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Letter to the Editor

New evidence against the existence of very massive stars

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Summary. The most luminous stars are our first probes for exploring the stellar content of distant galaxies. They have also been used as standard candles for extragalactic distance determinations. We show that Sk–66°41, one of the brightest stars in the Large Magellanic Cloud (LMC), is a multiple system consisting of at least six components. This result has important consequences for the understanding of star formation mechanisms, especially the upper limit to stellar masses. Moreover, when primary distance indicators are not available, care should be taken in using the brightest blue stars. The derived distances, depending on the number of cluster members, can easily be underestimated by more than a factor 2, leading to larger values for the Hubble constant.

Key words: Large Magellanic Cloud – massive stars – multiple systems – luminosity function – distance scale

1. Introduction

The upper limit to stellar masses constitutes one of the fundamental problems of astrophysics. The recent years have witnessed a surge of interest in both observational and theoretical study of the most massive stars. We know today that non-linear effects restrict the pulsational instability permitting stars with masses higher than the classical Ledoux–Schwarzschild–Härm limit of 60 $M_\odot$ (Appenzeller, 1970; Ziebarth, 1970). A basic issue is how far over this classical limit stars can go. The right answer to this question affects not only our understanding of star formation, but also the choice of distance indicators for determining the Hubble constant.

This letter is devoted to Sk–66°41 = HDE 268743 (Sanduleak, 1969), one of the most luminous stars in the LMC. Humphreys (1983) derived a bolometric magnitude of –11.2 for this star, corresponding to a mass higher than 120 $M_\odot$. In a recent paper (Heydari–Malayeri et al., 1987, hereafter Paper I) we carried out a detailed investigation of Sk–66°41 and its associated HII region N11C (Henize, 1956). From the analysis of several CCD spectra a spectral type of O5 V was assigned to Sk–66°41. The photometry led to V=11.72, B–V=–0.12, U–B=–0.92, V–R=0.00.

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2. Observations

CCD images of Sk–66°41 were obtained in March 1988 with the 3.60m and 2.20m telescopes at ESO (La Silla, Chile). At the 3.60m telescope, the ESO Faint Object Spectrograph and Camera (EFOSC) was used. In both cases, the detector was a high resolution RCA CCD chip (type SID 503, 1024×640 pixels of 15 μm^2). The observational data are summarized in Table 1.

Table 1. **CCD images**

Filter	*Exposure* sec.	*Telescope*	*Date*	*Seeing* "	*pixel size* "
B	20	2.20m	10 March 88	1.3	0.176
V	2	3.60m	6 March 88	1.0	0.338
R	30	2.20m	10 March 88	0.9	0.176

3. Image Processing

The images were reduced in the standard way using the MIDAS package at ESO, La Silla, and subsequently deconvolved using an improved version (Magain, 1988) of a simple recursive restoration algorithm (Meinel, 1986). The point spread function was determined from double Gaussian fits of neighbouring stellar images. The method was tested on several known objects and shown to lead to very reliable results (Magain, 1988). The image restoration was carried out on all the images. We also checked that the star images are not affected by nebular contribution.

4. Results

A part of the R frame showing Sk–66°41 is presented in Fig. 1. The exposure time was 30 seconds and the seeing 0".9 FWHM. The processed image after 10 iterations, depicted in Fig. 2, has a resolution of ~ 0".5. It is clearly seen that Sk–66°41 is resolved into six components. The main components of the cluster, stars (a) and (b), are separated by 0".8. Due to the good seeing, star (f), situated 2".4 SW of star (a), is already resolved on the non-processed image. The geometry and photometry of the system are summarized in Table 2. The positions of the various stellar images with respect to star (a), are listed in columns 2 and 3. The contribution of each star to the total flux is indicated in column 4. The tentative R magnitude for each component derived from the global magnitude of the cluster R=11.72 (Paper I) is presented in the last column. Since the inte-

