UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

Spectral evolution of Very Massive Stars on the Main Sequence

Joris Josiek

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Zentrum für Astronomie der Universität Heidelberg (ZAH) /
Astronomisches Rechen-Institut (ARI)

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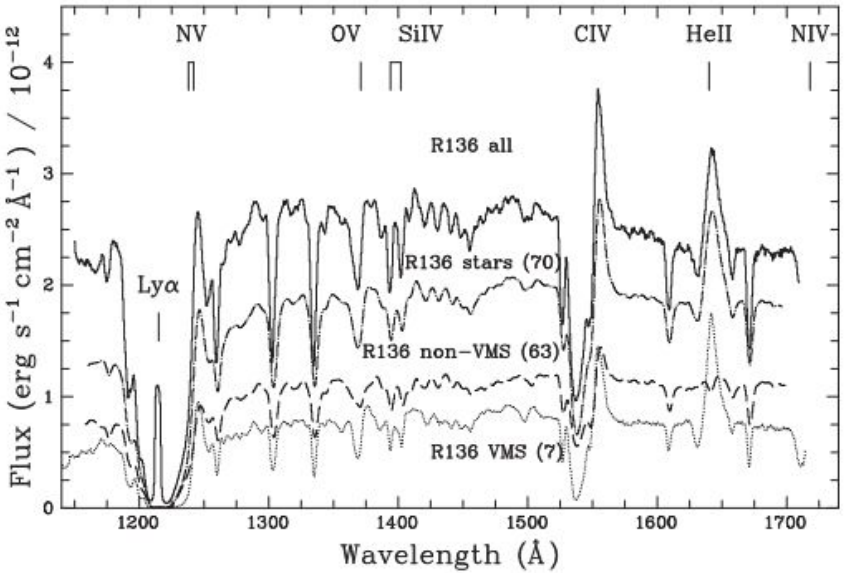
R136 spectrum + VMS contribution

Crowther et al. (2016)



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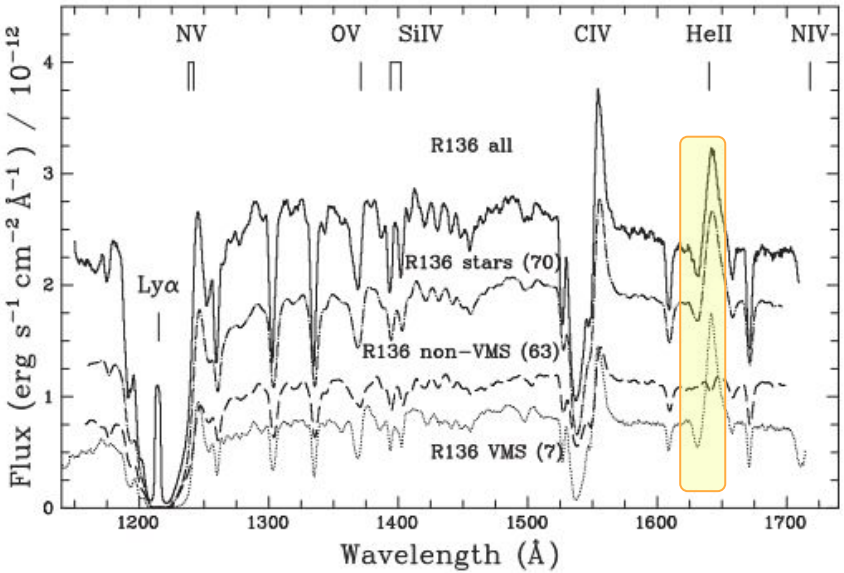

