NON - LTE ANALYSIS OF MASSIVE O-STARS

K. P. Simon and R. P. Kudritzki
Institut für Astronomie und Astrophysik der
Ludwig-Maximillians-Universität, München

Abstract: Non-LTE analyses of five very massive O-stars yield effective temperature, gravity and helium abundance of their photospheres. From these results together with photometric data an estimation of the stellar mass is possible. The comparison of the position in the log g - log T_{eff} diagram relative to theoretical evolutionary tracks allows three compatibility-checks: (1) masses, (2) helium-abundance and (3) age of the stars. From these checks it is inferred, that (a) the stars are in an advanced main-sequence-phase, and (b) they have suffered from considerable mass-loss. Furthermore it seems to be likely that (c) mass-loss-rates $\dot{M} = -N \cdot L/c^2$ do not scale with N > 200, (d) the age of the stars in the η Carinae region is less than 2 mio yrs., and (e) HD 93128 is in the background of Tr14.

1. INTRODUCTION

The integral parameters of the stars on the very hot end of the main sequence are rather uncertain due to the weakness of the most important temperature indicator, the neutral helium line 4471 Å . According to Walborn (1971) the absence of this line classifies the spectral type O3. Short evolutionary time scales and the observational fact of the considerably widened upper main sequence, however, make these stars candidates for tests of stellar evolution.

2. OBSERVATIONS

The low noise emulsion IIIaJ renders it possible to detect HeI even in the spectra of O3-stars. So spectrograms of the stars HD 93128, HD93129A, HD93250 and HDE303308(12 Å/mm) have been taken using the Coude spectrograph of the ESO 1.52m telescope in March 1978 and February 1980 (Kudritzki, 1979, Simon et al., 1983). Furthermore spectrograms of HD 66811 (2.6 Å/mm) were secured using the holographic grating (Kudritzki et al., 1983). Calibration was performed with the ESO-ETA spectrograph. The plates were traced with a PDS microdensitometer. We

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found no signs of spectrum variability, not even in the spectra of HD93129A, though this star was reported to be probably spectroscopically variable (Smith, 1968). So we superimposed several spectra of each star in order to improve the signal to noise ratio. For further details of the observations refer to the above cited papers.

3. NON-LTE ANALYSIS AND MODEL FIT

The necessity of the use of non-LTE-methods for model atmospheres of hot stars is established elsewhere(cf Auer and Mihalas,1972). Details of our computations are given in former papers, Kudritzki (1976) and Kudritzki and Simon (1978). The fit is performed by adjusting the profiles of the Balmer-lines and the equivalent width of the HeI line presuming normal helium abundance. This assumption is then verified by inspection of the lines of ionized helium. For ζ Puppis the helium abundance must be increased in order to achieve a satifying fit. H_β and HeII 4686 Å were not used, because their profiles may be affected by atmospheric motions. The masses are evaluated from gravity and radius, the latter was estimated using photometric data. Results are compiled in Table 1.

	log g ±0.15	T_{eff}	X ±0.06	$M / M_\odot$
HD 66811	3.50	42000 ±2000	0.61	40 +40/-20
HD 93128	3.85	48000 ±3000	0.70	30 +30/-15
HD 93129A	3.60	45000 ±3000	0.70	70 +70/-40
HD 93250	3.95	52500 ±2500	0.70	120 +80/-50
HDE303308	3.90	45500 ±3000	0.70	50 +50/-30

Table 1: Results of the non-LTE analyses.(X=mass fraction of hydrogen)

4. DISCUSSION

The analyses reveal that the massive O-stars are significantly cooler than previously assumed: Conti and Frost (1977), f.i., estimated T_{eff} of the O3-stars to be higher than 50000K. The main reason for this misjudgement was the assumption of log g = 4. According to the NLTE-calculations a supergiant of the same spectral type as a main sequence star has a much lower temperature. This is illustrated by figure 1.

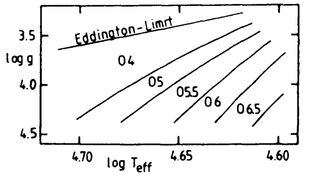

Fig. 1. The regions of the spectral types O4 to O6.5 in the log g - log T_{eff} diagram as obtained from NLTE calculations. The boundaries are given by W_λ(HeI 4471)/W_λ(HeII 4542) = 0.25,0.35,0.50,0.63, and 0.79 .