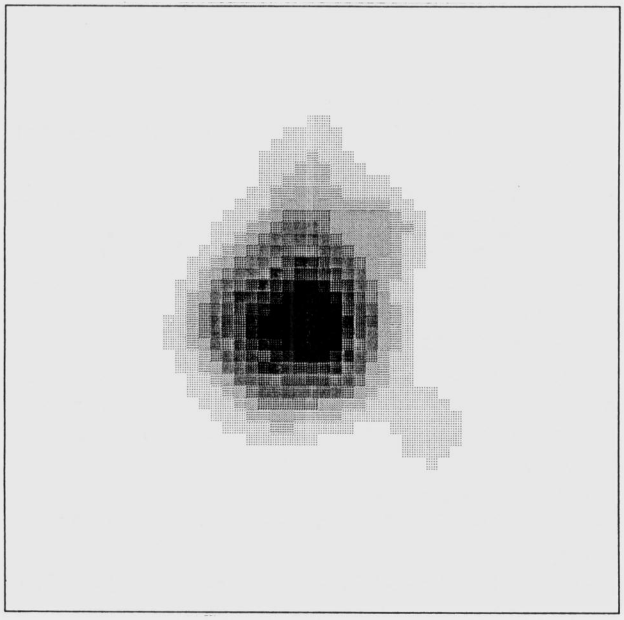

Fig. 1. The CCD R frame of Sk-66°41. The field, 51×51 pixels, corresponds to ~ 9"×9" on the sky. North is at the top, east to the left.

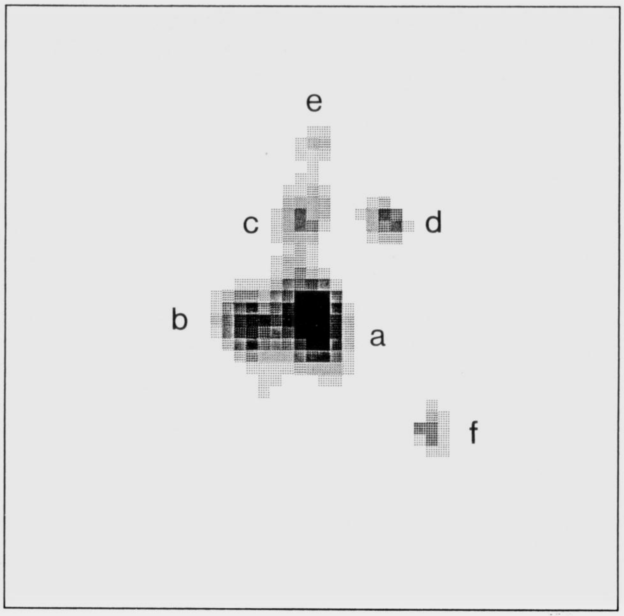

Fig. 2. Same image after deconvolution.

grated V–R=0.00 for Sk–66°41, the R magnitude for component (a) should not be very different from the V magnitude for this star.

In Paper I we assigned a spectral type of O5 V to SK–66°41. This classification should naturally correspond to the brightest components (a) and (b). The mean colour excess E(B–V)=0.19±0.05 derived photometrically for Sk–66°41 and three other stars associated with N11C is in good agreement with the mean value E(B–V)=0.22 obtained from the Balmer decrement for the associated ionized gas (Paper I). Thus, using a distance modulus of 18.45 for the LMC (Stift, 1982), we derive absolute visual magnitudes for components (a) and (b) of –6.6 and –5.7 respectively. The value for component

Table 2. **Component stars**

Star	*X* "	*Y* "	*Relative flux %*	*R mag.*
a	0.0	0.0	66.1	12.2
b	0.9E	0.1N	21.0	13.4
c	0.2E	1.4N	5.0	15.0
d	1.0W	1.4N	3.9	15.2
e	0.0W	2.6N	1.9	16.0
f	1.7W	1.7S	2.1	15.9

(b) agrees very well with model predictions for a main sequence O5 star (Humphreys and McElroy, 1984), while the luminosity of component (a) is higher than the value expected for this type of star. Using a bolometric correction BC=–3.9 (Humphreys and McElroy, 1984) the above results yield bolometric magnitudes –10.5 and –9.6 for (a) and (b) respectively, corresponding to stars of ~ 90 and $60M_\odot$. Note that the deconvolved image of star (a) shows a slight elongation in the N–S direction, which suggests that it may consist of more than one component, in which case the estimated mass would of course decrease significantly.

