Spectral modelling of OB-type stars and the Wind momentum Luminosity Relationship

Natalia Machuca[1], Michel Curé[1] and Ignacio Araya[2]

[1]Universidad de Valparaíso, [2]Universidad Mayor

Instituto de Física y Astronomía

Universidad de Valparaíso CHILE

Abstract

Our study investigates the Wind Momentum Luminosity Relationship (WLR) which links wind momentum ($D_{mom} \equiv \dot{M} v_\infty \sqrt{R}$) to stellar luminosity (L). We integrate hydrodynamics and NLTE radiative transport calculations to explore this relationship. Using a multiprocessing code, we analyze spectral lines from 100 OB-type stars, employing the ISOSCELES grid developed with `HYDWIND` and `FASTWIND` codes. Our findings reveal a correlation between the solution type and luminosity class of stars, and it propose a method to calibrate distance measurements.

Grid of synthetic spectra: ISOSCELES

ISOSCELES, gr**I**d of **S**tellar atm**OS**phere and hydrodynami**C** mod**EL**s for massiv**E S**tars, is the first grid of synthetic data for massive stars that involve both, the m-CAK hydrodynamics (instead of the generally used β-law) and the NLTE radiative transport. ISOSCELES has been set up to cover the complete parameter space of O-, B- and A-type stars.

ISOSCELES

Free access to models in this QR code.

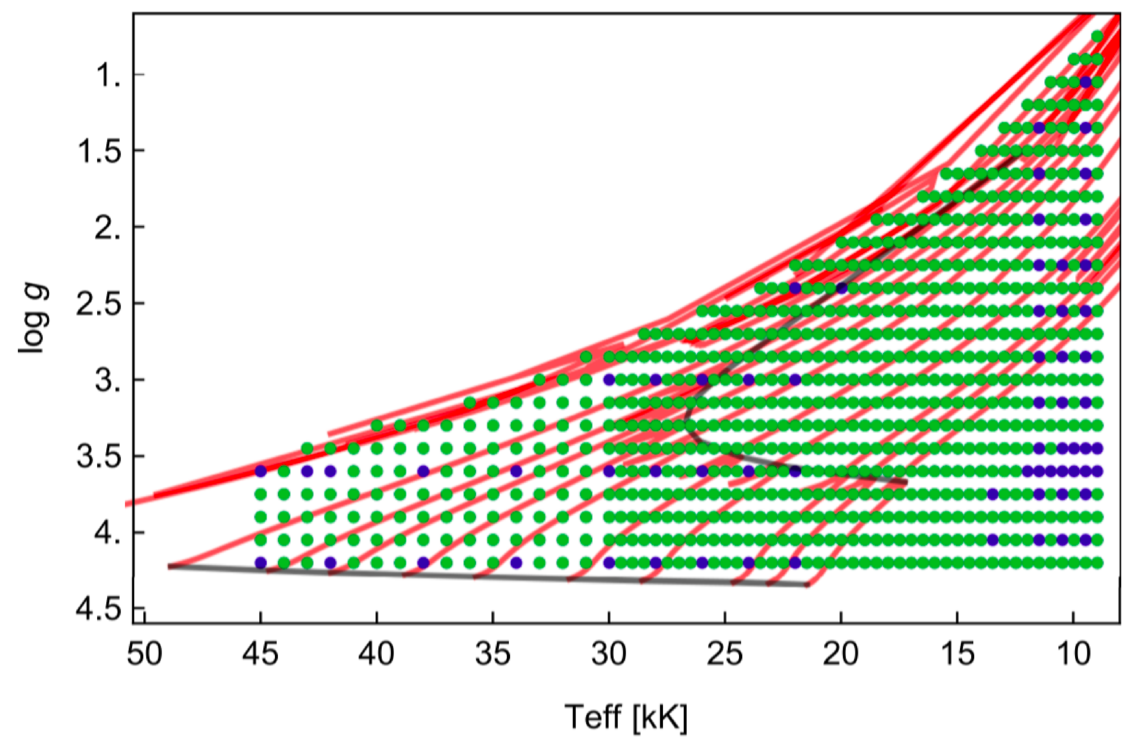

Figure 1. Coverage of the grid in the $T_{eff} - log(g)$ plane. Red lines are the evolutionary tracks of massive stars above 7 $M_\odot$. Blue dots are models discarded due to a lack of convergence to a solution. ***Green dots correspond to converged models in `FASTWIND` and `HYDWIND`.***

Observations

Spectra of 100 stars were used for the first estimation of the WLR. IACOB and ESO-UVES are open databases. CASLEO data was obtained in collaboration with the group of La Plata.