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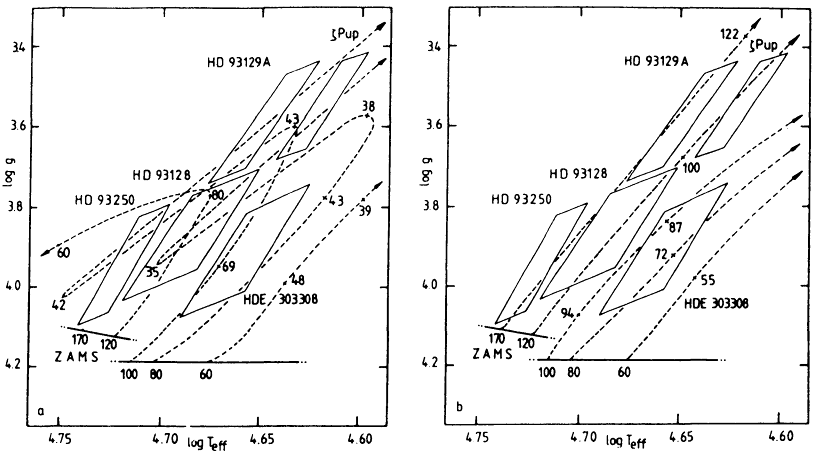

Fig. 2. The positions of the stars in the log g - log T_{eff} diagram and evolutionary tracks. Numbers denote masses in solar units. Right part: 'normal' mass loss rates - left part: 'high' mass loss rates.

The tracks in fig. 2 are adapted from De Loore et al. (1978) and Maeder (1980). The ZAMS is broken due to different input physics in the two sets. With the exception of HD93128 the stars are located on tracks of the appropriate mass in both diagrams. Perhaps HD93128 is in the backgroung of Tr14. Assuming 'normal' mass loss rates ($\dot{M}=-N\cdot L/c^2$, $N\sim 100$), the age of all stars is less than 2 mio. yrs, in case of 'high' rates ($N\sim 300$) the Of-stars must be older than 2 mio. years. This is compatible with estimations of the age of the η-Car-associations from the expansion velocity of the nebula. The theory of stellar evolution predicts an increased helium abundance of the outer layers long before hydrogen exhaustion. This is confirmed for ζ Puppis, where we find X=0.61 (see Tab. 1). From the observed helium abundance we suspect, that the mass loss rates do not scale with $N>200$. Otherwise the Of-stars should exhibit a very helium rich atmosphere. Even in the case of 'normal' mass loss rates this restricts the initial mass of HD93129A to $M_i < 150\ M_\odot$.

REFERENCES

Auer, L.H., Mihalas, D.:1972, Astrophys.J.Suppl.24, pp. 193-246
Conti, P.S., Frost, S.A.:1977, Astrophys. J. 212, pp. 728-742
DeLoore,C.,DeGreve,J.P.,Vanbeveren,D.:1978,Astr.Astroph.67,pp.373-379
Kudritzki,R.P.:1976, Astron. Astrophys. 52, pp. 11-21
Kudritzki,R.P.:1980, Astron. Astrophys. 85, pp. 174-183
Kudritzki,R.P., Simon,K.P.:1978, Astron. Astrophys. 70, pp. 653-663
Kudritzki,R.P., Simon,K.P.,Hamann,W.R.:1983,Astr.Astroph.118.pp.245-254
Maeder,A.:1981,Astron.Astrophys.99,pp.97-107
Simon,K.P.,Jonas,G.,Kudritzki,R.P.,Rahe,J.:83,Astr.Astroph.125,pp.33-44
Smith, L.F.:1968, Monthly Notices Roy. Astron. Soc. 138,pp.109-124
Walborn, N.R.:1971, Astrophys. J. 167, pp. L31-L33

DISCUSSION

Lynas-Gray: Do you predict eventual helium abundances as high as ~ 50 % or more by numbers?

Simon: The abundances are for hydrogen and quoted as mass fractions. The high helium abundances are predicted by the evolutionary calculations and are exhibited by stars in a stage when hydrogen-burning is nearly finished.

Schatzman: Which temperature profile did you use for your non-LTE calculations?

Simon: The temperature stratification of the atmospheres is a result of the self-consistent non-LTE models. We assumed radiation equilibrium.