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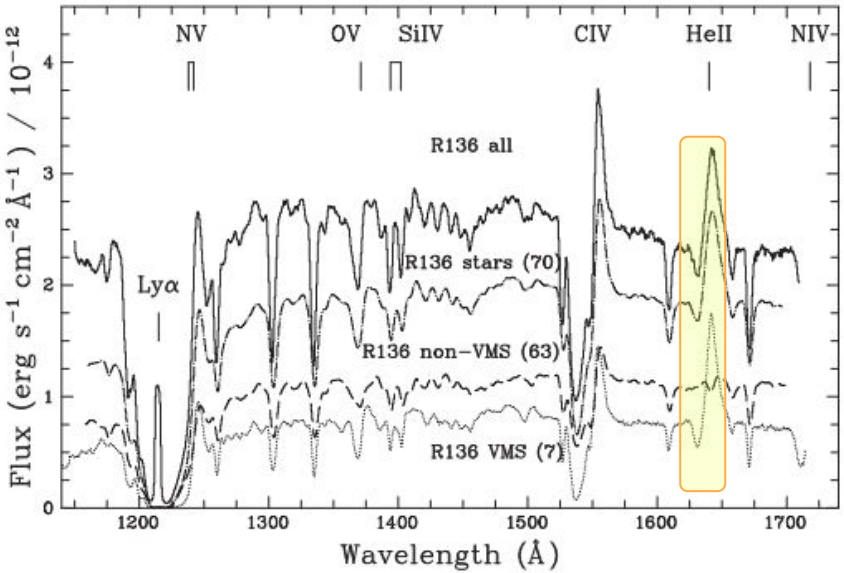
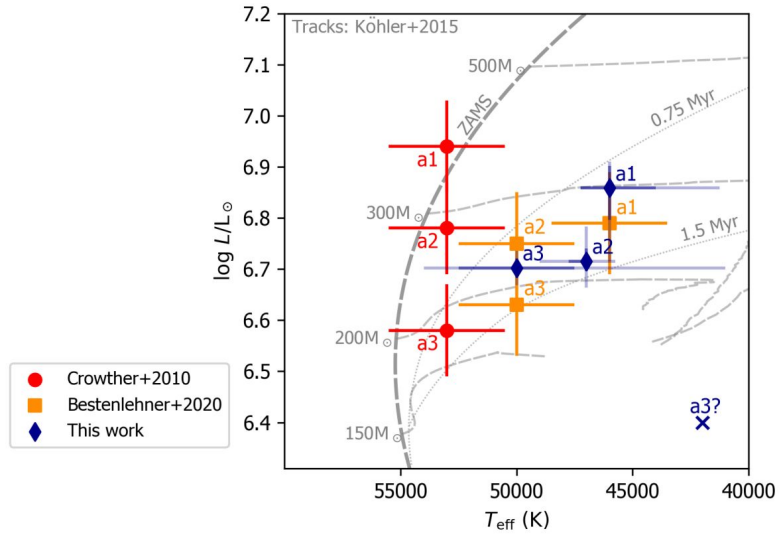


VMS in the R136 cluster (LMC)

Brands et al. (2022)



Evolution modeling — a broad overview

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Codes: MESA, GENEC, BEC, PARSEC, …

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→ Mean opacities from tables

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→ Grey atmosphere approximation (no wind!)

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Simplified radiative transfer
→ Mean opacities from tables

Simplified boundary conditions
→ Grey atmosphere approximation (no wind!)
→ In outer 2% of the star (by mass):
- no convection
- no nuclear reactions
- no hydrostatic equilibrium

Modeling stellar evolution of VMS

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Dedicated mass-loss scheme (Sabhahit et al. 2022)

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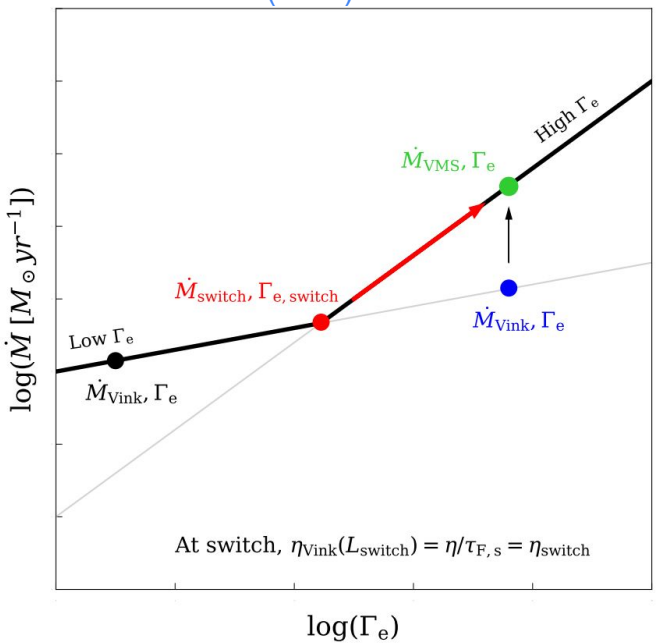

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Initial masses: 100–350 $M_\odot$

