Massive Stars Near and Far
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ISOSCELES: Grid of stellar atmosphere and hydrodynamic models of massive stars

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Abstract. Spectroscopy can decode the radiation from stars in an appropriate way and derive many properties of different stellar objects. In this work we seek to derive simultaneously stellar and wind parameters of massive stars. To model the data we use the radiative transport code FASTWIND with the hydrodynamic solutions derived using our stationary code HYDWIND as input, instead of the β-law. Then, ISOSCELES, our grid of stellar atmosphere and hydrodynamic models of massive stars, is used to derive the physical properties of the observed spectra through spectral line fittings. This quantitative spectroscopic analysis provide an estimation about the line–force parameters, whose theoretical calculations are complex. In addition, we expect to confirm that the hydrodynamic δ-slow solutions, describe quite reliable the radiation line-driven winds of A and late B supergiant stars and, at the same time, explain disagreements between observational data and theoretical models for the Wind–Momentum Luminosity Relationship (WLR).

Keywords. stars: early-type, stars: atmospheres, stars: mass loss

1. Introduction

ISOSCELES is the first grid of synthetic data for massive stars that involves both, the m-CAK hydrodynamics and the NLTE radiative transport. To produce the grid of synthetic line profiles, we first computed a grid of hydrodynamic wind solutions with our stationary code HYDWIND (Curé 2004). These hydrodynamic wind solutions, based on the CAK theory and its improvements (Castor et al. 1975; Friend & Abbott 1986; Curé 2004; Curé et al. 2011) are used as input in the NLTE radiative transport code FASTWIND (Puls et al. 2005). Each HYDWIND model is described by six parameters: $T_{\rm eff}$, logg, R_*, α, k, and δ. All these models consider, for the optical depth, the boundary condition $\tau = 2/3$, at the stellar surface. In the case of the FASTWIND grid, we calculated a total of 573 433 models. From these models line profiles of H, He, and Si elements were calculated in the optical and infrared range. Also, it is important to notice, that all our models are calculated without stellar rotation.

2. Method and Results

The observational data was pre-processed using the *iacob broad* tool Simón-Díaz & Herrero to derive the projected rotational and macroturbulent speeds. Then, these values were used in our search code to perform the spectral fitting with the purpose to obtain stellar and wind parameters. First, the code reads an input file that contains the information of the observational data, the convolution parameters and (optional) the

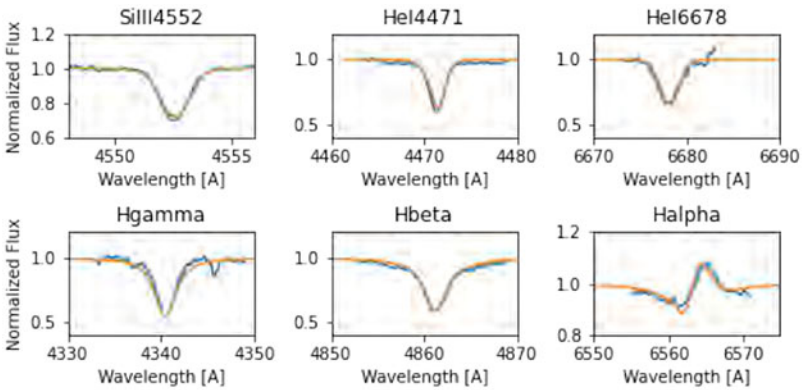

Figure 1. Spectral line fitting for HD 99953. Blue solid line shows the spectra retrieved from Haucke et al. (2018). Orange solid line corresponds to a model with the following parameters: $T_{\rm eff} = 18500$ K, $\log g = 2.4$, $\alpha = 0.45$, $k = 0.25$, $\delta = 0.32$, $v_{\rm micro} = 15$ km/s and $\log \epsilon_{\rm Si} = 7.81$.

type of solution we are searching for, fast or δ-slow. In a second step, it uses multiprocessing tools to search through the grid. The line profiles are rotationally convolved and interpolated with the observed line. Then a χ^2 test is performed. Finally, the code collect all these results and sort them from lower to higher χ^2 values, selecting and returning the one that most resembles to the observational data. By way of example, we present the results for the star HD 99953 considering six line profiles (see Figure 1). We derived stellar parameters similar to the ones obtained by Haucke et al. (2018). Regarding to the wind parameters, they found $\dot{M} = 0.08 \times 10^{-6}\, M_\odot$/year and $v_\infty = 250$ km/s, with $\beta = 2$, for the velocity profile. We obtained line force parameters that corresponds to a δ-slow solution, with the following wind parameters: $\dot{M} = 0.243 \times 10^{-6}\, M_\odot$/year and $v_\infty = 254$ km/s.

3. Conclusions

According to our experience in spectral line fittings, we predict that the models with values of $\beta \gtrsim 1.5$ can be properly reproduced with the hydrodynamic solution δ-slow. Further studies with more stars and analysis of more spectral lines will give us more precise estimates of the stellar and wind parameters, leading us to calibrate the WLR accurately. As future work, we expect to analyze the χ^2 distributions and then use it to compute the uncertainties for each derived parameter, also, we are working in a statistical study of the theoretical line profiles shapes in contrast with stellar and wind parameters from ISOSCELES in order to study the influence of the wind in the observed line profiles.

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