HIGH RESOLUTION SPECTROSCOPY OF SIX NEW EXTREME HELIUM STARS

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ABSTRACT. High resolution spectra of six newly discovered extreme helium stars are presented. LSS 5121 is shown to be a spectroscopical twin of the hot extreme helium star HD 160641. A preliminary LTE analysis of LSS 3184 yielded an effective temperature of 22000 K and a surface gravity of log g = 3.2. Four stars form a new subgroup, classified by sharp-lined He I spectra and pronounced O II spectra, and it is conjectured that these lie close to the Eddington limit. The whole group of extreme helium stars apparently is inhomogenous with respect to luminosity to mass ratio and chemical composition.

1. INTRODUCTION

The group of extreme helium stars at present comprises 17 stars. Only four of them were analyzed, model atmosphere techniques being used. The results indicate that the group is inhomogenous with respect to chemical composition (see Heber, these proceedings). It was therefore deemed necessary to analyze all members of the group and an observational campaign was started to secure UV and visual spectra. In the meantime, 12 stars have been observed with IUE (low resolution mode) in the UV and high resolution visual spectra of 16 stars were obtained with the CTIO 4 m and ESO 3.6 m telescopes (see also Drilling and Heber, these proceedings). The UV energy distributions had already been analyzed for effective temperatures (Drilling et al., 1984) which revealed that hot extreme helium stars are rare: only two stars (HD 160641 and BD-9°4395) are hotter than 18000 K. For two other stars (LSE 78 and LS II+33°005), derived effective temperatures are considerably lower than indicated by their intrinsic UBV colours. Four newly discovered stars (LSS 99, LSS 3184, LSS 4357 and LSS 5121) are also intrinsically blue (see Table I). Since UV measurements are not available, we estimated their effective temperature by comparing the dereddened colour index Q to model predictions. Intrinsic colours were calculated from model fluxes as

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described by Heber and Schönberner (1980). The calibration of Matthews and Sandage (1963) was used. The interstellar extinction was derived by comparing the measured B-V to a model prediction. The results (given in Table I) indicate that these stars are hot (T_{eff} > 18000 K) and that some are highly reddened. Owing to the rarity of hot extreme helium stars and the above-mentioned discrepancy for LSE 78 and LS II+33°005, a high resolution study of these six stars appears to be of high priority. Presented here are high resolution spectra taken with the ESO Cassegrain Echelle spectrograph.

TABLE I: Effective temperatures and reddening estimated by comparison of observed and synthetic colours

star	B	B-V	Q	T_{eff} (Q)	E(B-V)
LSS 99	12.99	0.70	- 0.80	18700	0.89
LSS 3184	12.63	0.03	- 0.86	21700	0.26
LSS 4357	13.02	0.41	- 0.80	18700	0.60
LSS 5121	13.57	0.32	- 0.92	28300	0.61
LSE 78	11.28	0.06	- 0.88	23300	0.25
LS II+33°005	10.68	0.14	- 0.84	20200	0.33

2. OBSERVATIONS

The program stars were observed with the Cassegrain Echelle spectrograph (CASPEC) attached to the ESO 3.6 m telescope at La Silla, Chile. An Echelle grating with 52 lines/mm was used and a spectral resolution of 0.25 Å achieved. The spectral range from 3900 Å to 4800 Å was recorded with a CCD detector. The spectrum of LSS 5121 was binned and, thus, the spectral resolution degraded to 0.5 Å. Data reduction proceeded in two steps: first, the raw data were wavelength calibrated and the signal and background of each order extracted with a numerical slit using the Midas Software at ESO, Garching. Since the Echelle orders are well-separated, even in the blue, the background correction was straightforward. The main problem with the data reduction process was the correction for the Echelle blaze function ("ripple correction"). The best results were obtained when standard stars were used to define empirical "ripple functions". Subluminous O stars are well-suited for this purpose since very few absorption lines are present in their spectra (apart from Balmer lines). Empirical "ripple functions" were derived by least square fits of the (almost) line-free Echelle orders. Those orders containing Balmer lines were excluded and, instead, their "ripple functions" were derived from fits of the continuum of the extreme helium star BD-9°4395 which does not show strong Balmer lines. Vice versa, an extreme helium star can be efficiently used as a standard star to reduce Echelle orders containing strong Balmer lines.

3. INDIVIDUAL OBJECTS

3.1. LSS 5121

The high resolution spectrum is almost identical to that of the hot extreme helium star HD 160641 (T_{eff} = 31900 K; Drilling et al., 1984). The spectral range from 4600 Å to 4700 Å for both stars is plotted in Figure 1 demonstrating the strengths of C III and He II lines. The high effective temperature, indicated by the colours, is thus confirmed by the CASPEC spectrum.