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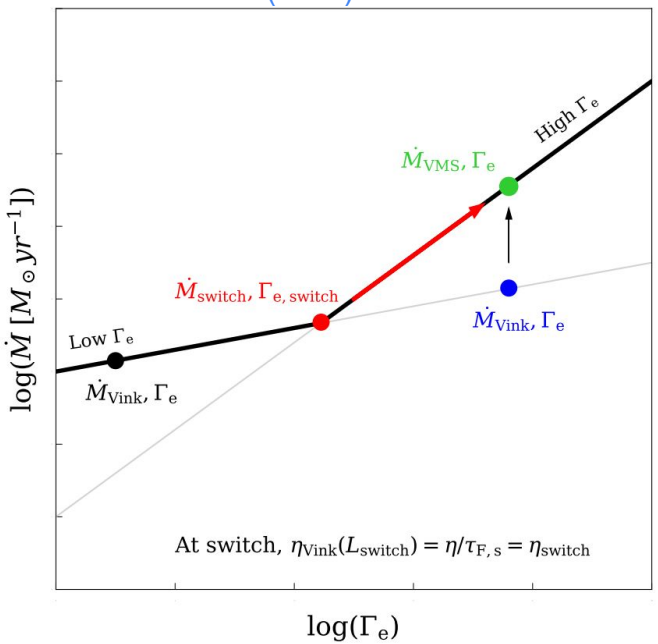

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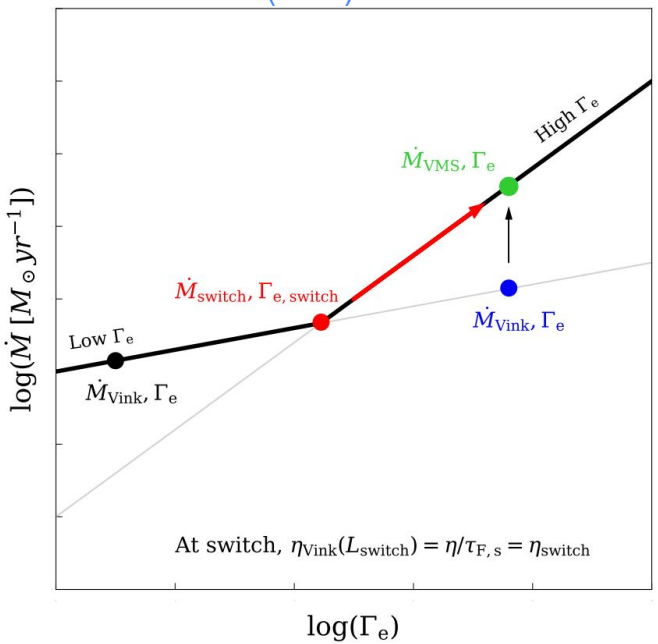

Modeling stellar evolution of VMS

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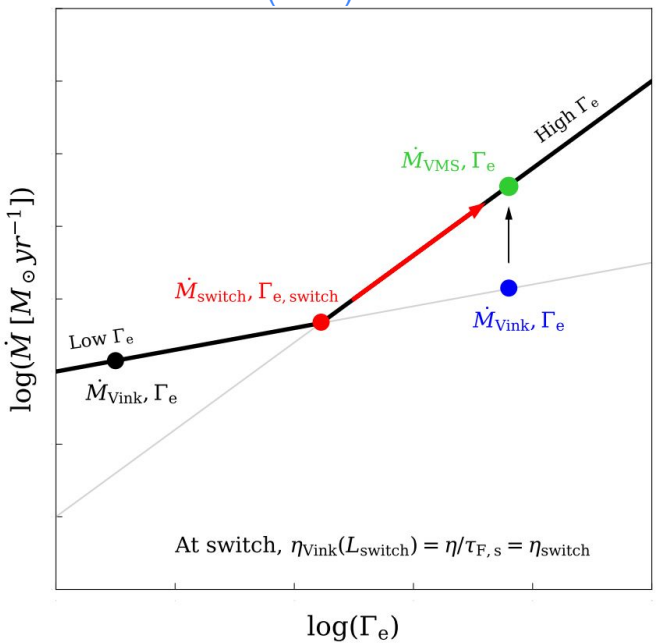
Metallicity: Solar

