Massive Stars Near and Far
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Dependence of Wolf-Rayet wind clumping on the surface temperature

André-Nicolas Chené[1], Nicole St-Louis[2], Guillaume Lenoir-Craig[2], Anthony F. J. Moffat[2] and Kenneth Gayley[3]

[1]Gemini Observatory/NSF's NOIRLab, 670 N. A'ohoku Place, Hilo, Hawai'i, 96720, USA
email: andrenicolas.chene@gmail.com

[2]Centre de Recherche en Astrophysique du Québec, Département de physique, Université de Montréal, Complexe des Sciences, Montréal, QC H2V 0B3, Canada

[3]Department of Physics and Astronomy, University of Iowa, Iowa City, IA 52242, USA

Abstract. We present our measurements of the amplitude of photometric and spectroscopic variability due to clumping in the wind of Wolf-Rayet (WR) stars. Photometric variability was assessed using *TESS* light-curves, while spectroscopic variations were obtained from almost 20 years of monitoring of nearly 100 classical (presumably single) stars. Our results show an apparent dependence of the variability amplitude with the stars' surface temperature and/or terminal velocity. Our interpretation is that it supports the idea that the dominating driver of the clumps in WR winds is a sub-surface convection region.

Keywords. stars: Wolf-Rayet, stars: mass loss, techniques: photometric, techniques: spectroscopic

1. Introduction

The discovery more than 35 years ago of stochastic clumps in the winds of a few Wolf-Rayet (WR) stars led to the current evidence that most if not all hot-star winds are pervaded by hierarchies of thousands of small, randomly varying clumps. This fundamental discovery has had a profound effect, such as the necessary reduction in the estimated mass-loss rates by a factor 2-5, which in turn affects the whole evolutionary history of massive stars. But the question of the origin of these structures remains uncertain and controversial.

The presence of clumps in WR winds leads to photometric, spectroscopic and polarimetric variability. In this work, we measured the amplitude of that variability for a large number of WR stars using *TESS* light-curves and spectra from various ground-based observatories.

2. Methods and results

From the *TESS* light-curves, we measure the amplitude of variability, α_0. It is obtained from a fit of the "amplitude spectrum" (equivalent to a periodogram, Lenoir-Craig et al. 2022). In spectroscopy, we measure $\sigma(\%)$, the amplitude of line profile variations expressed as a percent of the line intensity (Chené et al. 2020). It is obtained from a modified Temporal Variance Spectrum. The fundamental parameters of the WR stars, such as T_{eff} and $v_{\rm inf}$, were taken directly from the work of Hamann et al. (2019) and

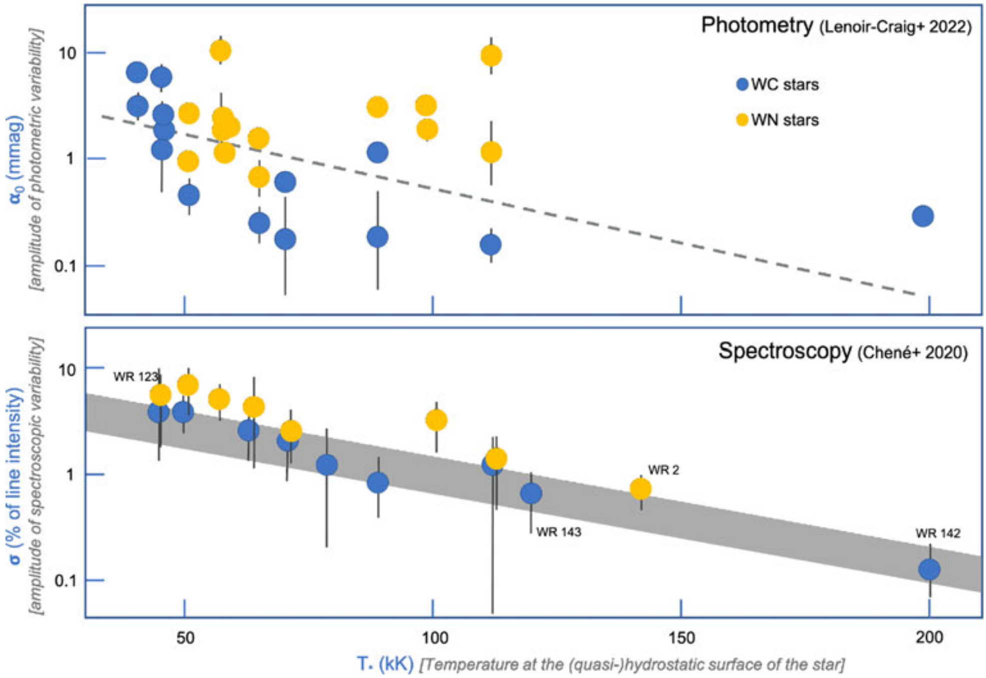

Figure 1. Amplitude of the photometric (*top*) and spectroscopic (*bottom*) wind variability for around 100 WR stars. The spectral types WN and WC are plotted in yellow and blue, respectively. In the bottom panel, stars with the same T_{eff} were grouped a single point.

Sander et al. (2019). Figure 1 shows our results. Both the photometric and spectroscopic amplitudes show a decline with increasing surface temperature (T_{eff}). Interestingly, that same decline is observed when the terminal velocity is used instead of T_{eff}. The same behaviour was also observed in polarimetry by Robert & Moffat (1989). That is in contradiction with the prediction that the inherently unstable nature of radiative line-driving should increase in hotter, faster winds.

3. Conclusions

Our results support the idea that a subsurface convection region is present in hot, massive stars, and is the main origin of wind clumps (Cantiello et al. 2009). It could also have many implications in our understanding of wind clumping, and on future works in atmosphere modeling. This poster opened the discussion with Nicolas Moens and Luka Poniatowski from KU Leuven who published their first 3D radiation-hydrodynamic simulations of WR winds (Moens et al. 2022). The plan is to expand the model to wider radii and extract realistic observables.

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