Obtaining stellar parameters using a self-consistent m-CAK procedure

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ABSTRACT

Massive stars present strong stellar winds that are described by the radiation driven wind theory. To properly describe an evolutionary track along the HR Diagram (HRD) we need an accurate determination of the mass-loss rate. For this purpose, we improved the self-consistent procedure developed by Gormaz-Matamala et al. (2019), introducing the stellar spectrum in the online code XTGrid Sandbox to obtain a first approximation of the effective temperature, surface gravity (log g), [He/H] abundance and projected rotation velocity (vsin i). Then, the line-force parameters were calculated by the procedure described in Gormaz-Matamala et al. (2019, code AKD27) where the output from HYDWIND is used as input in NLTE radiative transport code FASTWIND, obtaining a synthetic spectra, and compared our models with the observed (the one we use in Sandbox) and adjust the line profiles fine-tunning the stellar and wind parameters. With that method, we plan to make a grid of models varying the density at the stellar surface of the star as lower boundary condition in HYDWIND and calibrate the Wind Momentum-Luminosity relationship to measure stelar distances.

INTRODUCTION

The study of massive stars in stellar astrophysics is a relevant topic, because the physical conditions that these stars exhibits are some of the most extreme in the universe. These stars loss mass through their stellar winds (up to some 10^{-6} $M_{\odot}$/yr) contributing to the ISM in a relatively short timescale. Besides that, hot stars obey a the so called "Wind Momentum-Luminosity Relationship":

$$\log D_{mom} = x \log(L_*/L_{\odot}) + \log(D_0)\,, \quad (1)$$

where $D_0 = \dot{M} v_{\infty} (R_*/R_{\odot})^{1/2}$.
We want to adjust the (x, D_0) parameters using our self-consistent method (see next section).

From equation (1) we can obtain galactic or extragalactic distances to stars only knowing the stellar and wind parameters, determinate the empiric dependence of the mass-loss rate and the metallicity of O stars in the Local Group (Mokiem et al, 2006, Mokiem et al, 2007), and confirm the line-driven wind theory capability to make reliable predictions.

THE METHOD

In order to get a first approximation of the stellar parameters of the star, the spectrum of the observed star is introduced in the XTGrid Sandbox (TLUSTY code, Németh, P. et al., 2012), from which we use its output: effective temperature, surface gravity (log g), helium abundance and rotational speed. From the stellar parameters obtained by Sandbox, we use them in the hydrodynamic code HYDWIND (Curé, M., 2004) with the line-force parameters (k, α and δ) obtained using Gormaz-Matamala et al. (2019) methodology, obtaining the velocity profile, the mass loss rate ($\dot{M}$) and the terminal velocity (v_{∞}).

Using these obtained parameters (Teff, log g, [He/H], vsini, k, α, δ, $\dot{M}$ and v_{∞}), we make the input for the code FASTWIND (Puls, J. et al., 2005) to obtain a synthetic spectrum of the star and compare it with the observed line-profile. Using FASTWIND, we adjust the microturbulence and macroturbulence velocities and the stellar parameters if necessary. Adjusting the synthetic spectra we obtain the proper stellar and wind parameters, i.e., an accurate mass-loss rate for the star.

RESULTS

We apply our method for three O stars. Stellar and wind parameters are shown in Table 1.

For HD57682 (Figure 1) our fitted lines adjust pretty well in almost all lines except for the Hβ and the Hδ lines.

In the case of HD195592 (Figure 2) it works good for the 4471Å, 4713Å, 4200Å and 4922λÅ lines, but still are some problems with Hβ and the 4686Å line.

The last star, HD192639 (Figure 3), turns to be the most difficult to adjust, presenting a good fit for Hβ, Hδ, 4471Å and 4200Å lines, but problems for the 4686Å line and the absorption part of Hα.

Most of the problem is to find the proper He/H abundance and the line-force parameters. This, finding an accurate value for this parameters should resolve the current discrepancies.

	Parameters adjusted stars		
	HD57682	HD195592	HD192639
$T_{eff}(K)$	35720	29316	33500
log g	4.0	3.2	3.42
$R_*/R_{\odot}$	9.0	21.5	19.8
$M_*/M_{\odot}$	23.5	26.7	37.6
[He/H]	0.085	0.085	0.14
(k, α, δ)	(0.097, 0.613, 0.022)	(0.086, 0.696, 0.260)	(0.073, 0.703, 0.214)
$\dot{M}$ ($M_{\odot}$ yr^{-1})	$1{,}320 \times 10^{-7}$	$3{,}388 \times 10^{-6}$	$3{,}102 \times 10^{-6}$
v_{∞}(km s^{-1})	2938	1074	1628
f_{cl}	1.0	2.0	3.0
v_{rot}(km s^{-1})	10.0	60.0	150.0
v_{micro}(km s^{-1})	15.0	25.0	25.0
v_{macro}(km s^{-1})	30.0	30.0	30.0

Table 1: Adjusted parameters for the three stars from observed spectrum using our method.

DISCUSSION

In this work is shown our method to obtain accurate parameters for hot stars with stellar winds.

We plan with our method to make a grid of models varying the density of the stellar surface in order to obtain models with accurate mass-loss rates and calibrate the Wind Momentum-Luminosity Relationship

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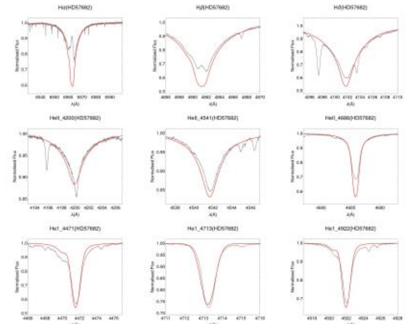

Figure 1: HD57682 spectrum with the best model obtained with v_{micro}=15 km s^-1 and v_{macro}=30 km s^-1

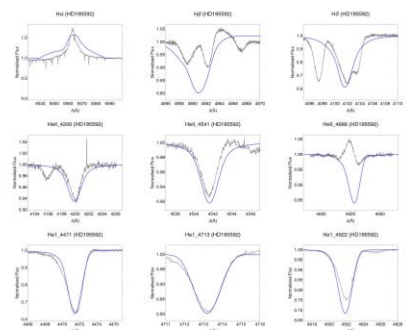

Figure 2: HD195592 spectrum with the best model obtained with v_{micro}=25 km s^-1 and v_{macro}=30 km s^-1

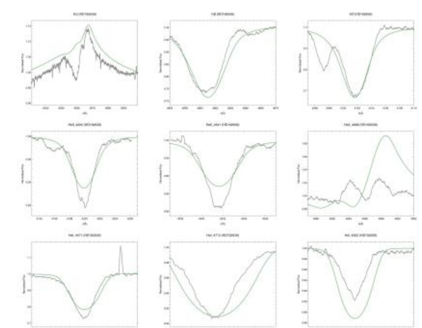

Figure 3: HD192639 spectrum with the best model obtained with v_{micro}=25 km s^-1 and v_{macro}=30 km s^-1