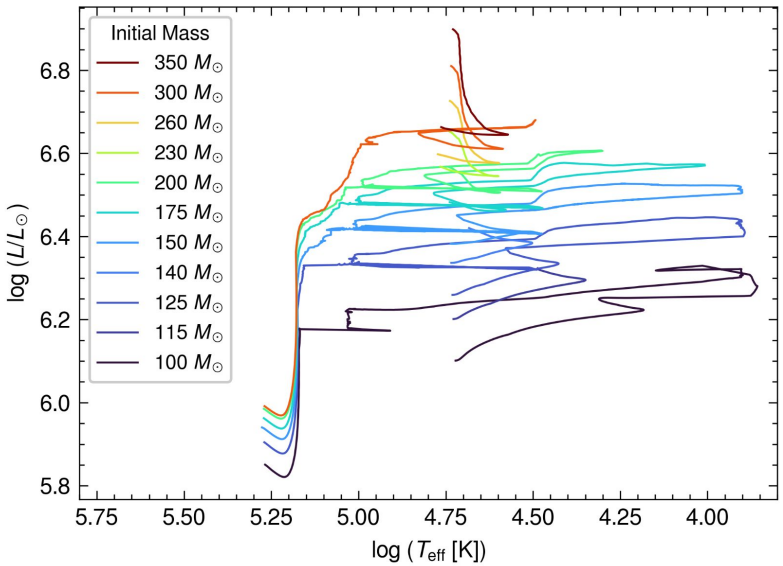
Rotation: 0; 10% V_{crit}

Sabhahit et al. (2023)



Evolution grid

Non-rotating



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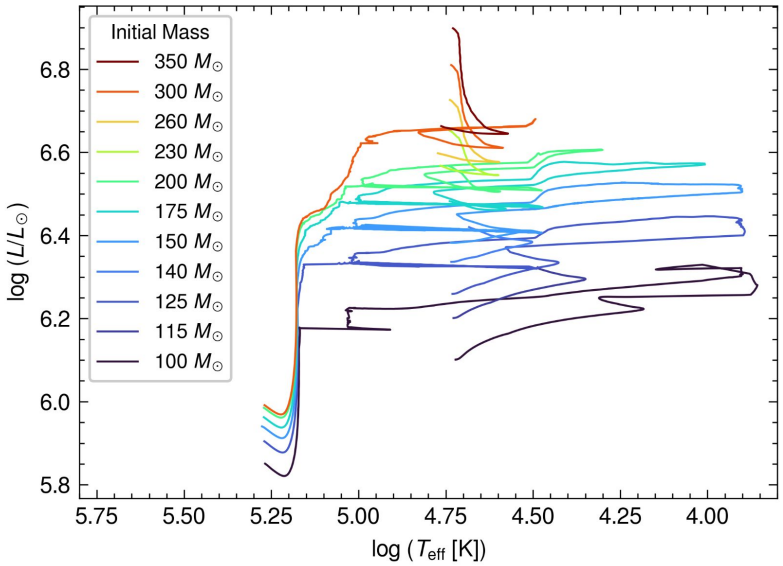
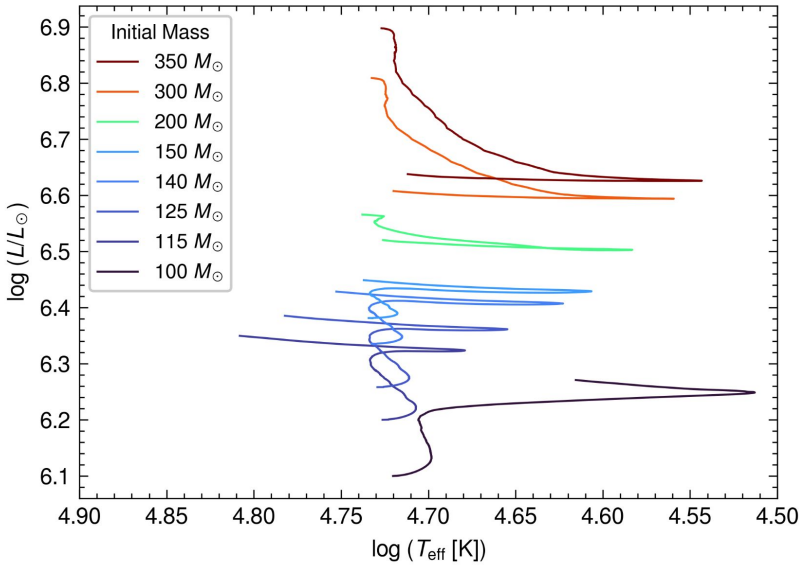


