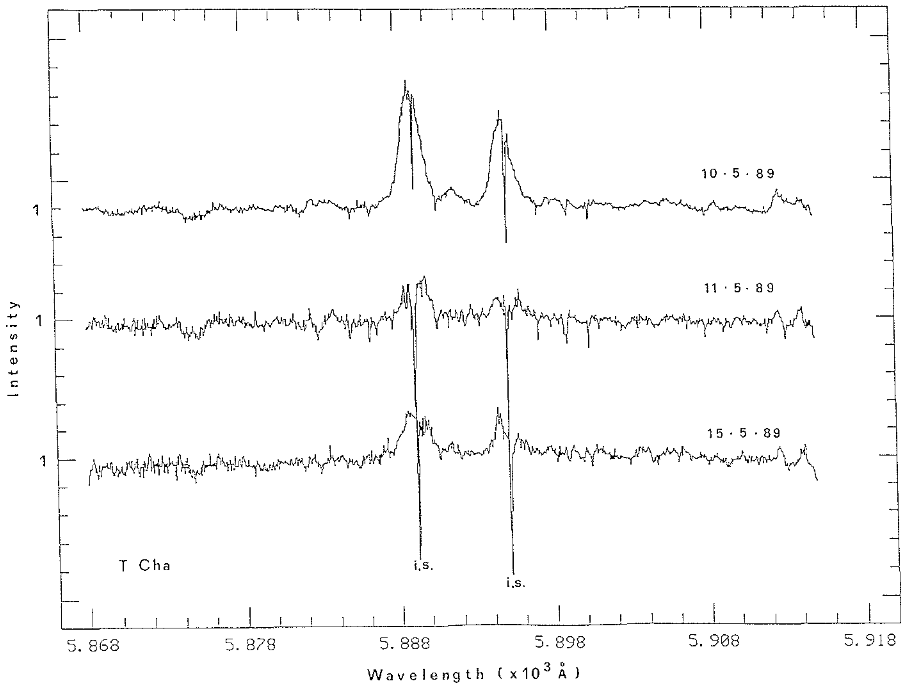

Figure 3: *The ratio between T Cha observed during the nights of May 10, 11 and 15, 1989 and the convolved spectrum of the standard star HD 190248 (G8 V). Radial velocities of blue-shifted and red-shifted components are indicated.*

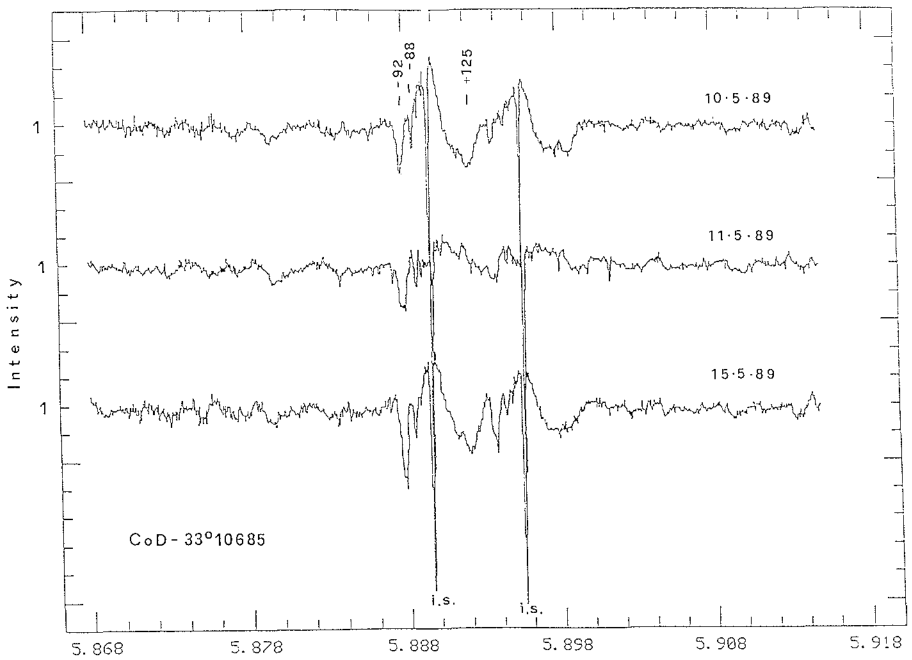

Figure 4: *The ratio between CoD −33° 10685 observed during the nights of May 10, 11 and 15, 1989 and the convolved spectrum of the standard star HD 191408 (K2 V).*

the variations suggest that this occurs near the star surface.