3.2. LSS 3184

The spectrum of LSS 3184 is characterized by broad He I absorption lines, similar to those of BD+10°2179. However, their spectra differ considerably as far as the weak lines are concerned. As can be seen from Figure 2, He II, λ 4686 Å, the C III and O II lines are much stronger in LSS 3184 than in BD+10°2179, this pointing to a higher effective temperature of the former. An analysis was started using line-blanketed LTE model atmospheres. In the first step, the gravity, as a function of effective temperature, was determined by matching the line wings of He I λ 4471 Å. The effective temperature was derived from the ionization equilibria of N II/N III and Si II/Si III/Si IV. T_{eff} = 22000 K and log g = 3.2 result. Nitrogen is over-abundant by a factor of about 50. These results are still in the preliminary stage and additional calculations will have to be made to accurately determine the atmospheric parameters. Nevertheless, it is safe to state that LSS 3184 is indubitably as hot as is indicated by its intrinsic colours.

3.3. LSS 99, LSS 4357, LSE 78 and LS II+33°005

The high resolution spectra of these four objects are unique amongst the extreme helium stars: no He II lines are present; the He I lines appear to be as sharp as in the cool extreme helium stars, e.g. LSS 3378 (T_{eff} = 9400 K; Drilling et al., 1984). However, the metal line spectra, as well as the intrinsically blue colours, are not consistent with such a low temperature. Besides the ions (e.g. C II, N II, Al III, Si II/III/IV) usually observed in the hotter extreme helium stars, e.g. HD 124448, the O II line spectrum is well-developed and much stronger than in other extreme helium stars. These absorption line spectra cannot be reproduced from our LTE-model grid (Drilling et al., 1984). We, therefore, conjecture that these stars have very low gravities or, more precisely, very large luminosity to mass ratios not covered by our model grid. If this were true, their L/M ratio would be larger than $10^{4.6}$ $L_\odot/M_\odot$ (upper limit of the model grid). It is then doubtful whether the assumption of plan-parallel geometry (as in our models) would still apply.

The region in the (log T_{eff}, log g)-plane, where the LSS 99, LSS 4357, LS II+33°005 and LSE 78 stars can probably be found, is shown in Figure 3 (hatched area). The dashed lines indicate the approximate

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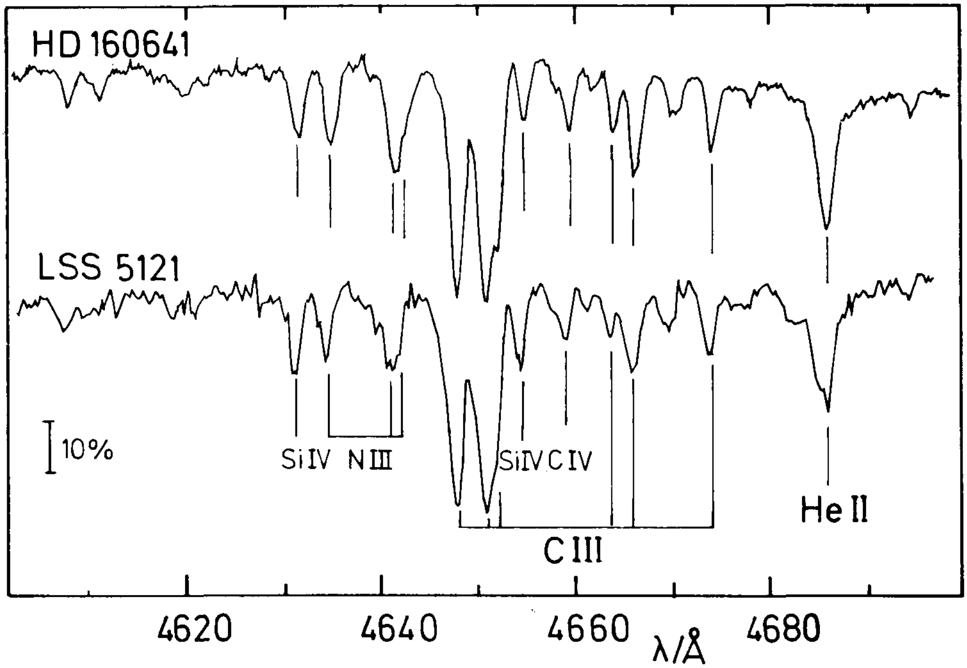

Fig. 1 CASPEC spectra of HD 160641 (top) and LSS 5121 (bottom).