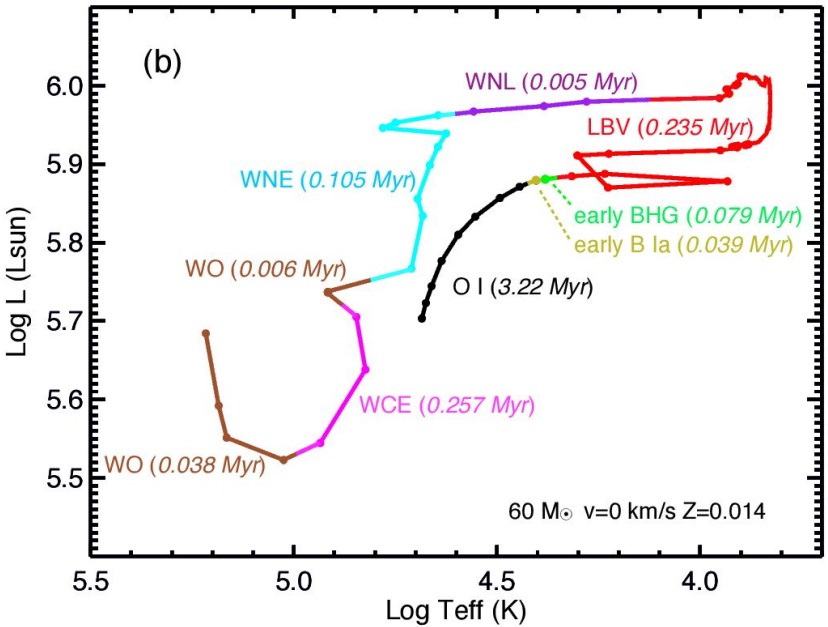
Rotating (Main sequence only)



Atmosphere models on evolution tracks

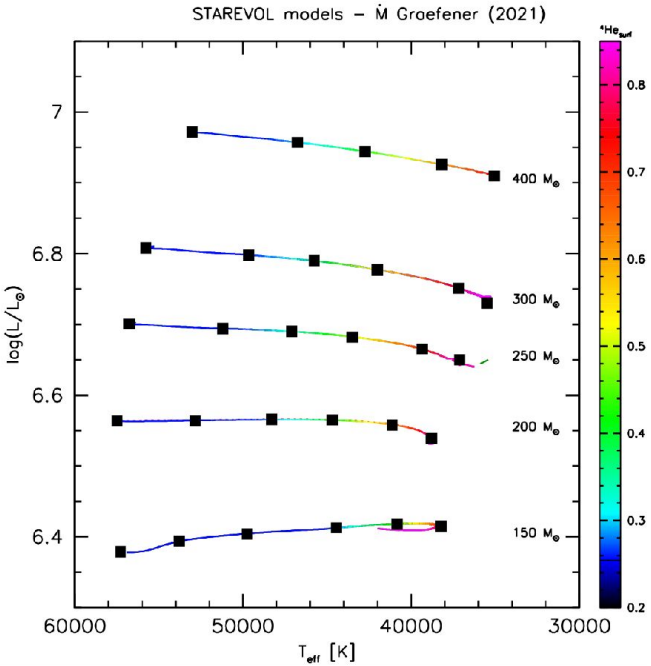
Non-rotating 60$M_\odot$ model

Groh et al. (2014)



Very massive stars in LMC

Martins & Palacios (2022)



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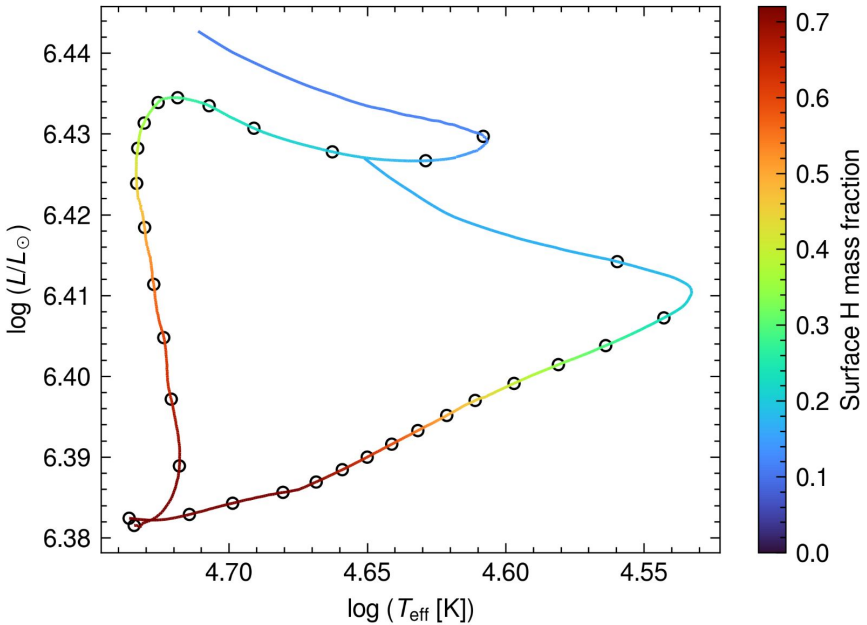
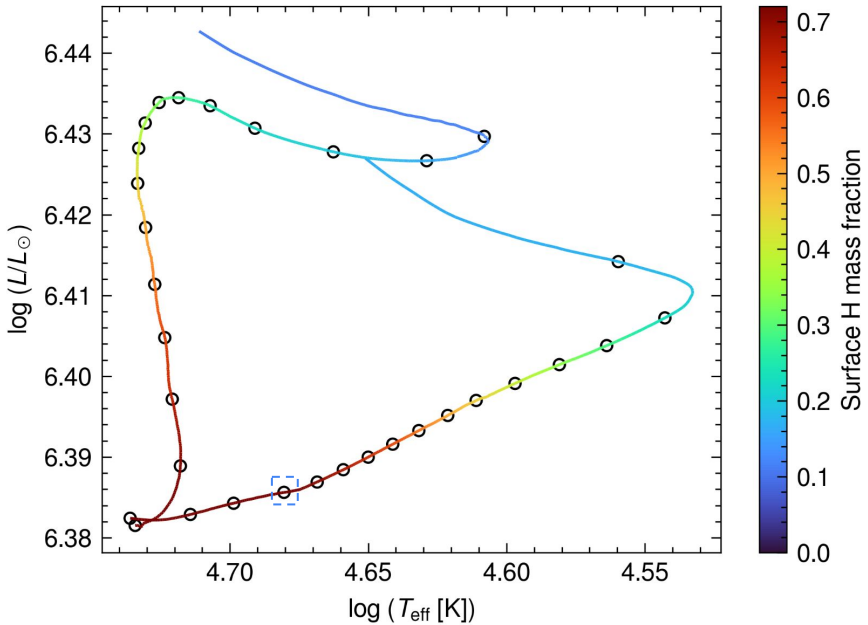