References

Bastian, U., Mundt, R.: 1979, *Astron. Astrophys. Suppl.*, **36,** 57.
Bouvier, J., Bertout, C., Benz, W., and Mayor, M.: 1986, *Astron. Astrophys.*, **165,** 110.
Finkenzeller, U., Basri, G.: 1985, *The Messenger,* **42,** 20.
Glass, I.S., Penston, M.V.: 1974, *Mon. Not. Roy. Astron. Soc.*, **167,** 237.
Herbig, G.H.: 1977, *Ap. J.,* **214,** 747.
Herbig, G.H., Bell, K.R.: 1988, *Lick Obs. Bull.* No. 1111.
Mauder, H., Sosna, F.M.: 1975, *I.B.V.S.,* 1049.
Mundt, R.: 1980, *Ap,. J.,* **280,** 749.
Mundt, R., Bastian, U.: 1980, *Astron. Astrophys. Suppl.* **39,** 245.

STAFF MOVEMENTS

Arrivals

Europe:

DIERCKX, Peter (B), System Manager
KRAUS, Maximilian (D), Mechanical Design Engineer
LIU, X. (RC), Associate
PRAT, Serge (F), Mechanical-Project Engineer
SCHLÖTELBURG, M. (D), Fellow
STIAVELLI, M. (I), Fellow
WANG, L. (RC), Associate
ZUFFANELLI, E. (I), Secretary

Chile:

CARTON, Ph. (F), Optical Technician
GIRAUD, E. (F), Associate
HAINAUT, O. (B), Coopérant

Departures

Europe:

AZIAKOU, P. (F), Administrative Clerk Purchasing
FANG, Y. (RC), Associate
GROENEN, E. (B), Assistant Head of Administration
PONZ, D. (E), Science Applications Programmer

Chile:

BAUERSACHS, W. (D), Senior Mechanical Engineer

Discovery of a Low Mass B[e] Supergiant in the SMC

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1. Introduction

Peculiar emission-line B supergiants are a group of early-type stars with the following typical characteristics: (a) strong Balmer emission lines frequently with P Cygni profiles, (b) permitted and forbidden lines of FeII, [FeII], [OI], etc. and (c) strong infrared excess possibly due to thermal radiation from circumstellar dust. They represent one of the two main groups of early-type emission line stars in the Magellanic Clouds

(MCs). The other group consists of the classical P Cygni stars and their hotter counterparts, Of-like objects. The S Dor variables, also called Hubble-Sandage variables, are the most extreme variables of the P Cygni and Of-like objects (Stahl et al., 1985). The B[e] supergiants are located in the HR diagram in the same region as S Dor variables and represent evolved evolutionary stages of the most luminous and presumably the most massive O stars (Zickgraf et al., 1986).

The B[e] supergiants are very rare objects: only nine stars of this type have been detected in the MCs among which three belong to the SMC: R4, R50 and S18 (Zickgraf et al., 1986; Zickgraf et al., 1989, and references therein). Here we report the discovery of a new B[e] supergiant in the SMC. This star, lying in a relatively isolated region of the wing, roughly 30 minutes south of the H II regions N81 and N83, was originally catalogued as an H α emission line nebula by Henize (1956) – hence its designation N82. In Lindsay's (1961) catalogue of emission-line stars and planetary nebulae N82 is listed as number 495. No detailed observational data have been reported for N82. We came across this star serendipitously in the course of a study of low-excitation compact H II regions in the SMC (Heydari-Malayeri, 1989).