IACOB	**MS**	**Giants**	**Supergiants**
B-type	18	17	10
O-type	11	7	10
ESO-UVES	**MS**	**Giants**	**Supergiants**
B-type	0	0	15
CASLEO	**MS**	**Giants**	**Supergiants**
B-type	0	4	8

Methodology

1. Determine the rotational parameters **vsin*i*** and $\mathbf{v_{macro}}$ with the *iacob_broad* tool *(Simón-Díaz & Herrero, 2014)*.
2. Perform rotational and instrumental convolution. Then, interpolation.
3. Employ **multiprocessing** to conduct a χ^2 **test** to compare observed and synthetic spectra following the expression:

$$\chi^2 = \frac{1}{n_{lines}} \sum_{j}^{n_{lines}} SNR_j \sum_{i}^{n_\nu} \frac{(y_{obs} - y_{ij})^2}{y_{ij}},$$

4. Export stellar and wind parameters including $\mathbf{D_{mom}}$ and **Luminosity**.

Results

Wind momentum depends on the mass-loss rates, terminal velocity and radius of the star as shown in the *y-axis*. With this, we defined the WLR as $\log(D_{mom}) = x \log(L/L_\odot) + D_0$.

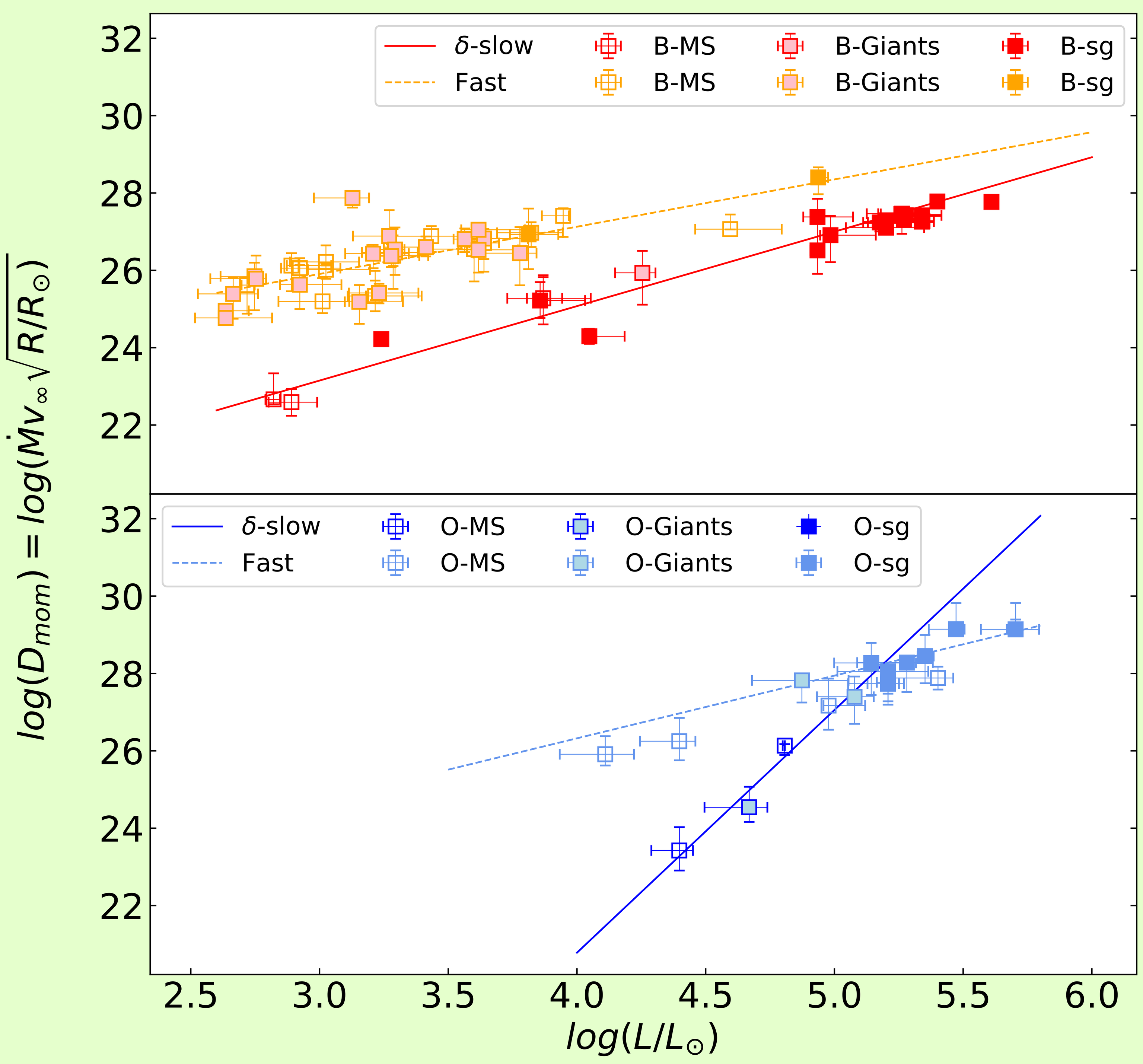

Figure 2. WLR for O and B-type stars. Dashed lines are linear fits for both hydrodynamical solutions. Filling styles represent different luminosity classes. Values of the WLR found for B-type stars are $x = 1.92 \pm 0.14$ and $D_0 = 17.37 \pm 0.65$ for δ-slow solutions and $x = 1.22 \pm 0.17$ and $D_0 = 22.23 \pm 0.58$ for fast solutions. For O-type stars, these values are $x = 6.27 \pm 1.85$ and $D_0 = -4.31 \pm 8.57$ for δ-slow solutions and $x = 2.07 \pm 0.20$ and $D_0 = 17.23 \pm 1.07$ for fast solutions.