Rotating & non-rotating 150$M_\odot$ model (main sequence only)

Atmosphere grid



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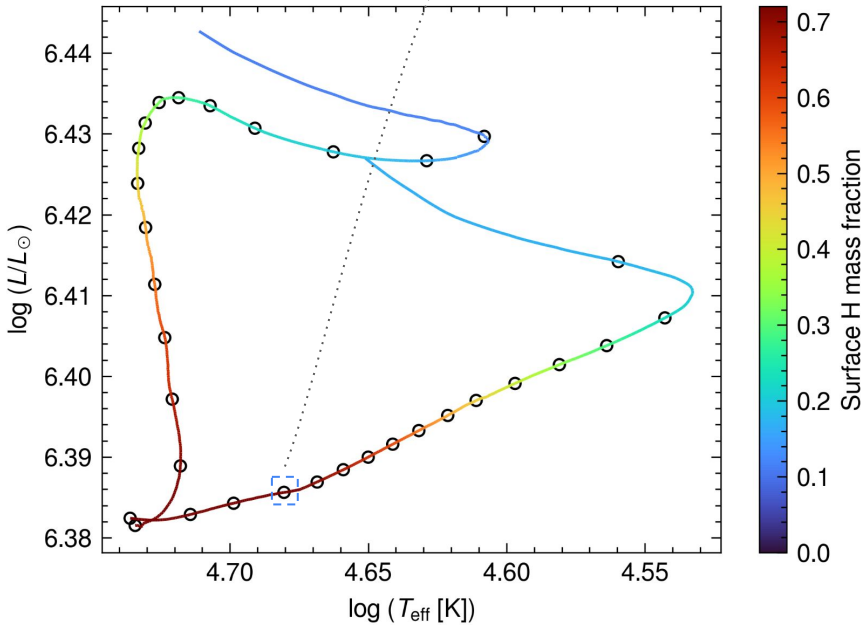

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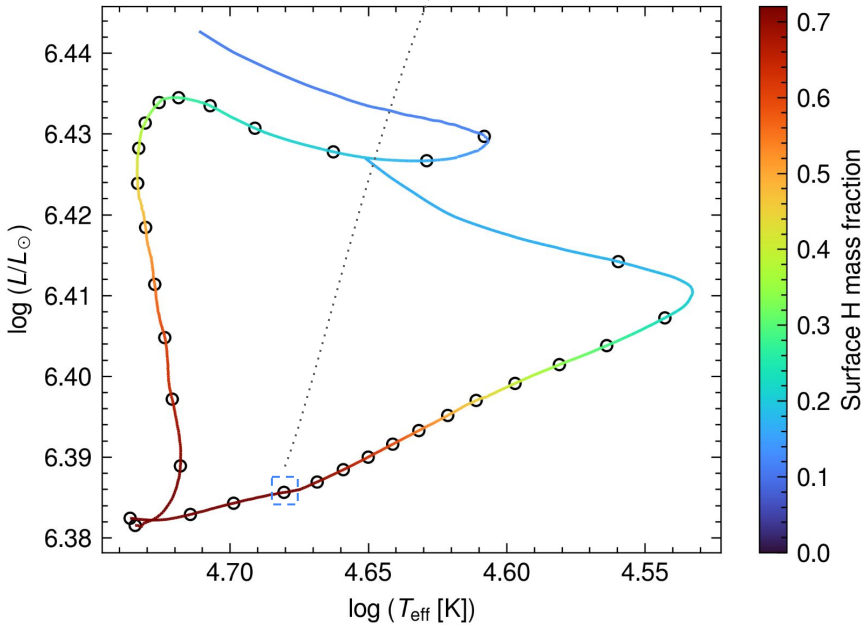
STELLAR SURFACE

