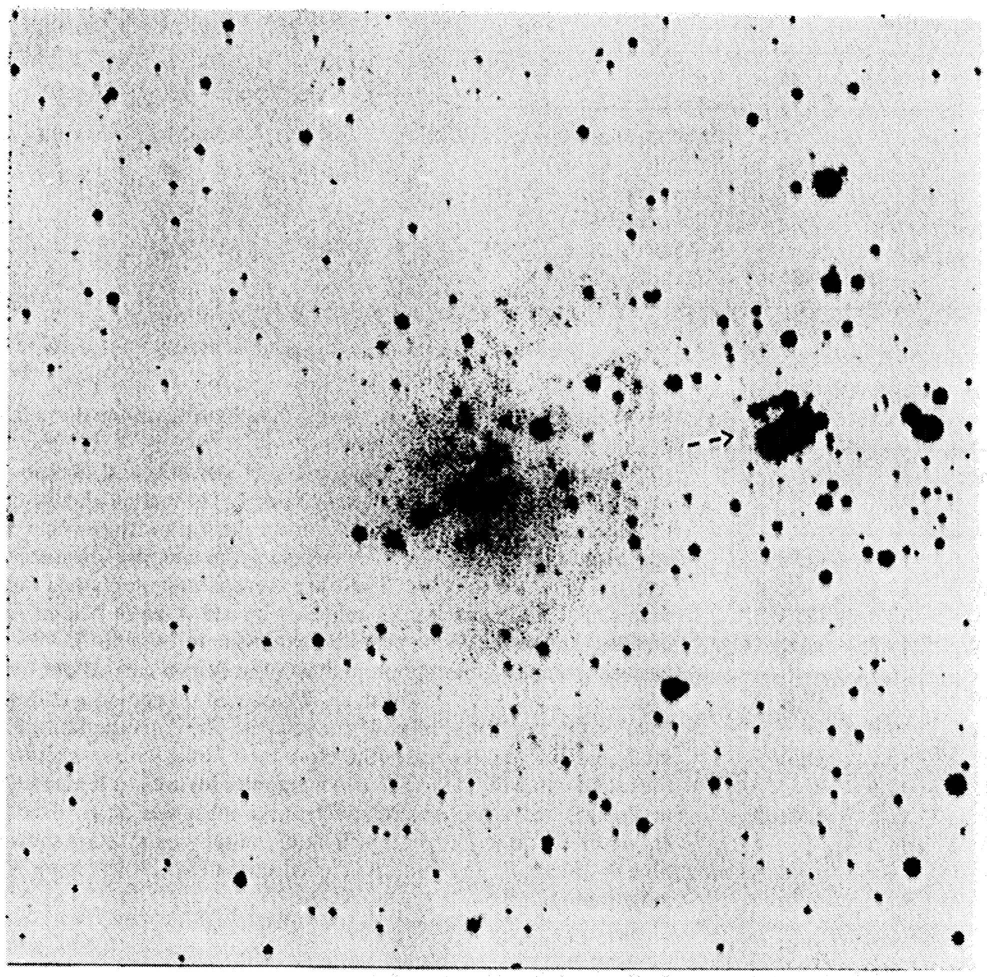

Fig. 1. HDE 269676 (indicted with an arrow) and its neighboring ionized region N 206 A (NGC 2018) observed with the ESO NTT using an *R* filter. Seeing 0″.79 (FWHM). Field 120″ × 107″. North is at the top, east to the left

