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The effect of micro-turbulence in O-type star analyses

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Abstract. We study here the influence of micro-turbulence in the synthesis of H and He lines, in order to quantify its effect on the determination of stellar parameters of O-type stars, in particular on the stellar He abundance. We find that only He I lines and He II λ4686 are considerably affected, the effect being more relevant for models corresponding to supergiant stars. We also find that neglecting micro-turbulence in the analyses of O-type stars introduces deviations in the derived parameters that are within our standard error box. The He content is not or slightly reduced, thus micro-turbulence cannot be responsible for the He-*discrepancy* to all its extent.

1. Introduction

A considerable number of O- and early B-type stars in the sample of Herrero *et al.* (1992) (hereafter Paper I) were found to be He-enriched, when comparing their spectroscopic He-abundances with the ones predicted by standard stellar evolutionary models (the so-called He-*discrepancy*). There has been a lot of work since then to try and explain this. One of the possible explanations, supported by the results of McErlean *et al.* (1998), is that in Paper I micro-turbulence was not taken into account when performing the analyses. However, the former results only refered to early B- and late O-type supergiants, while the Herrero *et al.* sample covered stars from O5 to B0.5 of all luminosity class. Thus we decide to study the behaviour with micro-turbulence of H and He model profiles, the ones used to analyse these spectra, in the parameter range typical from O to early B stars, in order to see how they are affected by it and how the parameters obtained from the analyses can change. Finally, we perform new analyses for four stars, with a fixed value for the micro-turbulence of $15\,\mathrm{km\,s^{-1}}$, to quantify these changes, specially in the He-abundance: $15\,\mathrm{km\,s^{-1}}$ is a suitable value in early stars.

2. Micro-turbulence in H- and He-profiles

We calculate profiles in NLTE planeparallel hydrostatic models with parameters $T_{\rm eff} = 30\,000$–$45\,000\,\mathrm{K}$, $\log g = 3.0$–4.0, and $\epsilon = 0.08$–0.25. We let micro-turbulence change between 0 and $20\,\mathrm{km\,s^{-1}}$. The codes used are ALI (Kunze 1995) and DETAIL & SURFACE (Butler & Giddings 1985). We have included *line-blocking* extensively in the present work; for details see Herrero *et al.* (1999). Micro-turbulence is introduced in DETAIL & SURFACE by adding an extra Doppler-width to the thermal broadening. Hγ, Hβ, He I 4387, 4471, 4922, and He II 4199, 4541, 4686 Å were the lines used for the analyses in Paper I. Of all these, only He I lines and the core of He II λ 4686 are affected by micro-turbulence,

showing the corresponding behaviour of saturated and non-saturated lines, in each case. For the rest of the lines Stark-broadening dominates the profiles and hides the effect of micro-turbulence. Effects are more relevant as $\log g$ decreases, thus supergiants will show the larger changes in the parameters.

3. Analysis with micro-turbulence

Values of micro-turbulence of 10 to 12 $\mathrm{km\,s^{-1}}$ are found for late O-type and early B-type stars (Gies & Lambert 1992), and as we have seen, supergiant spectra are the most sensitive to micro-turbulence, so we decide to analyse two late and two early O-type supergiants with a value for the micro-turbulence of 15 $\mathrm{km\,s^{-1}}$, in order to quantify the changes in their parameters.

Table 1. Analyses with and without micro-turbulence. Parameters are determined with an accuracy of 1 000 K in $T_{\rm eff}$, 0.1 in $\log g$ and 0.03 in ϵ, for a fixed $v_{\rm turb}$.

star	spectral type	$v_{\rm r} \sin i$ ($\mathrm{km\,s^{-1}}$)	$T_{\rm eff}$ (kK)	$\log g$ (cgs)	ϵ $\frac{N(\mathrm{He})}{N(\mathrm{He})+N(\mathrm{H})}$	$v_{\rm turb}$ ($\mathrm{km\,s^{-1}}$)
HD 14947	O5 If	140	45.0	3.50	0.15	0
			45.0	3.45	0.15	15
HD 5689	O6	250	40.0	3.40	0.25	0
			40.0	3.35	0.25	15
HD 18409	O9.7 Ib	160	31.5	3.10	0.11	0
			32.0	3.10	0.09	15
HD 210809	O9 Iab	120	33.5	3.10	0.10	0
			34.5	3.15	0.08	15

4. Conclusions

Only He I model lines and He II λ 4686 Å are considerably affected by the presence of micro-turbulence, thus the models for supergiants are the most sensitive. Our analyses, with a value of the micro-turbulence of 15 $\mathrm{km\,s^{-1}}$ introduce changes in the parameters obtained, but not beyond our standard error box. The He-abundance is lowered by 0.02 in the later type supergiants, earlier types keep the same value. So micro-turbulence cannot explain the He-*discrepancy*, neither for earlier type stars, nor for the very overabundant stars.

References

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