The present investigation is important for several problems concerning the evolutionary stages of massive stars, in particular the interpretation of S Dor or Hubble-Sandage variables, the upper mass cut-off of massive stars, stellar stability, mass loss and circumstellar envelopes. Furthermore, in view of the very small number of B[e] stars in the MCs, especially in the SMC, search for new members is very important in order to improve our knowledge of the physical properties of these stars.

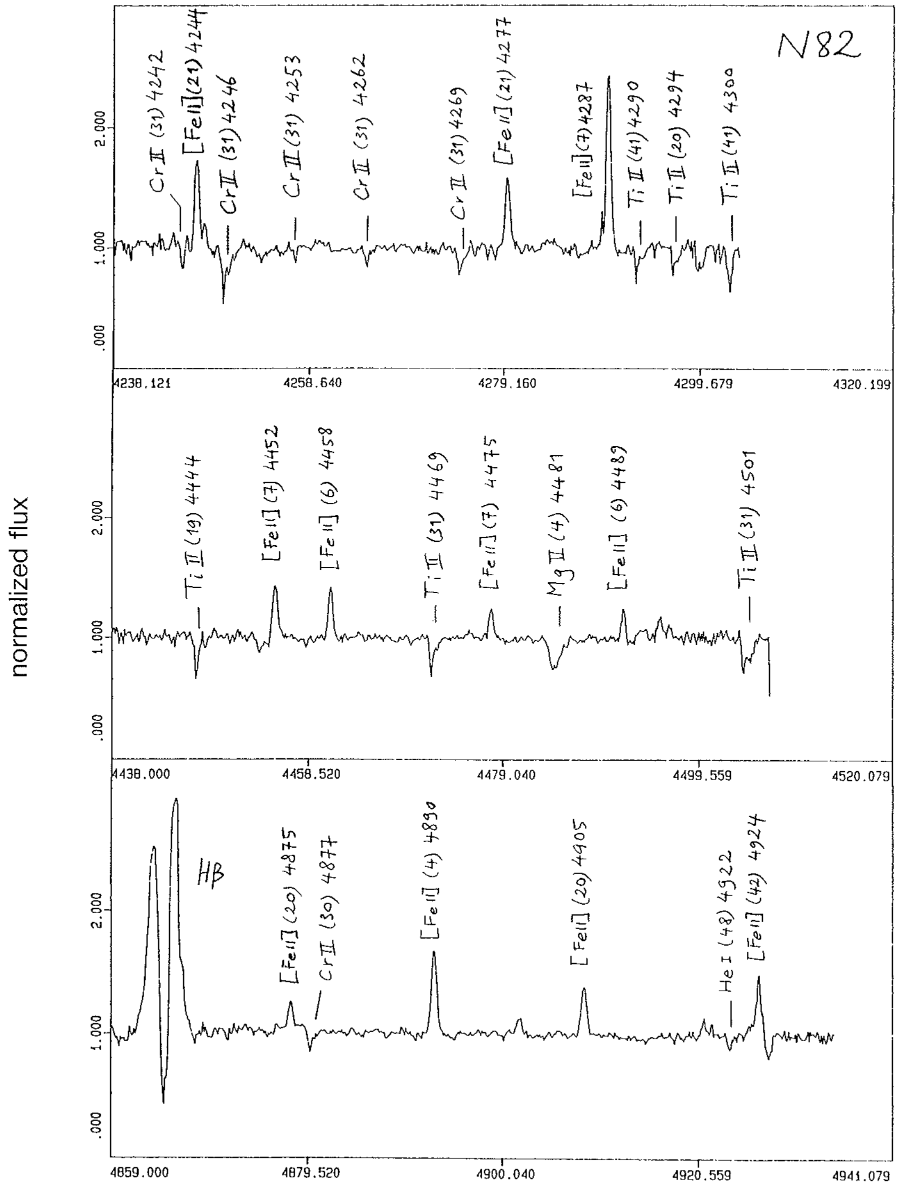

Figure 1: *Three sections of the high dispersion spectrum of N82 obtained using the CASPEC in the blue.*

