



Wolf-Rayet evolution computations with realistic atmospheres

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Abstract

Massive stars evolution computations currently don't account for the complex physics of massive stars atmospheres. This physics has however been progressively included in stellar atmosphere simulations over the last decades. A proper inclusion of this physics is particularly important for Wolf-Rayet stars, as they possess extended atmospheres with thick winds which strongly impact their surface properties. Here I present results of the inclusion of state-of-the-art model atmospheres in the evolution computations of massive Wolf-Rayet stars, and how it allows us to better explain observations of these stars.

Numerical tools

STAREVOL stellar evolution code

- 50 and 60 M_{\odot} , Z_{\odot}
- single stars, no rotation
- described in Amard et al. (2019)

CMFGEN (Hillier and Miller, 1998) atmosphere models

- non-Local Thermodynamic Equilibrium.
- sphericity and wind extension.
- line-blanketing.

Methods

We first computed a grid of CMFGEN models encompassing the evolutionary track in the relevant parameter space. We then computed an evolutionary model. At each iteration of the Henyey scheme, we interpolated CMFGEN temperature, density and radius profiles as functions of the optical depth. We used the values of the temperature and density at the optical depth of the outermost shell, chosen to be located at an optical depth of 10, as surface boundary conditions for the resolution of the stellar structure and evolution equations. The photospheric radius was then determined using the interpolated radius profile and used to recompute the effective temperature and photospheric gravity.

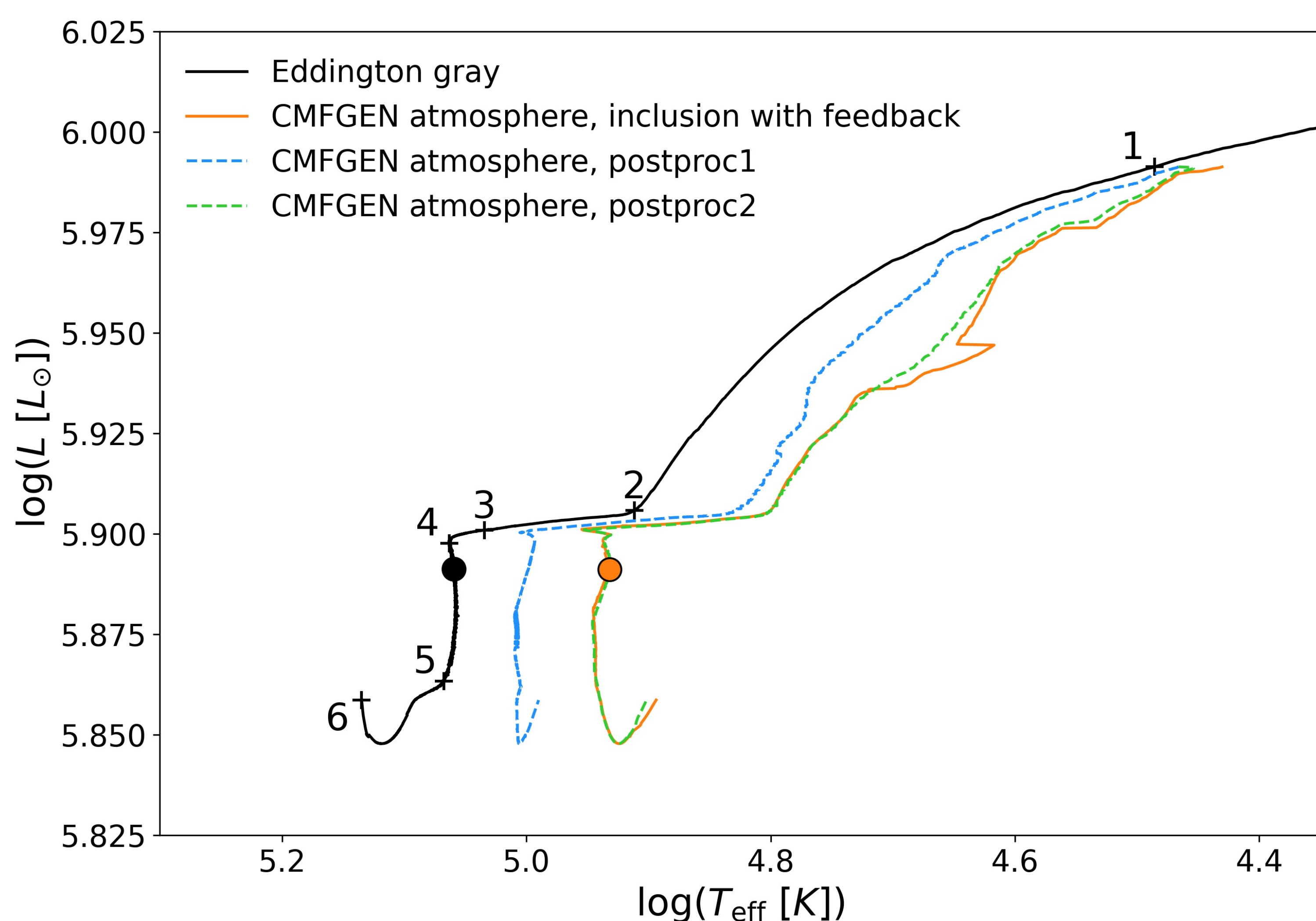


Figure 1 : Evolutionary track of a 60 M_{\odot} stellar evolution model at solar metallicity with a CMFGEN atmosphere (orange) compared to an identical model with an Eddington gray atmosphere (black). Models computed using post-processing methods are also shown for comparison (blue and green).