Conclusions and Future work

- For the WLR we found a strong dependency on the type of solution and luminosity class which could lead to a potential **estimation of distance with purely spectroscopic analysis**.
- **For B-supergiants we found that 94% of these stars present a δ-slow solution**.
- O-type stars exhibit a complex relation to the luminosity class, suggesting a new theoretical model of their wind such as the **weak wind** phenomena.
- Future work will include modelling UV lines and LMC data to study the dependence of the WLR on metallicity.

Modelling Examples

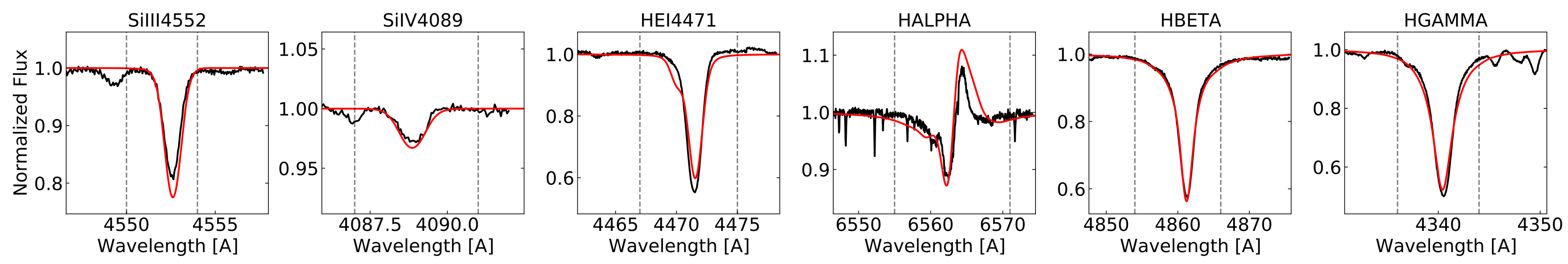

Figure 3 (Top) Modelling of Blue Supergiant star HD79186 (B5 Ia). Photospheric lines (SiIII 4552, SiIV 4089 and HeI 4771) show a good agreement with the model and with the expected stellar parameters (Teff = 18000 K, log(g) = 2.4), while wind parameters ($\alpha = 0.53$, $k = 0.15$, $\delta = 0.34$) properly model the hydrogen lines Hα, Hβ, Hγ.

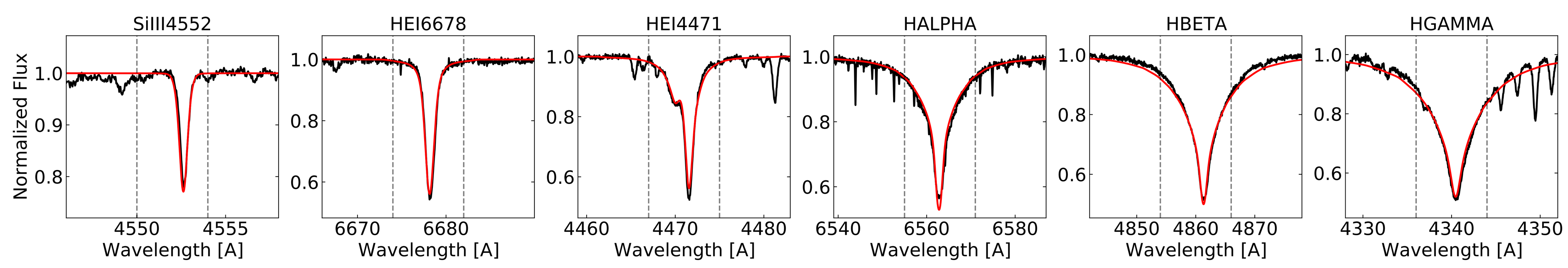

Figure 3 (Bottom) Modelling of MS star HD36512 (O9.7 V). Photospheric lines (SiIII 4552, HeI 4771 and HeI 6678) show a good agreement with the model and with the expected stellar parameters (Teff = 31000 K, log(g) = 4.2), while wind parameters ($\alpha = 0.55$, $k = 0.2$, $\delta = 0.2$) properly model the hydrogen lines Hα, Hβ, Hγ.

Acknowledgement

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