GENEC

STELLAR INTERIOR

Atmosphere grid



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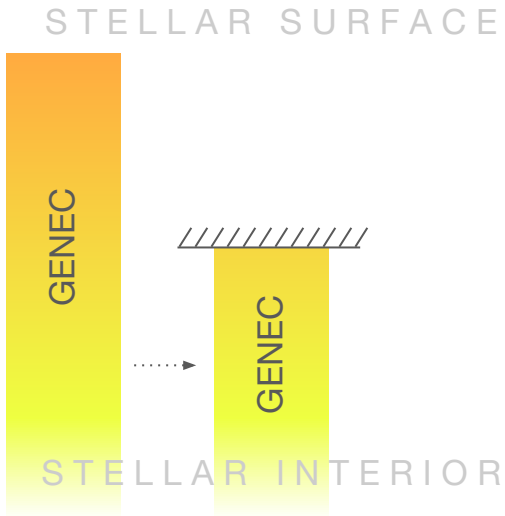

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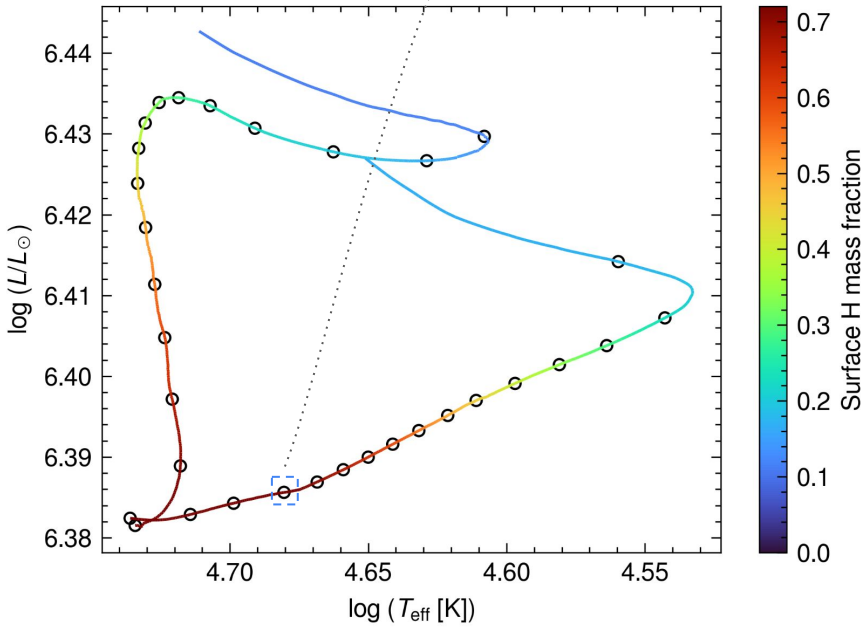

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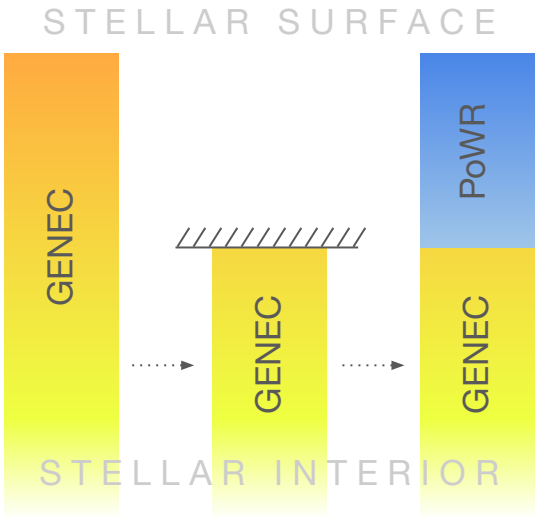