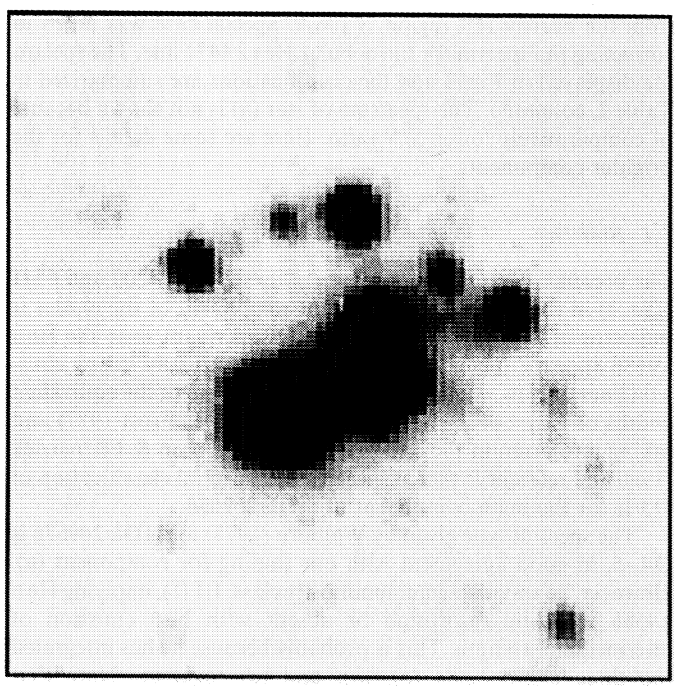

Fig. 2a. Blow-up of HDE 269676 from Fig. 1. Field 15″ × 15″

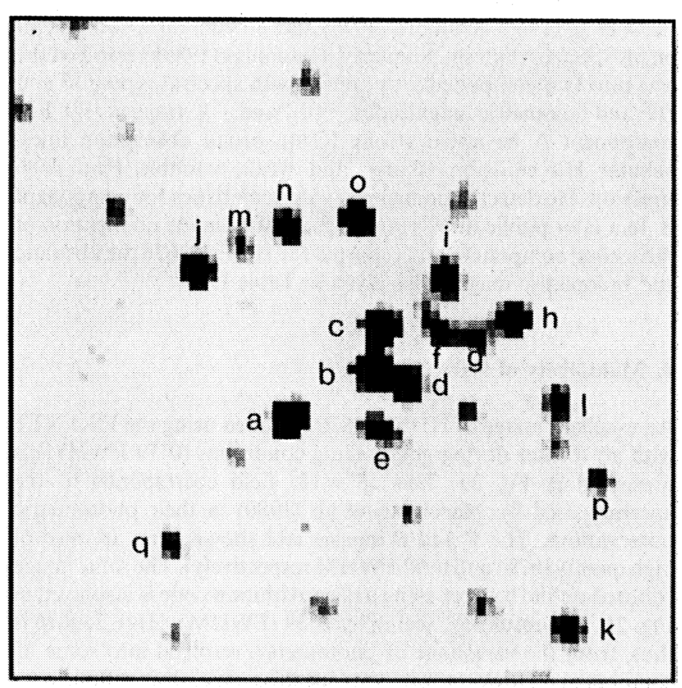

Fig. 2b. The same image restored after 20 iterations. Resulting resolution 0″.39 (FWHM)

Table 1. Reported photometry of HDE 269676

V	$B-V$	$U-B$	Type	M_V	M_b	Ref.
11.7			O6e			Feast et al. (1960)
11.6			OB			Sanduleak (1969)
10.9	−0.33					Lucke (1972)
			O4–5 III (f)	−7.7		Walborn (1977)
11.51	−0.19	−0.91				Macchetto et al. (1980)
			O6f	−7.6	−11.4	Hutchings (1980b)

Table 2. Brightest component stars

Star	X (″)	Y (″)	Distance (″)	V	Sp. type
a	0.0	0.0	0.0	12.2	O5 If
b	1.9 W	1.1 N	2.2 NW	13.1:	O6.5 V
c	2.0 W	2.2 N	3.0 NW	14.8	O7 V
d	2.7: W	0.8: N	2.8: NW	14.8:	Early O
e	2.0 W	0.2 S	2.0 SW	16.7	–
h	5.0 W	2.4 N	5.5 NW	15.9	Late O
i	3.5 W	3.2 N	4.8 NW	17.0	–
o	1.5 W	4.6 N	4.8 NW	15.2	O8 V
n	0.1 E	4.4 N	4.4 NE	17.6	–
j	2.1 E	3.4 N	4.0 NE	16.1	Late O
k	6.3 W	4.7 S	7.9 SW	17.5	–

HDE 269676 was classified by Walborn (1977) as O4–5 III (f) who cautions that the spectral type is slightly uncertain because of nebular He I emission. The duplicity of the star was first noticed by Feast et al. (1960). Walborn (1977) also noted a third component on his spectrograph slit. Similarly, Hutchings (1980a) resolved the star into two components, A and B, with spectral types O6 and O9: and bolometric magnitudes −10.7 and −9: respectively. For component A he noted strong [O III], broad absorption lines, nebular Hα emission (sharp) and weak, variable He II 4686 emission. He detected no mass loss characteristics for component B. In a later publication, Hutchings (1980b) made no mention of the second component and reported for HDE 269676 the absolute and bolometric magnitudes given in Table 1.

4. Multiplicity of HDE 269676

An excellent image of HDE 269676 obtained using the ESO NTT with an R filter during good seeing conditions (0.″79 FWHM) is presented in Fig. 2a. This 15″ × 15″ field corresponds to the aperture used by Macchetto et al. (1980) in their photometric observations. The V and B images, not shown here, are also of high quality (0.″84 and 0.″92 FWHM respectively). The same image restored on the basis of using a deconvolution code is displayed in Fig. 2b. The resulting "seeing" is 0.″39 (FWHM). HDE 269676 is thus, from the viewpoint of photometry, resolved into some 25 components! However, previous spectroscopic observations probably refer only to components (*a*) to (*g*) or (*a*) to (*i*). The fainter components are not labelled in Fig. 1 since they contribute much less to the total brightness. However, they show up in the three B, V, and R images.