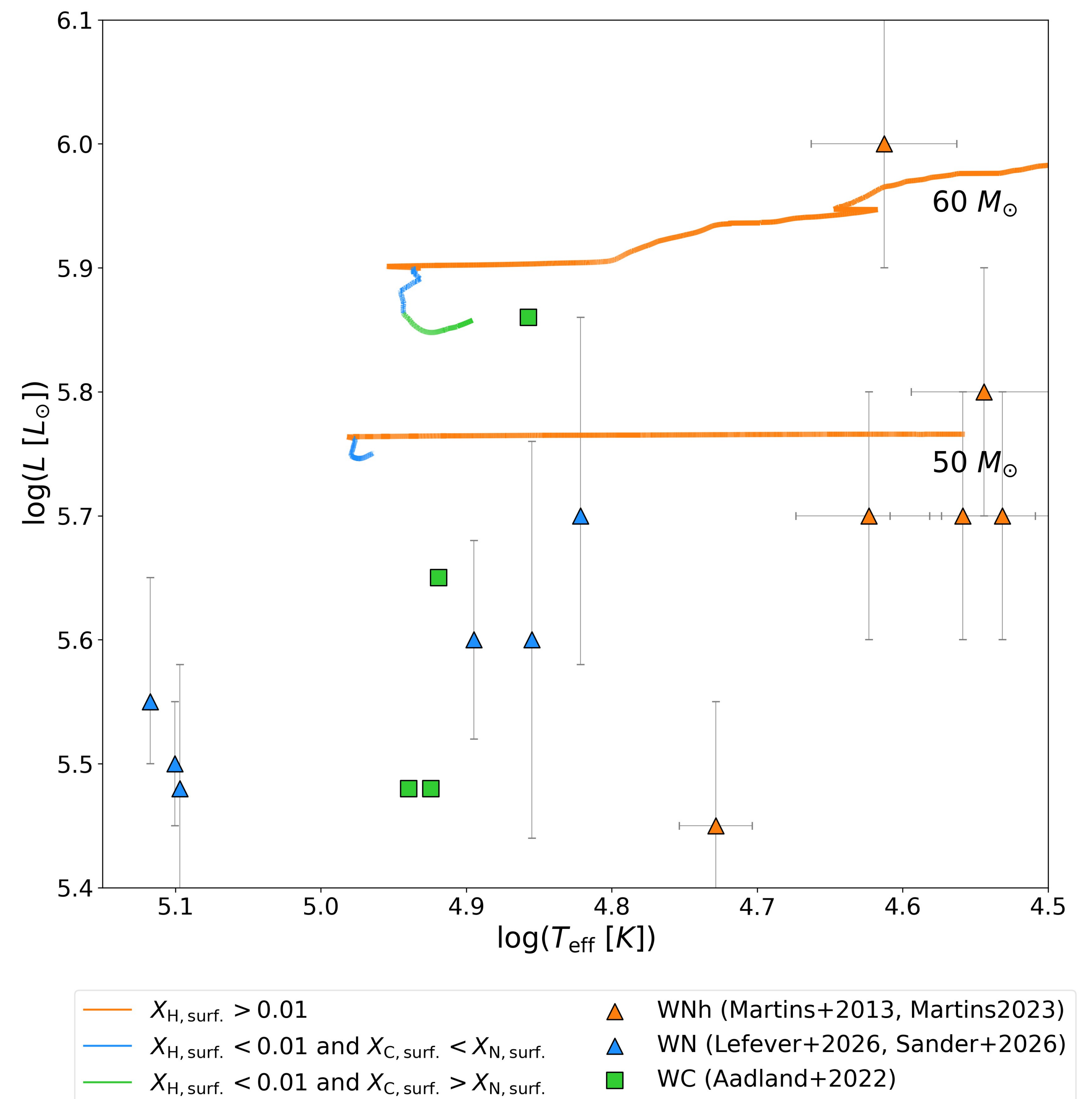


Figure 2 : Evolutionary tracks of stellar evolution models with CMFGEN atmospheres compared to observations of galactic WN stars from Martins et al. (2013), Martins (2023) and Lefever et al. (2026), of galactic and LMC WN2 stars from Sander et al. (2026), and of LMC WC stars from Aadland et al. (2022). The evolutionary tracks and the observational points are color-coded to indicate the different spectral types (WNh, WN, WC).

Results

We show in Fig. 1 the evolutionary track of our 60 M_{\odot} model compared to an otherwise identical Eddington gray evolution model. The effective temperature of our model with CMFGEN atmospheres is reduced by more than 25 kK compared to the Eddington gray evolution model for more than half the evolution time on the Wolf-Rayet phase. This is due to the strong increase of the photospheric radius because of the stellar wind. The other stellar parameters along with the internal structure stay mostly unchanged. We show that we can reproduce the results of our method using a post-processing method (i.e. a method where we correct the radius and effective temperature after the full completion of the evolution computation).

In Fig. 2 we compare the evolutionary tracks of our 50 and our 60 M_{\odot} models with CMFGEN atmospheres with observations of Wolf-Rayet stars. We show that our method allows for a better reproduction of the observations than the Eddington gray approximation for all of the different spectral types (WNh, WN and WC stars).

The figures presented in this poster are from
Voje, T., Palacios, A., Martins, F., A&A, 2026, in press.

References

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