2. Observations

2.1 High dispersion spectroscopy

N82 was observed with the CASPEC spectrograph attached to the ESO 3.6-m telescope on June 16 and 17, 1989. The 31.6 lines mm^{-1} grating was used with a 300 lines mm^{-1} cross dispersion grating and an f/1.5 camera. The detector was a high resolution CCD chip of type RCA SID 503, 1025 × 640 pixels, each pixel 15 μm. We used two central wavelengths at 4500 Å and H α with exposure times from 30 minutes to 2 hours. The effective spectral ranges were 4000–5020 Å and 6140–7240 Å respectively. The resulting resolution was ~0.3 Å in the 2 × 2 binned mode. Thorium-Argon lamp spectra were used for the wavelength calibrations. Flatfield exposures were also taken. Initially, low dispersion spectra of N82 had been obtained on June 4, 1988, using EFOSC at the 3.6-m telescope (3600–7000 Å).

2.2 Photometry

The single-channel photometer was used at the Cassegrain focus of the ESO 1-m telescope on June 5, 7 and 8 and July 10, 1989 to obtain UBVRI photometry of N82. The magnitudes are as follows: V = 14.25, U-B = −0.13, B-V = 0.12, V-R = 0.21, V-I = 0.20, accurate within ~±0.02 mag. The V magnitude agrees well with the photographic magnitude (14.24) derived by Lindsay (1961). The near IR photometry was obtained on August 12, 1989 using the ESO 2.2-m telescope with its standard IR photometer. The results are: J = 13.42, H = 12.58, K = 12.38 with errors ±0.04 and L > 10.

3. Spectral Characteristics

Using the derived colours, a colour factor of Q = −0.22 was obtained for N82. This corresponds to spectral types B7–B8 (Henden and Kaitchuk, 1982). The presence of strong Balmer emission lines, especially very strong H α, implies a spectral type earlier than A0 (Slettebak, 1986; Jaschek et al., 1988; see below Sect. 5). The spectrum of N82 is typical of B[e] stars. It is very rich in emission lines of singly ionized iron, both forbidden and permitted. Apart from the Balmer hydrogen lines, the [Fe II] lines are the strongest emission lines of the spectrum. The [Fe II] lines (typical FWHMs ~40 km s^{-1}) are much more numerous than FeII lines. There are also a large number of absorption lines of CrII and TiII. Neutral oxygen around N82 is evidenced by the [OI] emission line at 6300 Å. Three sections of the spectrum are displayed in Figure 1. Note the striking similarities with the other SMC B[e] star R50 (Zickgraf et al., 1986, Fig. 8). However, unlike R50, N82 shows no central absorption on FeII lines.

P Cygni profiles of Beals (1950) type III stand out for Hγ, Hβ and Hα Balmer lines. The central absorption dip in all cases is well pronounced. The separation of the longward and shortward components of all the P Cygni profiles for Hγ, Hβ and Hα are 152.6, 146.2 and 104.6 km^{-1} respectively. Hδ does not display a P Cygni profile; it appears as a strong absorption line inside a broad absorption feature.

The radial velocities of the different species were measured with respect to the Sun. The mean radial velocity derived from the [FeII] lines is 204.8 ± 5.6 km s^{-1}. The FeII lines show a similar mean velocity, but the scatter is much larger. These values compare well with the radial velocities of the central absorption dips in Hγ, Hβ and Hα, i.e. 200.7, 207.3 and 201.5 km s^{-1} respectively. The mean radial velocities derived from the absorption lines of CrII and TiII seem to be somewhat higher, 217.5 and 210.2 km s^{-1} respectively.

An interesting feature of N82 is that the absorption lines mostly show an asymmetric two-component profile. The blue component is usually stronger than the red one which shows broad wings (Fig. 1). Some of the absorption lines were deconvolved into their components. For instance, the components of CrII 4246.4 have heliocentric velocities of 237 and 273 km s^{-1}, while those of TiII 4468.5 show velocities of 207 and 250 km s^{-1} respectively.

The spectral type of N82 is quite uncertain since, as for the other MC B[e] supergiants, it is difficult to derive a spectral type from the photospheric lines. The only photospheric lines detected are MgII 4481.1 and HeI 4921.9 Å.

