Wolf-Rayet Phenomena in Massive Stars and Starburst Galaxies
Proceedings IAU Symposium No. 193, ©1999 IAU
K.A. van der Hucht, G. Koenigsberger & P.R.J. Eenens, eds.

Spectroscopic analysis of O-type stars in the upper part of the HR diagram

Artemio Herrero and M.R. (Charo) Villamariz

Instituto de Astrofísica de Canarias, 38200 La Laguna, Tenerife, Spain

Abstract. We present observations and analyses of stars earlier than O6. The analyses are done with NLTE planeparallel, hydrostatic model atmospheres. The effect of *line-blocking* for the determination of the stellar parameters is studied, and it is concluded that it must be taken into account for very hot stars. It is also shown that planeparallel models cannot fit properly the spectra of very hot stars. Thus, we perform new analyses with Unified Model Atmospheres, which result necessary for the reproduction of the spectra from the very upper part of the HR diagram.

1. Introduction

In a spectroscopic analysis of a sample of 24 galactic OB stars, Herrero *et al.* (1992, Paper I) found that some of them showed a surface He-abundance larger than predicted by evolutionary theories, and also that spectroscopic masses derived were systematically lower than those derived from the evolutionary tracks. These were called the *Mass and He discrepancies*, found mainly for supergiants. The study in Paper I was made with NLTE planeparallel hydrostatic models, and was limited to spectral types of O5 and later, because it was found that above 40 000 K He I singlet and triplet lines gave different stellar parameters. Herrero (1994) showed that this was due to the neglect of the so-called *line-blocking*, the UV background opacity due to metal lines, during the line-formation calculations. Thus, we include line-blocking extensively in order to analyse a sample of early stars, from O3 to O6. The results of this led us to make new analyses with a Unified code, that takes into account the wind and the extension of the atmosphere, in order to reproduce properly the early spectra and also to see how sphericity and mass loss can change the former discrepancies.

2. Planeparallel analysis including line-blocking

We calculate a grid of profiles from NLTE planeparallel hydrostatic model atmospheres, ranging from 25 000 to 50 000 K in $T_{\rm eff}$, 3.0 to 4.0 in $\log g$, and 0.06 to 0.30 in ϵ. Model atmospheres were made with ALI, line formation and formal solution were done with line-blocking by DETAIL & SURFACE (references on the codes as in Villamariz & Herrero, these Proceedings). The best fit to the observed profiles of H_γ, H_β, He I 4387, 4471, 4922 Å, and He II 4199, 4541, 4686 Å, give the parameters of the star. No microturbulence needs to be included (see Villamariz & Herrero). With the obtained $T_{\rm eff}$, log g and ϵ, we calculate radii, luminosities, spectroscopic and evolutionary masses as explained in Paper I. Errors are $\pm$ 1500 K in $T_{\rm eff}$, $\pm$ 0.1 dex in $\log g$, and $\pm$ 0.03 in ϵ. See our results in Table 1.

3. Unified analysis

The difficulties in finding a planeparallel fit for the two most luminous stars of the sample are clearly related to sphericity and mass loss. Thus, we use the unified code of Santolaya-Rey *et al.* (1997) to perform new analyses. To the previous parameters we add the stellar radius, terminal velocity and the β exponent of the velocity law. By fitting H_α and H_γ we find the mass loss rate and the new gravity. Why the other parameters are fixed is explained in Herrero *et al.* (1995).

Table 1. For each star, the first row gives planeparallel parameters and the second row gives unified ones. M_s and M_{ev} are the spectroscopic and evolutionary masses.

star	type	$v_r \sin i$ (km s^{-1})	T_{eff} (kK)	log g (cgs)	ϵ $(\frac{N(He)}{N(He)+N(H)})$	log $\dot{M}$ (M$_\odot$ yr^{-1})	M_s (M$_\odot$)	M_{ev} (M$_\odot$)
Cyg OB2 #7	O3 If	105	51.0	3.66	0.12	—	46.2	111.8
		105	51.0	3.81	0.12	–4.90	65.4	111.8
HD 15570	O4 If	105	50.0	3.51	0.15	—	51.1	139.1
		105	50.0	3.76	0.15	–4.77	101.1	139.1
HD 15629	O5 V((f))	90	48.0	3.81	0.09	—	37.5	69.9
		90	48.0	3.91	0.09	–6.13	47.6	69.9
HD 15558	O5 III	120	46.5	3.71	0.07	—	63.8	91.7
		120	46.5	3.86	0.07	–5.40	90.0	91.7
HD 14947	O5 If	140	45.0	3.53	0.15	—	26.5	65.8
		140	45.5	3.68	0.15	–5.26	38.1	65.8
HD 210839	O6 I	250	41.5	3.47	0.25	—	38.7	67.0
		250	41.5	3.57	0.25	–5.50	48.2	67.0
HD 5689	O6	250	40.0	3.57	0.25	—	7.8	30.1
		250	40.0	3.57	0.25	–6.70	7.8	30.1

4. Conclusions

Planeparallel, hydrostatic models cannot fit massive star spectra above 50 000 K, even including *line-blocking.* Line-blocking effects are important for He I singlet lines above 40 000 K, and they only introduce changes in T_{eff} of 1000 to 3000 K. Using unified models, we obtain larger gravities by 0.10–0.25 dex. Sometimes we had difficulties in fitting H_α and H_γ for the same mass loss rate, which produces an uncertainty in its value of a factor of two in the worst cases. All stars but one exhibit mass discrepancy, only reduced by the inclusion of sphericity and mass loss, and some of them are helium enriched.

References

Herrero, A., Kudritzki, R.P., Vílchez, J.M., Kunze, D., Butler, K., Haser, S. 1992, A&A 261, 209 (Paper I)

Herrero, A. 1994, in: D. Vanbeveren, W. van Rensbergen, C. de Loore (eds.), Evolution of Massive Stars: A Confrontation between Theory and Observation, SSR 66, 137

Herrero, A., Kudritzki, R.P., Gabler, R., Vílchez, J.M., Gabler, A. 1995, A&A 297, 556

Santolaya-Rey, A.E., Puls, J., Herrero, A. 1997, A&A 488, 512