The geometry and the photometry of the brightest components of the system are presented in Table 2. The second and third columns give the X and Y separations of the stars with respect to component (*a*) and column 4 presents the angular distances referred to this component. These are average values obtained for each star from distance measurements on the three B, V, and R images. The tentative V magnitudes, listed in column 5, were derived from the global photometry of the system carried out by Macchetto et al. (1980). The main component (*a*) provides about 55% of the total brightness of the system. The corresponding V magnitude of 12.2 decreases therefore by 0.7 mag with respect to the initial value of 11.51. The $B-V$ magnitudes are not presented in Table 2 because of the relatively large inaccuracies involved. However, we underline that the bulk of the component stars show blue $B-V$ colors. The faintest labelled star in Fig. 2b, (*n*), has a V magnitude of 19.8.

5. Spectral classification of the components

The stellar spectra are contaminated by nebular emission lines from the nearby H II region N 206A. Special care was taken in correcting the spectra for the nebular He I λ4471 line. The spectra are displayed in Fig. 3 and the classifications are summarized in Table 2, column 6. The spectrum of star (*h*) is not shown because of comparatively lower S/N ratio. Here are some details for the brighter components.

5.1. Star (a)

The presence of the He II absorption lines λ4026, 4200 and 4541 (Fig. 3) in the spectrum of the main component of the cluster is indicator of O type stars. This is an O supergiant since the He II λ4686 appears in emission accompanied by equally strong emission lines of N III at λ4634-40-42. From the ratio of the equivalent widths of He I λ4471 and He II λ4541 (Conti & Frost 1977) and taking into account the criteria given by Walborn & Fitzpatrick (1990 and references therein) we derive a spectral classification of O5 If for the main component of HDE 269676.

The spectral type given by Walborn (1977) for HDE 269676 is O4–5, in good agreement with our finding for component (*a*). However, he assigns a giant luminosity class, III (f), implying He II λ4686 weak in absorption or absent with N III emission of intermediate strength. This is probably because he has integrated the three components (*a*), (*b*), and (*d*) together. Note that Hutchings (1980) gave a classifications of O6 for the main component of HDE 269676.