No [NII] lines at 6548,84 are detected in the red CASPEC spectra. Likewise, there is no sign of emission from [OII] λ 3727 or [OIII] λ 5007 in our long slit spectra. This probably means that N82 is not associated with nebulosity as confirmed by images obtained through R and Hα filters.

4. Mass

From a distance modulus of 19.1 we derive an absolute magnitude of $-4.85+A_V$ for N82 which corresponds to supergiants (Humphreys and McElroy, 1984). Assuming two extreme cases, i.e. supergiants of type B0 and B9, we derive colour excesses E(B-V) of 0.35 and 0.12 respectively (Schmidt-Kaler, 1982). From the corresponding bolometric corrections (Humphreys and McElroy, 1984) we obtain two limiting bolometric magnitudes of −8.6 and −5.6. Using the grids of evolutionary models of massive stars with mass loss and overshooting (Maeder and Meynet, 1988), initial masses of ~35 $M_\odot$ and 15 $M_\odot$ are derived for N82. Similarly, when a black body is fitted to the dereddened UBVRI data (Fig. 2) bolometric magnitudes of −6.5 and −5.5 are obtained for B0 and B9 stars respectively, corresponding to masses of ~20 and 10 $M_\odot$. These values should be compared with the masses of the three SMC stars R4, R50 and S18 which have been estimated to be 30–50 $M_\odot$ (Zickgraf et al., 1986; 1989). Consequently, N82 seems to be the lowest mass B[e] star in the SMC. Note that all the B[e] stars of the MCs are classified as B0–B3 supergiants, except R66 which is B8Ia. The lower visual magnitude of N82 with respect to those of R4, R50 and S18 (13.09, 11.56 and 13.31 respectively) is unlikely due to extinction, as N82 lies in the SMC wing; moreover its extinction is comparable with those of the abovementioned stars.

5. Discussion and Conclusions

Many properties of the B[e] supergiants can be understood in terms of a two-component wind model first put forward by Zickgraf et al. (1985) to interpret the characteristics of R126 (M_b = −10.5), considered to be the prototype of B[e] stars in the MCs. The model consists of a cool, dense and slowly expanding disk-like wind component and a hot-line-driven fast polar wind. Accordingly, the emission lines come from the pole-on viewed disk produced by a Be type mass loss from equatorial regions of the stellar atmosphere. The difference between the velocities of FeII and [FeII] is attributed to the differential rotation of the slowly expanding disk. The broad absorption lines of highly ionized species (FeIII, AlIII, SiIV, CIV and NV), detected in the ultraviolet range, originate in the high-velocity polar wind. It will be interesting to observe N 82 in the UV to check for the presence of a "hybrid spectrum". However, note that Waters et al. (1987) using the IRAS far-IR observations to study the characteristics and mass loss ratios of Be stars conclude that very luminous stars with $M_b > -7.8$ to −8.5 cannot form disks due to the high radiation pressure that dominates the winds, and that mass loss due to the Be mechanism is negligible. At lower luminosities, the Be mechanism dominates the mass loss, resulting in enhanced equatorial mass loss.

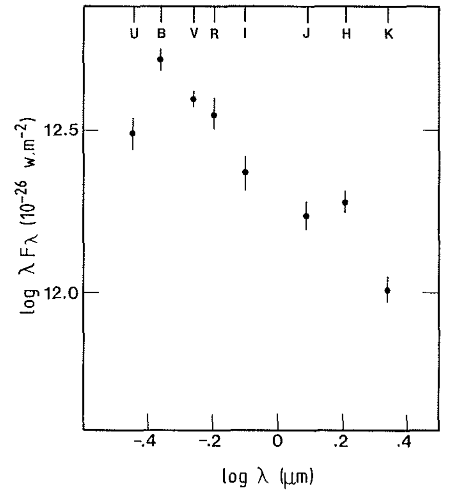

Figure 2: *Continuum energy distribution of N82 deduced from broad band photometry.*

