Quantitative spectroscopic analyses in the IACOB project: A distance independent test of the Wind-momentum Luminosity Relationship

ghulgado@iac.es

Gonzalo Holgado Alijo[1,2], Sergio Simón-Díaz[1,2], Artemio Herrero[1,2], Joachim Puls[3]

1: Instituto de Astrofísica de Canarias, E-38200 La Laguna, Tenerife, Spain.
2: Departamento de Astrofísica, Univ. de La Laguna, E-38205 La Laguna, Tenerife, Spain.
3: LMU Munich, Universitätssternwarte, Scheinerstr. 1, D-81679 München, Germany.

Abstract + Conclusions

We have determined atmospheric and wind parameters for **244 Galactic O-type stars** targeted by the IACOB [1] and OWN [2] high resolution spectroscopic surveys. In this poster, we concentrate on results from the study of the **stellar wind properties** of the sample.

⇛We propose two different ways to evaluate our results with respect to previous theoretical and empirical studies, using spectroscopic parameters alone (i.e. no information about distances is needed)

⇛Both ways yield highly consistent results, and agree well with the theory of radiatively driven winds

Wind-momentum Luminosity Relationship (WLR)

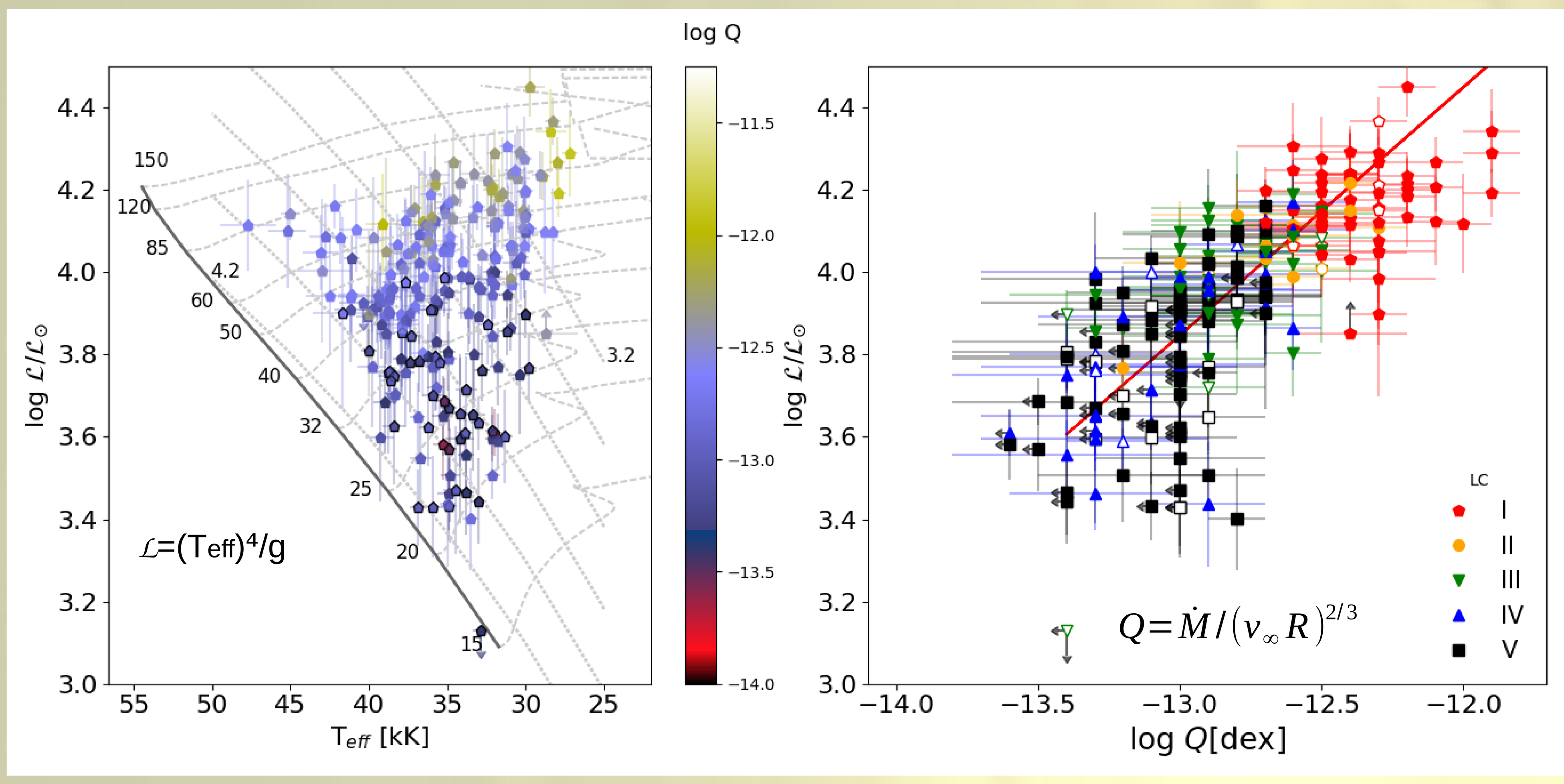
The theory of radiatively driven winds (based on [8]) predicts a **relationship between the stellar wind momentum** and the stellar **luminosity** [3,4]: $\log D_{mom} = x \log L/L_o + D_0 \,;\, D_{mom} = \dot{M}\, v_\infty\, R^{1/2} \quad [A]$

At present, **we lack** accurate information about **distances (and hence R, L, M, and Ṁ)** for most stars in our sample. This limits the possibility to compare our results with those from theory and literature using the conventional WLR.

