Massive Stars Near and Far
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The multiplicity of Galactic Wolf-Rayet stars

Karan Dsilva[1], **Tomer Shenar**[1,2], **Hugues Sana**[1] **and Pablo Marchant**[1]

[1]Institute of Astronomy, KU Leuven, Celestijnenlaan 200D, 3001 Leuven, Belgium
email: karandsilva413@gmail.com

[2]Anton Pannekoek Institute for Astronomy, University of Amsterdam, Postbus 94249, 1090 GE Amsterdam, The Netherlands

Abstract. We present the results of a magnitude-limited spectroscopic survey of Galactic Wolf-Rayet stars with the HERMES spectrograph mounted on the Mercator telescope. Using cross-correlation to measure radial velocities, we measured the observed binary fractions of the Galactic carbon- (WC) and nitrogen-rich (WN) Wolf-Rayet stars to be $f_{\rm obs}^{\rm WC} = 0.58 \pm 0.14$ and $f_{\rm obs}^{\rm WN} = 0.41 \pm 0.09$. We used Monte-Carlo simulations with a Bayesian framework to derive the intrinsic multiplicity properties and found $f_{\rm int}^{\rm WN} = 0.52^{+0.14}_{-0.12}$ and $f_{\rm int}^{\rm WC} = 0.96^{+0.04}_{-0.22}$. We find that the majority of WN binaries reside in short-period systems, similar to O stars. However, the orbital period distribution of the Galactic WC population peaks at 5000 d, a discrepancy that challenges our current understanding of binary evolution in Wolf-Rayet stars.

Keywords. stars: Wolf-Rayet, stars: binaries, stars: evolution

1. Introduction

Wolf-Rayet (WR) stars are a spectroscopic class of objects characterised by strong, broad emission-line spectra. They are the descendants of O-type stars with initial masses $M_i \gtrsim$ 20-30 $M_\odot$ (for a review, see Crowther 2007). Based on the chemical composition of their atmospheres, they are classified as carbon- (WC), nitrogen- (WN) or oxygen-rich (WO). Originally, it was thought that all WR stars are formed in binaries through envelope stripping by a close companion (Paczyński 1967). However, Conti (1976) hypothesised that an O star could strip its own envelope through mass loss via stellar winds (the Conti scenario). Knowledge of the multiplicity properties of WR stars is an important ingredient to understand the dominant formation channel of WR stars (see, e.g. Shenar et al. 2020).

In this contribution, we present the results of a homogeneous, magnitude-limited, spectroscopic survey of northern Galactic WR stars using the HERMES spectrograph (Raskin et al. 2011) on the Mercator telescope. Our sample consists of 27 WN and 12 WC stars. We collected at least six epochs for each object over four years. In Dsilva et al. (2020), we analysed the WC sample and found an intrinsic multiplicity fraction of at least 0.72 at the 10% significance limit. In Dsilva et al. (2022), we used a Bayesian framework to simulate the measured RVs and found the intrinsic fraction of early-type WN (WNE) stars to be $f_{\rm int}^{\rm WNE} = 0.56^{+0.20}_{-0.15}$. After analysing the late-type WN (WNL) stars, we found similar parameters to the WNE sample and hence performed a combined Bayesian analysis for the parent WN population.

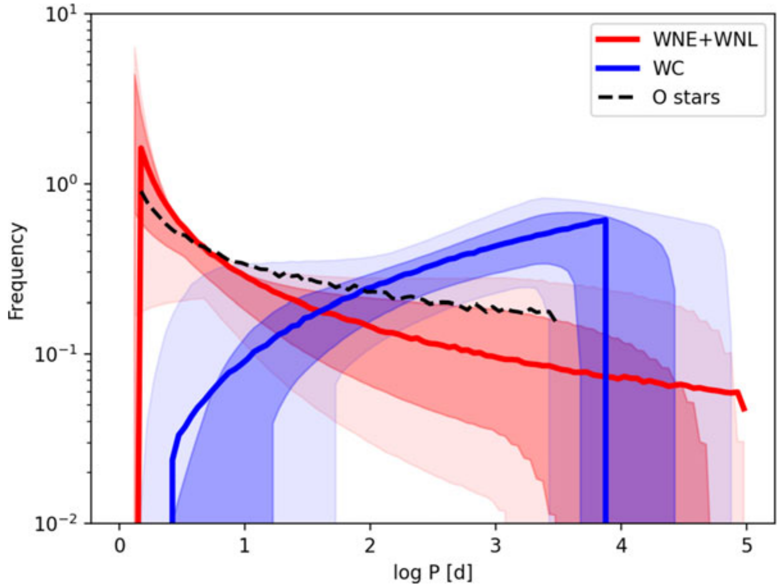

Figure 1. Visualisation of 10^7 period distributions for the WC (blue) and WN (red) populations. The dark and light shaded areas represent the parameter space covered by 68% and 95% of the simulated distributions.

2. Bayesian analysis of the intrinsic multiplicity properties

After measuring radial velocities (RVs) using cross-correlation, we calculated the RV amplitude for each object (ΔRV). To correct for observational biases, we divided the sample into various ΔRV bins and simulated our observations over the power-law index (π), minimum ($\log P_{\rm min}$) and maximum bounds ($\log P_{\rm max}$) of the underlying period distribution. The defined ΔRV bins for the WC and WN populations can be found in Dsilva et al. (2022). We assumed random eccentricity, and orientation in three dimensional space and simulated 10 000 populations of WN and WC subtypes. For the combined WN population, we calculated the highest probability intervals to be $f_{\rm int}^{\rm WN} = 0.52^{+0.14}_{-0.12}$, $\pi^{\rm WN} = -0.99^{+0.57}_{-0.50}$ and $\log P_{\rm max}^{\rm WN} = 4.99^{+0.00}_{-1.11}$ and assumed $\log P_{\rm min}^{\rm WN} = 0.15$ [d]. We sampled these posteriors and those for the WC (Dsilva et al. 2022) 10^7 times and simulated their respective period distributions. This can be seen in Fig. 1, where the red and blue solid lines show the distributions for the WN and WC respectively constructed using the best-fit posteriors.

3. Conclusions

The period distribution of the WN population is similar to that of the O stars. Our simulations indicate a shift in the period distribution of the WC population, which cannot easily be reconciled with our current theory of binary evolution. It is possible that we do not detect long-period companions to WN stars due to wind variability, but short-period WN binaries do not seem to become WC binaries, potentially due to mergers.

References

Conti, P. 1976, in Proc. 20th Colloq. Int. Astrophys., Univ. Liege, 193

Crowther, P. A. 2007, Annual Review of Astronomy & Astrophysics, vol. 45, Issue 1, pp.177-219, 45, 177

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Dsilva, K., Shenar, T., Sana, H., & Marchant, P. 2020, Astronomy & Astrophysics, Volume 641, id.A26, 16 pp., 641, A26
—. 2022, Astronomy & Astrophysics, in press (arXiv: 2204.12518)
Paczyński, B. 1967, Acta Astronomica, 17, 355
Raskin, G., et al. 2011, Astronomy and Astrophysics, Volume 526, id.A69, 12 pp., 526, A69
Shenar, T., Gilkis, A., Vink, J. S., Sana, H., & Sander, A. a. C. 2020, Astronomy & Astrophysics, Volume 634, id.A79, 12 pp., 634, A79