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A. Siebert, K. Baillié, M. Béthermin, F. Cantalloube, E. Josselin, N. Lagarde, J. Malzac, J. Richard, L. Selliez, O. Venot (eds)

REALISTIC ATMOSPHERE IN STELLAR EVOLUTION MODELS FOR MASSIVE STARS

T. Voje[1], A. Palacios[1] and F. Martins[1]

Abstract. Atmosphere models of massive stars have become increasingly more realistic over the last 50 years, with the progressive inclusion of non-LTE effects, wind extension, and line-blanketing. However the vast majority of massive stars evolution computations still use the Eddington gray approximation, whereas complex atmosphere models are now routinely included in the evolution computations of low- and intermediate-mass stars. Here we present preliminary results of the inclusion of realistic atmosphere models in the evolution calculations of massive stars.

Keywords: stars: evolution – stars: massive – stars: atmospheres

1 Introduction

The position of Wolf-Rayet stars in the Hertzsprung-Russell diagram is difficult to explain with current evolution models, as shown by (Hamann et al. 2006). A possible explanation for this is that the Eddington gray approximation generally used to model the atmosphere in stellar evolution models doesn't account for the complex physics that occurs in Wolf-Rayet stars atmospheres. The purpose of this work is thus to include more realistic atmosphere models in stellar evolution computations and to study the impact these atmosphere models have on massive stars evolution computations.

2 Evolution and atmosphere codes

We use the STAREVOL stellar evolution code to compute the stellar evolution models (Amard et al. 2019). This code uses the Henyey method (Henyey et al. 1964) to solve the stellar structure and evolution equations. To compute the atmosphere models we use the CMFGEN code (Hillier & Miller 1998), a non-Local Thermodynamic Equilibrium radiative transfer code that takes into account sphericity, wind extension and line-blanketing.

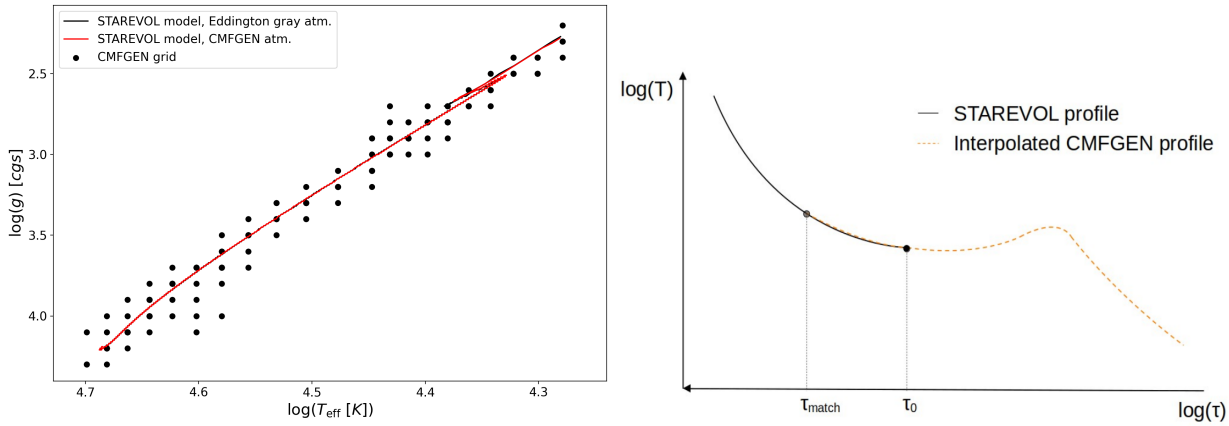

Fig. 1. Left: Grid for the main-sequence computation represented in the Kiel diagram. **Right:** Scheme of a temperature profile showing the inclusion of the interpolated CMFGEN atmosphere models in STAREVOL.

[1] LUPM, Univ. Montpellier, CNRS, Montpellier, France

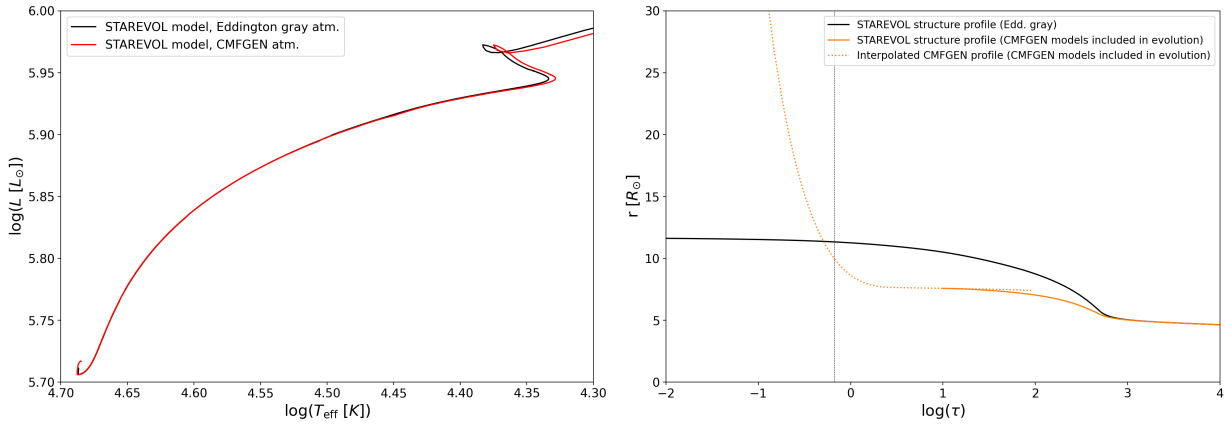

Fig. 2. Left: Evolutionnary tracks on the main sequence of a STAREVOL model with a CMFGEN atmosphere compared to one with an Eddington gray atmosphere in the Hertzsprung-Russell diagram. **Right:** Radius profile produced with STAREVOL on the Wolf-Rayet phase using the CMFGEN inclusion method compared with the Eddington gray profile.

3 Inclusion of CMFGEN atmosphere models in STAREVOL

The CMFGEN models are included in STAREVOL through interpolation in a precomputed grid of atmosphere models. This grid is computed to encompass the evolutionary track of the model we want to compute in the interpolation parameter space (see Figure 1, left). We fix the numerical surface of the evolution model to be located at an optical depth τ_0 where the diffusion approximation is valid. At this optical depth we apply boundary conditions on temperature and density taken from the interpolated atmosphere profiles (see Figure 1, right). Using the atmosphere radius profile we compute the photospheric radius, and with it the other photospheric values (effective temperature, gravity at the photosphere, etc.).

4 Preliminary results

We apply this method to the main sequence evolution of a 60 $M_\odot$ star at solar metallicity and without rotation. We compare this model and the same model computed with an Eddington gray atmosphere. We find that the impact of realistic atmospheres on the main sequence compared to Eddington gray approximation is rather small (see Figure 2, left). Preliminary results on the Wolf-Rayet phase of the same star show that using realistic atmosphere models produce important differences in radii compared to the Eddington gray models (Figure 2, right).

5 Conclusions

We study the impact of using realistic atmosphere models in stellar evolution computations instead of the Eddington gray approximation generally used. We find that using realistic atmosphere models have little effect on the main-sequence evolution of a 60 $M_\odot$ star at solar metallicity and without rotation. We are currently expanding this work to the Wolf-Rayet phase where preliminary results tend to show that there are important differences between realistic atmosphere and Eddington gray atmosphere evolution models.

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References

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