We propose an **alternative way to compare observational results and predictions by the theory of radiatively driven winds** using only parameters obtained from the spectroscopic analysis of optical spectra.

Spectroscopic approach to the WLR

Figure 1: *(Left)* Distribution of the wind-strength parameter, Q, in the spectroscopic HR diagram [5]. Non-rotating evolutionary tracks (and ZAMS) from the GENEVA group [6,7] in the background. (Right) log Q vs. log $\mathcal{L}$. Colors separate stars with different luminosity classes. The solid line represents the linear regression to the data (excluding binaries -- open symbols -- and stars for which only upper/lower limits could be obtained -- arrows).



By replacing the two spectroscopic parameters (Q, $\mathcal{L}$) into the WLR obtain:

$$\log Q = x \log \mathcal{L}/\mathcal{L}o + \frac{3}{4}\log\left(\frac{M}{R}\right) + f(x) \quad [B]$$

From the slope of our linear regression, including errors, we are able to obtain the parameter *x,* corresponding to 1/α' (with α' the slope of the line-strength distribution function, corrected for ionization effects [10]). A variety of empirical and theoretical studies of the WLR in the literature agree to a range of x ≈ 1.51 − 2.18 [9]. Our result, ***x* = 1.68±0.18**, is in agreement with studies providing lower values of x, hence higher values of α', **α' ≈ 0.59±0.06**. Our result even match studies made with UV spectra including clumping corrected values [10].

Regarding the current paradigm, this result implies that the ratio between the acceleration coming from optical thick lines and all lines is very similar to theoretically expected [3,11].

Note: See [12] for the complete description of Eq. B.

A previous similar test with B Supergiants

Markova et al. 2008 (M08) [13] presented an analogous work to study the theoretically suggested bi-stability jump of mass loss [3], using a sample of Galactic B Supergiants (B Sgs). With alike distance limitations to ours, they define a new, distance-independent parameter Q' as:

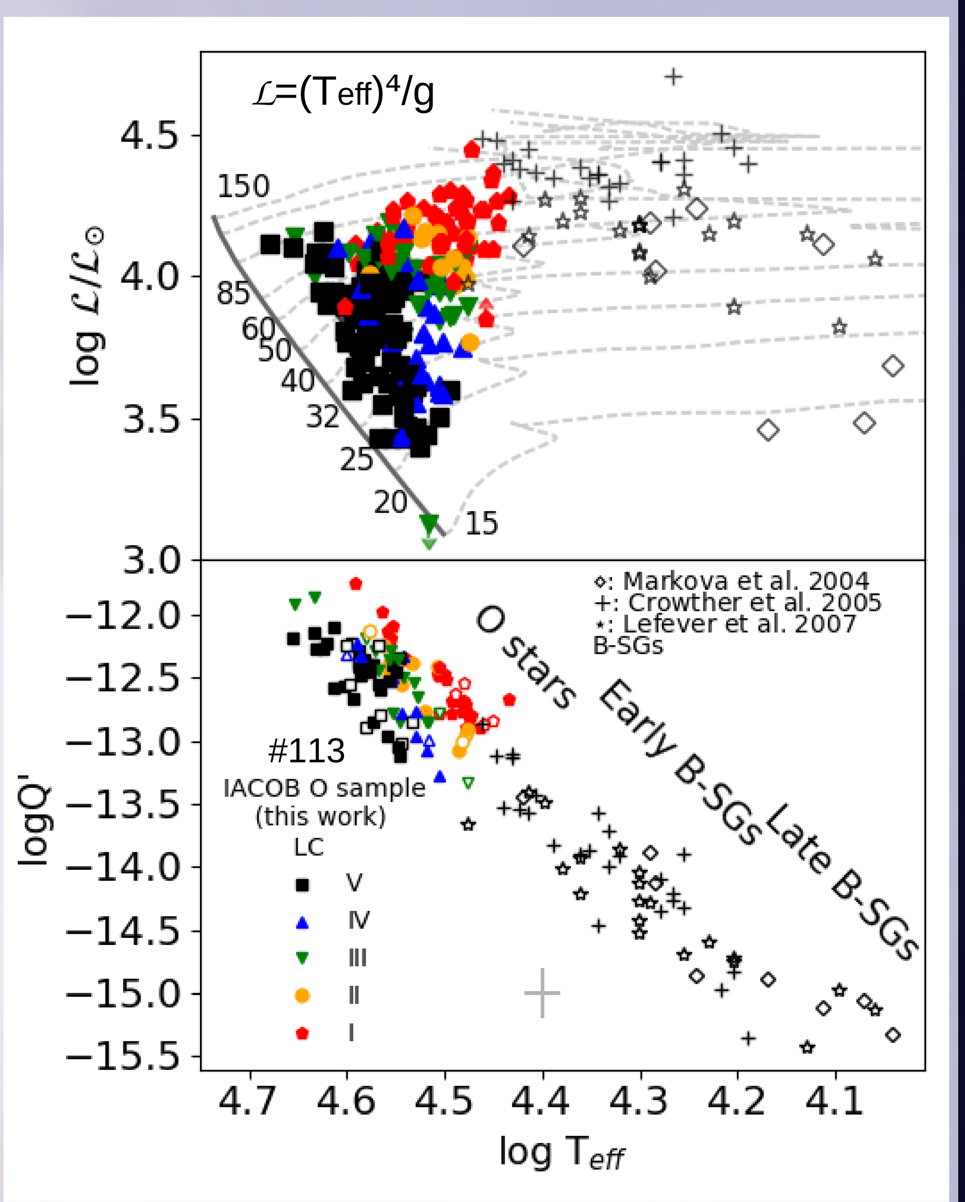
$$Q' = Q\, g_{eff}(v_\infty)^{1/2} ;\, g_{eff} = g(1-\Gamma)$$