The strong IR excess detected towards the B[e] supergiants in the MCs is interpreted to be due to thermal radiation from circumstellar dust. The B[e] supergiants form a clearly distinct group on the right-hand side of the (J-H)–(H-K) diagram due to their large (H-K) excess (Zickgraf et al., 1986). As far as N82 is concerned, no inference can be drawn on the presence of dust around it, since the object was not detected in the L band. A special feature of N82 is that an important IR excess is detected particularly in the H band (Fig. 3). If this feature is due to dust emission, the dust must have an unlikely extraordinary colour temperature of ~200 K! Therefore, the feature should have another origin, for example emission lines due to Brackett series or a late-type companion. The second hypothesis seems more plausible because the J-H and H-K colours of N82 correspond to late-type stars, especially since no ionized gas is detected towards N82. More observations in the future are needed in order to clear up the IR properties of N82. If the late-type companion is confirmed, N82 would represent the prototype of a new class of B[e] supergiants. Note that R84, an Of-like object and one of the most spectacular emission line stars in the LMC, is known to have a late-type companion classified as an M2 supergiant by Cowley and Hutchings (1978).

Now we argue that N82 is not an Ae or A-type shell star. According to Jaschek et al. (1988), there are very few A-type stars with emission in the Balmer lines. These cases belong to Ae/Be stars and to close binaries. As a rule, emission features in Balmer lines decrease towards later B types. Usually, at B9 only Hα is in emission and Hβ is only seen up to B8. Before A0 the emissions are much stronger than the level of the continuum (see also Slettebak, 1986) whereas for A-type stars no case is known with emission exceeding this level. This is so striking that one may discriminate the Be from Ae stars. P Cygni type profiles are only seen in two very peculiar objects HD31648 and 41511. Moreover no [FeII] emission lines are reported for Ae stars.

Similarly, N82 is probably not a pre-main sequence Herbig Ae/Be star, as it does not meet two of the three membership criteria (Strom et al., 1972): (1) it does not lie in an obscured region, and (2) it does not illuminate fairly bright nebulosity in its immediate vicinity. Moreover, N82 is too bright to be a Herbig Ae/Be star. Strom et al. (1972) give a list of 12 Galactic stars of this type with known distances. If we place these stars in the SMC, their V magnitudes will range from 17 to 22. The brightest one, HD 200775, assumed to lie at 440 pc from the Sun (Whitcomb et al., 1981), may be fainter than 17 if its distance is overestimated.

The two-component absorption feature is probably due to the shell phenomenon. It would probably suggest that non-radial pulsations can enhance the mass flux from the equatorial regions of rapidly rotating Be stars (Waters et al., 1987). This is the first time such a feature is detected in a Magellanic B[e] star.

Zickgraf et al. (1986) concluded that the MC B[e] stars are massive post-main sequence objects of mass $30 \leq M \leq 80\ M_{\odot}$. The present result hints that these stars may originate from lower initial masses. This raises the question: how small can the mass of a B[e] star in the MCs be? If future surveys confirm the presence of low mass B[e] stars in the MCs, this will have important implications for current models of massive star evolution in the Clouds.

In particular, it would support the binary hypothesis for the B[e] supergiants. It should be underlined that two of the three already known B[e] stars in the SMC, R4 and S18, are interpreted to be double systems (Zickgraf et al., 1987; Shore et al., 1987, Zickgraf et al., 1989). It is interesting to consider the case of the LMC P Cygni star R81. Wolf et al. (1981) had estimated a mass of higher than 50 $M_{\odot}$ for this star. Recently, Stahl et al. (1987), owing to several years of almost continuous monitoring with high photometric precision, discovered that R81 is an eclipsing close binary system. The new data reduce the mass of R81 to $\sim 33\ M_{\odot}$.

