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The mass discrepancy problem in O stars of solar metallicity. Does it still exist?

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Abstract. Using own and literature data for a large sample of O stars in the Milky Way, we investigate the correspondence between their spectroscopic and evolutionary masses, and try to put constraints on various parameters that might influence the estimates of these two quantities.

Keywords. stars: early type, stars: evolution, stars: fundamental parameters

1. Introduction

In its classical form, the so-called *mass discrepancy* refers to the systematic overestimate of evolutionary masses, $M^t_{\rm evol}$, compared to spectroscopically derived masses, $M_{\rm spec}$ (e.g., Herrero *et al.* 1992). While continuous improvements in model atmospheres and model evolutionary calculations have reduced the size of the discrepancy (e.g., Repolust *et al.* 2004), however without eliminating it completely (Mokiem *et al.* 2007; Hohle *et al.* 2010; Massey *et al.* 2012), there are also studies (e.g., Weidner & Vink 2010) which argue that, at least for O stars in the Milky Way, the mass discrepancy problem has been solved.

2. Stellar sample and methodology

Our sample consists of 51 Galactic dwarfs, giants and supergiants, with spectral types ranging from O 3 to O 9.7. Forty one of these are cluster/association members; the rest are field stars. For 31 of the sample stars, we used own determinations of stellar parameters, obtained by means of the latest version of the FASTWIND code (Markova *et al.*, in preparation); for the remaining 20, similar data have been derived by Bouret *et al.* (2012) and Martins *et al.* (2012a,b), employing the CMFGEN code instead.

For all sample stars, $M_{\rm spec}$ were calculated from the effective gravities corrected for centrifugal acceleration, whilst $M^t_{\rm evol}$ were determined by interpolation between available tracks along isochrones, as calculated by Ekström *et al.* (2012) and Brott *et al.* (2011). To put constraints on biases originating from uncertain distances and reddening, in parallel to the classical $\log L/L_\odot - \log T_{\rm eff}$ diagram we also consider a (modified) spectroscopic HRD (sHRD) that is independent of 'observed' stellar radii (for more information, see Markova *et al.* 2014 and Langer & Kudritzki 2014).

3. Results

Our analysis indicates that

i) for objects with $M^{\rm init}_{\rm evol} > 35\,M_\odot$, $M^t_{\rm evol}$ are either systematically lower (Ekström models) or roughly consistent (Brott models) with $M_{\rm spec}$. As $\dot{M}$ scales with $\log L/L_\odot$

(e.g., Vink *et al.* 2000; see also Puls *et al.*, this volume), and as – soon after the ZAMS – the Ekström models with rotation and $M_{\rm evol}^{\rm init} \geqslant 40\,M_\odot$become more luminous than the Brott models of the same $M_{\rm evol}^{\rm init}$ and $T_{\rm eff}$, we suggest that the *negative* mass discrepancy established for the Ekström tracks is most likely related to (unrealistically?) high mass-loss rates implemented in these models. (Warning! The good agreement between $M_{\rm spec}$ and $M_{\rm evol}^t$ read off the Brott tracks does not necessarily mean that the corresponding mass-loss rates are of the right order of magnitude, see next item).

ii) for objects with $M_{\rm evol}^{\rm init} < 35\,M_\odot$, $M_{\rm evol}^t$ tend to be larger than $M_{\rm spec}$. As massive hot stars can develop subsurface convection zones (Cantiello *et al.* 2009), and as they can be also subject to various instabilities, we are tempted to speculate that the neglect of turbulent pressure in FASTWIND and CMFGEN atmospheric models might explain the lower $M_{\rm spec}$ compared to $M_{\rm evol}^t$†. Indeed, one might argue that if our explanation was correct a similar discrepancy should be present (but is not observed) for the more massive stars as well. However, such caveat might be easily solved if also the Brott models over-estimate the mass-loss rates, as already suggested by Markova *et al.* (2014), and as also implied from up-to-date comparisons of theoretical and observed $\dot{M}$ (e.g., Najarro *et al.* 2011; Cohen *et al.* 2014)

iii) while for most sample stars the correspondence between $M_{\rm spec}$ and $M_{\rm evol}^t$ does not significantly depend on the origin of the latter (HRD or sHRD), there are a number of outliers which, for the case of Brott tracks, demonstrate $M_{\rm evol}^t$(sHRD) $>$ $M_{\rm evol}^t$(HRD), by a factor of 1.5 to 1.8. While specific reasons, such as, e.g., close binary evolution or homogeneous evolution caused by rapid rotation, can in principle explain discrepant masses read off the HRD and sHRD (Langer & Kudritzki 2014), it is presently unclear why this discrepancy does not appear in the Ekström tracks.

iv) the established mass discrepancy does not seem to be significantly biased by uncertain stellar radii; the presence of surface magnetic fields, or systematically underestimated $\log g$-values derived by means of the FASTWIND code (for more information, see Massey *et al.* 2013).

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† By including such a turbulent pressure, one would obtain a spectroscopic $\log g$ that is larger by 0.2 dex, for typical parameters and a turbulent speed of 15 km/s.