to obtain, via the WLR, a relationship with T_{eff}:

$$\log Q' = 4x \log T_{eff} + f'(x)$$

When plotted, this relationship did not show the expected discontinuous behavior. Below, we display it again, including those stars in our O sample with available v_∞.

Figure 2: *(Top)* spectroscopic HR diagram including the B Sgs used in M08 and our sample of O-type stars. *(Bottom)* log Q' vs log T_{eff} diagram presented in M08 (Fig. 13), including both samples. The O stars continue the trend present in the B Sgs domain. The later B Sgs appear to be separated from the general trend, but more data is required to assure the discontinuity.



The slope of the linear regression to the whole sample of O stars and B Sgs provides us with the parameter ***x* = 1.68±0.05**. This value is in perfect agreement with our previous determination using the log Q vs log $\mathcal{L}$ diagram, and marginally consistent with the results obtained in M08 for the B Sgs alone.

Sample and methods

Figures 1 and 2 are based on results obtained from the **quantitative spectroscopic analyses** of the whole sample of O stars in the IACOB+OWN databases (excluding spectroscopic binaries and peculiar objects e.g. magnetic and Oe stars). To this end, we used the IACOB-GBAT (grid based automatized tool, [14]) and a grid of **unclumped** FASTWIND [15] models.

Since we concentrate on the optical range, information about the stellar wind is mainly obtained from the **Hα/HeII4686 diagnostic lines** and condensed in the wind-strength parameter, $Q = \dot{M}/(v_\infty R)^{2/3}$

Words of caution

1.- The effect of using unclumped models is masking the actual values of log Q in the most luminous stars of our sample, expected to suffer more from the effect of micro-clumping.

2.- Compared to the WLR (Eq. A), a larger scatter is expected in our log Q-log $\mathcal{L}$ relation, due to the (weak) dependence of the second and third terms (rhs of Eq. B) on M and R.

Summary and future prospects

We studied the **wind properties** of a sample of 244 Galactic O-type stars, using results from a **purely optical spectroscopic analysis alone,** without the need of information about distances or the UV ranges. The results presented in this poster have two immediate applications:

⇛The empirical assessment of the validity of the theory of radiatively-driven winds in the O-star domain

⇛The construction of empirical calibrations allowing to better constrain the expected range of wind-strength parameter Q for Galactic stars, as a function of T_{eff} and log *g*. This will help to optimize the number of models used to build model grids.

Note:The imminent information about distances to these stars as provided by the **Gaia** mission [16] will allow us to independently construct the **WLR,** and hence to check the validity of both relationships in either way.

Bibliography

[1] Simón-Díaz, S., et al .2015, arXiv:1504.04257
[2] Barbá, R. H., et al. 2010, RMxAA-CS, 38, 30
[3] Vink, J. S., et al. 2000, A&A, 362, 295
[4] Kudritzki, R.-P., & Puls, J. 2000, ARA&A, 38, 613
[5] Langer, N., & Kudritzki, R. P. 2014, A&A, 564, A52
[6] Ekström, S., et al. 2012, A&A, 537, A14
[7] Georgy, C., et al. 2013, VizieR Online Data Cat., 355
[8] Castor JI, Abbott DC, Klein RI. 1975. Ap. J. 195:157
[9] Herrero, A., et al. 2002, A&A, 396, 949
[10] Mokiem, M. R., et al. 2007, A&A, 473, 603
[11] Puls, J., et al. 2000, A&AS, 141, 23
[12] Holgado, G. et al. 2017, in prep.
[13] Markova, N. et al. 2008, A&A, 478, 823
[14] Sabín-Sanjulián, C., et al. 2014, A&A, 564, A39
[15] Puls, J., et al. 2005, A&A, 435, 669
[16] Gaia Collaboration et al.,2016a, Gaia DR1.

The IACOB project