5. Discussion

The early type O stars in N11C tend to form in groups (Paper I). This may be a general trend of massive star formation. Some recent results seem to confirm this impression. The famous R136, the central object of the giant LMC HII region 30 Doradus, which was in recent years subject of intense research, is the best known example. Feitzinger et al. (1980) suggested that the brightest and bluest of the three components, R136a, might be a star of mass 250–1000 $M_\odot$. Cassinelli et al. (1981) from the IUE data concluded that R136a is a single supermassive star of ~ 3000 $M_\odot$ emitting an extremely powerful wind of $10^{-3.5}$ $M_\odot$ yr^{-1} at 3500 km s^{-1}. Today from the works of several workers, especially that of Weigelt et al. (1985), we know that R136a is a dense star cluster. Another example is provided by the star-like η Carinae, which is one of the most luminous stars in our Galaxy. Recently, Weigelt and Ebersberger (1986), using speckle interferometry methods, resolved it into four components. As a third example we can present the most luminous Galactic star, HD 93129A lying at a distance of 3.5 kpc. At about 3" from this blue supergiant of type O3 If* (Walborn, 1973) there is another massive star HD 93129B with spectral type O3 V((f)). Both stars belong to the cluster Trumpler 14 which contains at least two other early O type stars and covers ~ 1'.5 on the sky. At the distance of the LMC HD 93129A and B would merge into one object and the whole cluster would have a size < 6". If Trumpler 14 was placed at the distance of M31, the Andromeda galaxy, the whole cluster would appear as a single star.

The members of the cluster Sk–66°41 probably formed together. The fainter components (c–f) are probably early type O stars, as the formation of low mass stars needs a longer time scale. Such a system may be unstable. However, with the present techniques it is almost impossible to measure the velocities of the members in order to check on the stability of the system.

The results presented in this letter have two main implications for star formation models. In the classical method of star counts for deriving the luminosity function and then the initial mass function (IMF), the sample stars are usually taken from the published catalogues, the majority of which have used low resolution techniques. The possible multiplicity of the sample stars, especially for the upper mass limit, which is dependent on a relatively small number of stars, can significantly alter the shape of the upper part of the IMF.

Several investigators have concluded that the high mass cutoff of the IMF increases with decreasing abundances of heavy elements, as first predicted by Kahn (1975). For example, Vangioni–Flam et al. (1980) found that the number of the most luminous stars increases along the sequence the Milky Way–LMC–SMC–IZw18, the latter being the most metal poor galaxy known. On the contrary, Humphreys (1983) finds that although the SMC and IC 1613 have comparable metallicities, the lowest in the Local Group of galaxies, their brightest blue supergiants have very different luminosities. Moreover, the LMC and the solar neighbourhood have very similar massive star populations, but in the SMC there is an obvious lack of the most massive stars. Further investigation of this problem obviously needs high spatial resolution techniques. Before comparing the number of the most luminous stars in different types of galaxies one should make sure that the sample stars are not multiple.

Another consequence concerns the application of the brightest blue and red supergiants for intergalactic distance determinations. These stars, classified as secondary distance indicators, are used for distances up to $\sim$ 10 Mpc (Humphreys, 1983). The method is based on an absolute luminosity calibration obtained essentially for a sample of Galactic and LMC stars. If a star cluster is mistaken for a single star the apparent magnitude is overestimated by a factor depending on the number and relative brightnesses of the cluster members. This means that we might easily underestimate the distance by a factor 2, leading to larger values for the Hubble constant.

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