Massive Stars Near and Far
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A search for correlations between Wolf-Rayet stochastic wind variability and stellar parameters

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Abstract. We present the results of our analysis of 122 light-curves from 50 Wolf-Rayet (WR) stars using a red+white noise analysis, where we compare the fitted red noise features with stellar parameters to assess the presence of correlations with stellar parameters. A significant correlation between the amplitude of variability α_0 and v_∞ was found for the whole sample, along with several other correlations satisfying the Spearman-Rank $p < 0.001$ criterion for both He-burning and WNh stars. Our results are compatible with several plausible processes that can have an influence on the level of variability in the winds of these stars, including a subsurface convection zone and core-generated internal gravity waves.

Keywords. stars: Wolf-Rayet, stars: fundamental parameters, stars: variables, stars: interiors

1. Introduction

Like the winds of their O-star progenitors, Wolf-Rayet (WR) winds are radiatively driven and susceptible to various instabilities that ultimately lead to the formation of small-scale regions of higher density and lower velocity referred to as "clumps". While moving away from the star, these clumps create stochastic photometric, spectroscopic and polarimetric variability. In this work, we analyzed the amplitude of the temporal variability observed in 122 photometric datasets from 50 WR stars, including 36 classical He-burning stars (cWR) and 14 WNh stars from the MOST (Walker et al. 2003), BRITE-Constellation (Weiss et al. 2014) and TESS (Ricker et al. 2015) satellites, and search for the presence of correlations with various stellar parameters.

2. Methods and results

We characterize the amplitude of variability by fitting a semi-Lorentzian model with both a red and white noise component, following the same methodology presented in Bowman et al. (2019). The fitted red noise parameters are α_0, representing the amplitude of the frequency-dependent red noise in the limit of zero frequency, ν_{char} the characteristic frequency of the variability and γ corresponding to the logarithmic amplitude gradient.

The wind and stellar parameters were taken from Hamann et al. (2019) for WN stars and Sander et al. (2019) for WC and WO stars. Using an F-test comparing the χ^2 of the trend with a linear flat-model, we found a statistically significant negative trend between α_0 and v_∞ for both cWR and WNh stars as shown in Figure 1.

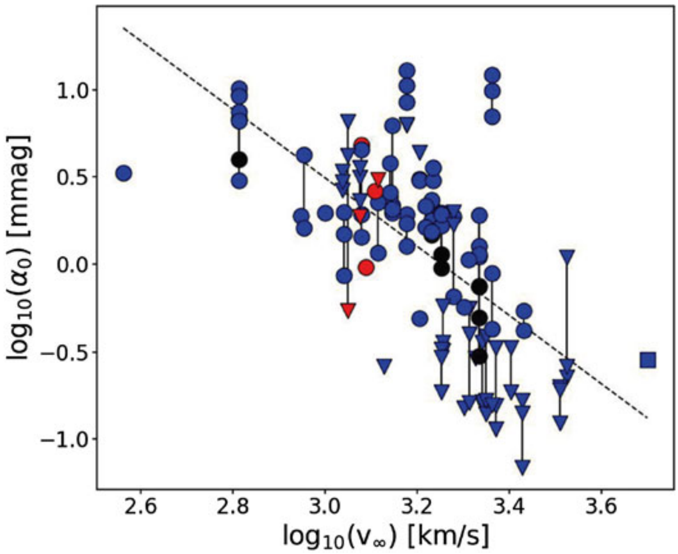

Figure 1. Amplitude of the photometric wind variability α_0 plotted against the terminal speed v_∞ of the wind for all the WR stars of our sample. Vertical black lines link the different datasets of individual stars observed by the same telescope, with TESS data shown in blue, BRITE-Constellation in black and MOST in red. Inverted triangles represent WC stars and circles are for WN stars.

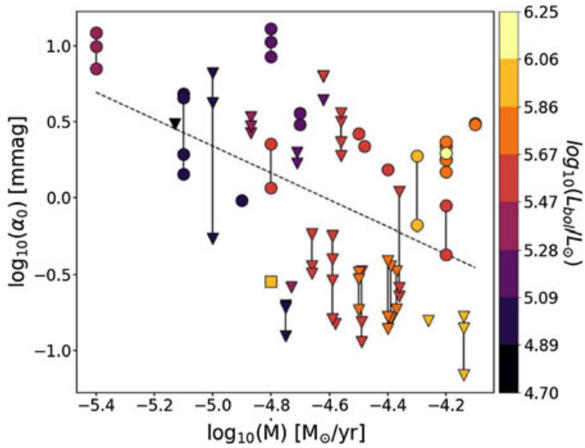

Figure 2. Amplitude of the photometric wind variability α_0 plotted against the mass-loss rate $\dot{M}$ for cWR stars, with a color-coding indicating the bolometric luminosity of each star.

For cWR stars only, correlations satisfying the Spearman rank (R_s) $p < 0.001$ criterion (but not the F-test) were observed between α_0 and both $\dot{M}$ and L_{bol}, as shown in Figure 2. Correlations also satisfying the R_s criterion where found for WNh stars between α_0 and T_* (evaluated in the references mentioned above through the Stefan-Boltzmann relation), along with correlations between ν_{char} and both v_∞ and T_*.

3. Conclusions

Our results show that hotter WR stars with faster winds tend to exhibit lower levels of stochastic variability in their photometry, which is in agreement with both the spectroscopic observations of Chené et al. (2020) and the linear polarimetric variability observed by Robert et al. (1989) and could be an indication that a subsurface convection region is present in these stars (Cantiello et al. 2009). Other plausible processes that are compatible with our results (and non-mutually exclusive) are the presence of core-generated gravity waves (e.g. Bowman et al. (2019)) and the action of the line de-shadowing instability (e.g. Sundqvist et al. (2018)).

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