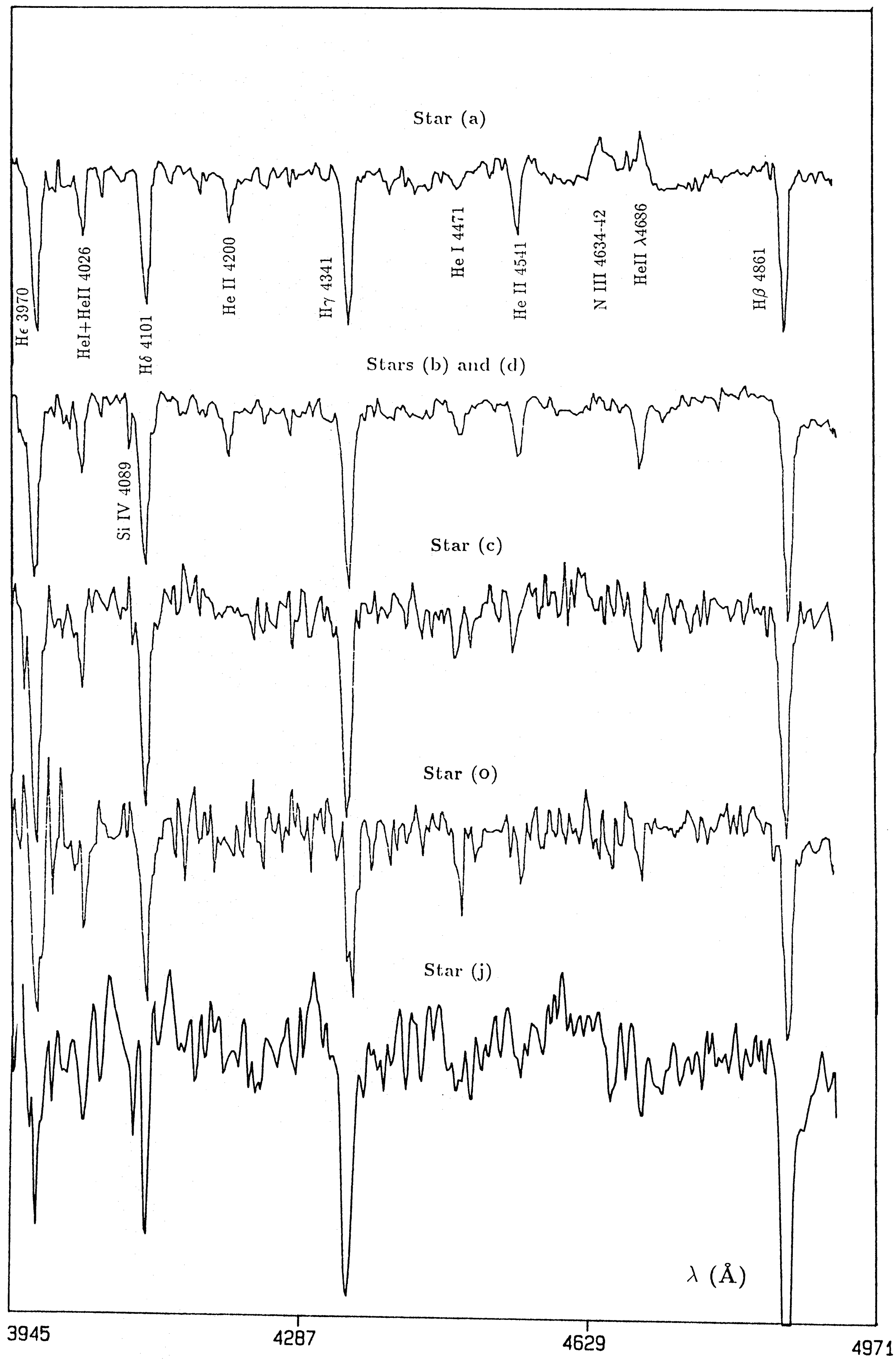

Fig. 3. Rectified spectrograms of the main components of HDE 269676. Arbitrary flux units

5.2. *Stars (b) and (d)*

The spectrograph slit positioned EW takes components (*b*) and (*d*) simultaneously. The spectrum displayed in Fig. 3 is typical of main sequence O6.5 stars according to the criteria given by Conti & Alschuler (1971). This classification corresponds therefore to both (*b*) and (*d*). This means that star (*d*) also should be of type O because in the global spectrum there are no absorption lines characterizing B or A type stars. Since component (*d*) is only 1.7 mag fainter than (*b*), the absorption lines of Si III λ4552-68 and Si II λ4128-30 characterizing B type stars, if they exist, are expected to show up. On the other hand, we may underestimate the spectral type of star (*b*) due to contamination by component (*d*) which may be a late type O star.

5.3. *Star (c)*

This component lies 1''.1 north of star (*b*) and has a *V* magnitude of 14.8 (Table 2). The spectrum presented in Fig. 3 indicates an O7 V star. The seeing conditions during the observations were very good (0''.9 FWHM). We therefore believe that there is insignificant contamination from star (*b*).

6. Discussion and concluding remarks

The photometric results of Macchetto et al. (1980) give a visual absolute magnitude of -7.33 for HDE 269676 using a distance modulus of 18.5 (Westerlund 1989). This corresponds to a bolometric magnitude of -11.3 when the bolometric correction (*BC*) for O4 supergiants (Massey et al. 1989) is used. The bolometric magnitude will be even higher, -11.6, if we use Walborn's (1977) absolute magnitude (Table 1). Therefore, the luminosities will be $\sim 2.6\ 10^6$ and $3.5\ 10^6\ L_\odot$ respectively corresponding to zero age main sequence (ZAMS) masses more than 120 $M_\odot$ on the basis of the evolutionary tracks given by Maeder (1990) for the LMC massive stars.

However, the most massive star of the system, i.e. component (*a*), has a visual magnitude of 12.2 (Table 2). From $BC = -3.78$ and $\log T_{\rm eff} = 4.605$ for O5 supergiants (Massey et al. 1989), using isochrones of Maeder (1990), we derive a ZAMS mass of $\sim 80\ M_\odot$ for component (*a*). The ZAMS mass of the second brightest component (*b*) will thus be 50 $M_\odot$.

Here we have shown that there are at least seven O type stars towards HDE 269676 instead of the one or two previously known. Similar conclusions were reached for the other very massive stars we analyzed (Heydari-Malayeri et al. 1988, 1989; Heydari-Malayeri & Hutsemékers 1991). This is particularly important for the shape of the initial mass function (IMF) in the LMC since it implies that the number of O type stars in the LMC is underestimated. This means also that star formation processes produce much more massive stars of mass ranging from 40 to 60 $M_\odot$ than previously thought and that there are much less stars of mass more than 70 $M_\odot$.

The present observations confirm the collective nature of massive star formation. From the evolutionary models of Maeder (1990) we estimate that the cluster formed some 3.3 10^6 yr ago. The most massive star of the group has evolved faster than the others since it has left the main sequence to become a supergiant of type O5.

We are once more confronted with the fact that the classical photometry based on using large apertures and low resolutions (especially for bright stars) overestimates the apparent magnitudes when the star lies in a crowded field. This is how all the 25 components of HDE 269676 were included in the 15'' aperture and a most luminous star was created.

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