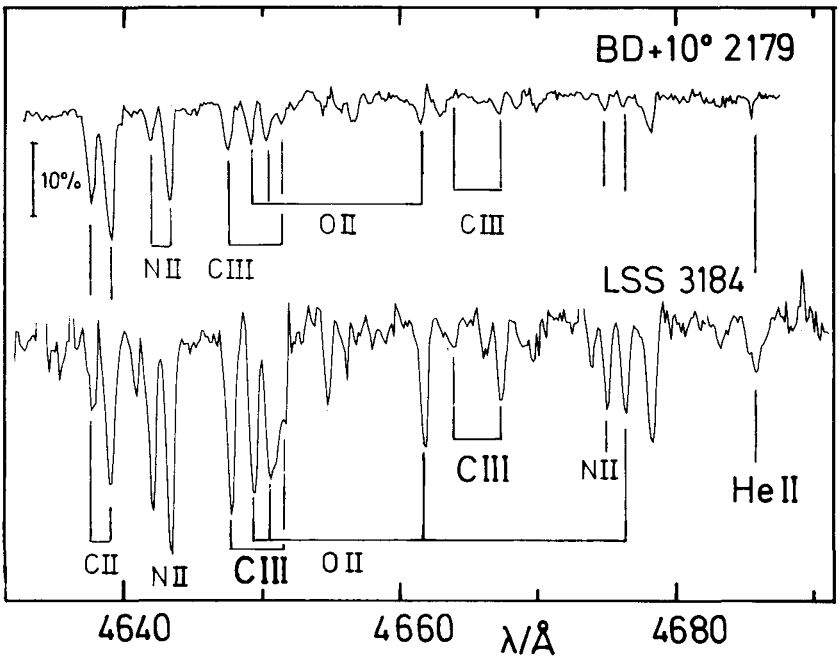

Fig. 2 CASPEC spectra of BD+10°2179 (top) and LSS 3184 (bottom)

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limits of our model grid ($10^{3.6} L_\odot/M_\odot \leq L/M \leq 10^{4.6} L_\odot/M_\odot$). The hatched area is bound by the Eddington limit for pure electron scattering (see Mihalas, 1978, p.554) and the upper model L/M, the temperature being restricted by colour- and UV-temperature estimates.

4. DISCUSSION

In this presentation, high resolution spectra of six intrinsically blue extreme helium stars have been discussed. Two stars, LSS 5121 and LSS 3184, have been shown to have effective temperatures in excess of 20000 K. Only two other extreme helium stars (HD 160641 and BD-9°4395) are known to have such high T_{eff}. Four stars (LSS 99, LSS 4357, LSE 78 and LS II+33°005) apparently form a subgroup classified by sharp-lined He I spectra and pronounced O II spectra and it is conjectured that these star lie close to the Eddington limit (see Fig. 3).

In Figure 3, the positions of LSS 3184 and four previously analyzed extreme helium stars are shown. It can be seen that LSS 3184 has L/M smaller than the previously analyzed extreme helium stars while the stars close to the Eddington limit have a larger L/M ratio.

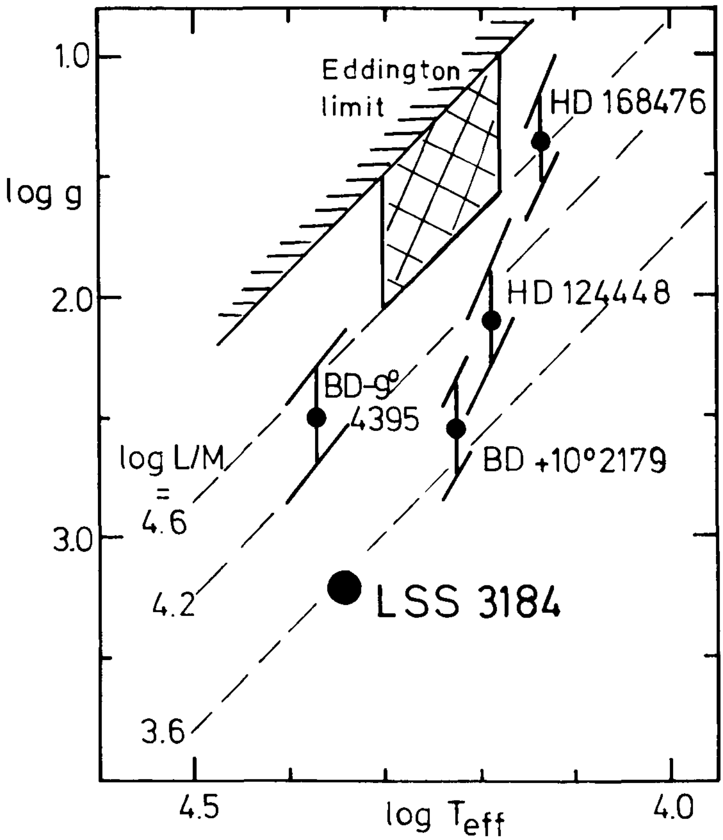

Fig. 3

Position of extreme helium stars in the (log T_{eff}-log g) -plane. The hatched line is the Eddington limit. The hatched area indicates the most likely position of LSS 99, LSS 4357, LSE 78 and LSS II+33°005 (see text). Lines of constant L/M are dashed.

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We conclude, therefore, that there is a larger spread of the luminosity to mass ratio amongst the extreme helium stars than previously assumed.

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