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References

Beals, C.S.: 1950, *Publ. Dominion Astrophys. Obs.* **9,** 1.
Cowley, A.P., Hutchings, J.B.: 1978, *Pub. Astron. Soc. Pacific* **90,** 636.
Henden, A.A., Kaitchuk, R.H.: 1982, *Astronomical Photometry,* New York, Van Nostrand Reinhold.
Henize, K.G.: 1956, *Astrophys. J. Suppl.* **2,** 315.
Heydari-Malayeri, M.: 1989, *Astron. Astrophys.* submitted.
Humphreys, R.M., McElroy, D.B.: 1984, *Astrophys. J.* **284,** 565.
Jaschek, M., Jaschek, C., Andrillat, Y.: 1988, *Astron. Astrophys. Suppl. Ser.* **72,** 505.
Lindsay, E.M.: 1961, *Astrophys. J.* **66,** 169.
Maeder, A., Meynet, G.: 1987, *Astron. Astrophys. Suppl. Ser.* **76,** 411.
Schmidt-Kaler, T.H.: 1982, in Landolt-Börnstein, New Series Group IV, Vol. 2b, eds. K. Schaifers and H.H. Voigt, Springer, Berlin.
Shore, S.N., Sanduleak, N., Allen, D.A.: 1987, *Astron. Astrophys.* **176,** 59.
Slettebak, A.: 1986, *Publ. Astron. Soc. Pac.* **98,** 867.
Stahl, O., Wolf, B., de Groot, M., Leitherer, C.: 1985, *Astron. Astrophys. Suppl. Ser.* **61,** 237.
Stahl, O., Wolf, B., Zickgraf, F.-J.: 1987, *Astron. Astrophys.* **184,** 193.
Strom, S.E., Strom, K.M., Yost, J.: 1972, *Astrophys. J.* **173,** 353.
Waters, L.B.F.M., Coté, J., Lamers, H.J.G.L.M.: 1987, *Astron. Astrophys.* **185,** 206.
Whitcomb, S.E., Gatley, I., Hildebrand, R.H., Keene, J., Sellgren, K., Werner, M.W.: *Astrophys. J.* **246,** 416.
Wolf, B., Stahl, O., de Groot, M.J.H., Streken, C.: 1981, *Astron. Astrophys.* **99,** 351.
Zickgraf, F.-J., Wolf, B., Stahl, O., Leitherer, C., Klare, G.: 1985, *Astron. Astrophys.,* **143,** 421.
Zickgraf, F.-J., Wolf, B., Stahl, O., Leitherer, C., Appenzeller, I.: 1986, *Astron. Astrophys.* **163,** 119.
Zickgraf, F.J., Wolf, B.: 1987, in *Circumstellar Matter* (eds.) I. Appenzeller, C. Jordan, p. 439.
Zickgraf, F.-J., Wolf, B., Stahl, O., Humphreys, R.M.: 1989, *Astron. Astrophys.* **220,** 206.

CASPEC Observations of the Most Metal-Deficient Main-Sequence Star Currently Known

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The apparent absence of first generation stars with zero or negligible amounts of heavy elements is a long-standing problem in connection with theories of nucleosynthesis in stars and models of galactic chemical evolution. Despite extensive search on objective-prism plates, only two stars are known to have a metal abundance less than 1/1000 of the solar metal abundance, i.e. $[Fe/H] < -3.0$. The first one is G64-12, a main-sequence turnoff star, with $[Fe/H] = -3.5$ (Carney and Peterson 1981). The other one is CD −38°245, a red giant with $[Fe/H] = -4.5$ (Bessell and Norris 1984). Here I briefly report on some CASPEC observations of a main-sequence turnoff star having a similar low metal abundance as CD −38°245. Surprisingly, this new ultra-metal-deficient star is a double-lined spectroscopic binary.

The observations with the Cassegrain Echelle Spectrograph (CASPEC) at the ESO 3.6-m telescope were carried out October 13–17, 1989, under excellent conditions. The sky was clear and the seeing was extremely good. At Cerro Vizcachas the monitor displayed an *average* FWHM of the seeing profile of 0.″66, 0.″49, 0.″61 and 0.″66 on the four nights. At the 3.6-m the seeing was around one arcsec. This gave a high throughput of CASPEC even if the entrance slit was set to a width of 1.″2 only in order to obtain the maximum (two pixel) resolution, R = 35.000, of the instrument.

The aim of the observing programme