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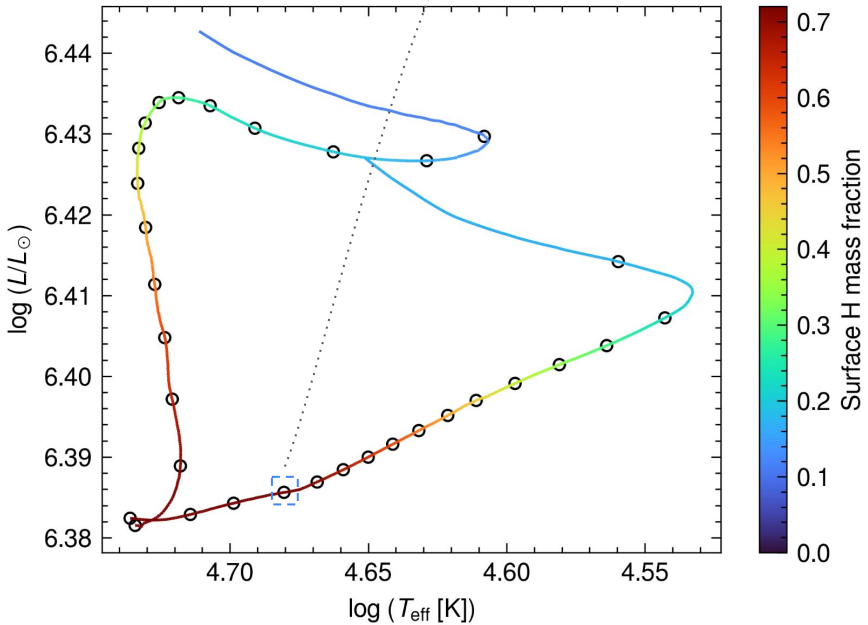

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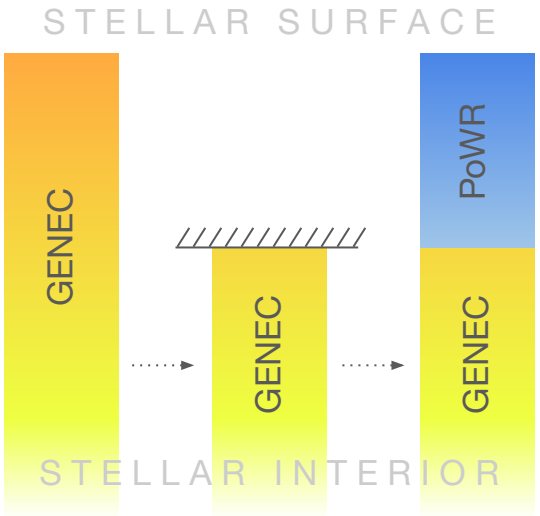

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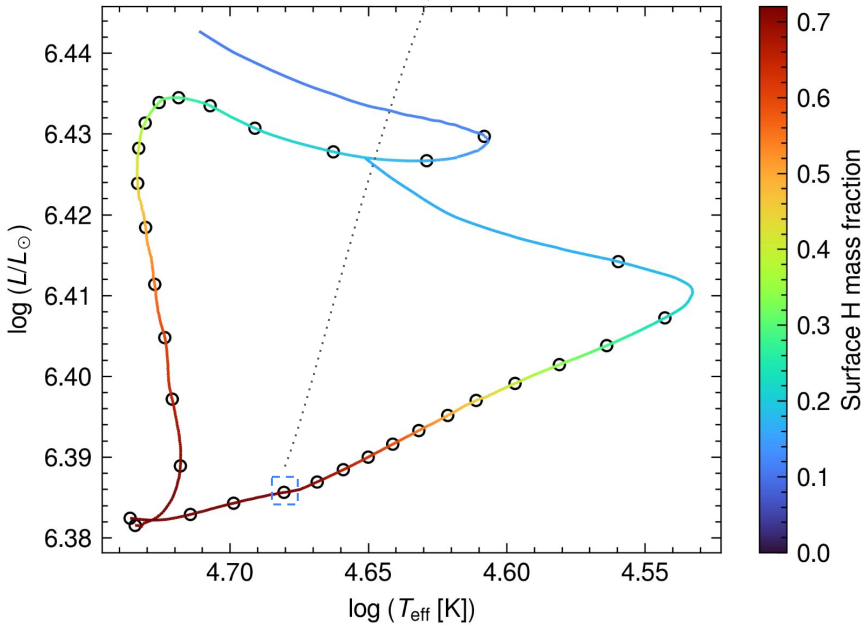

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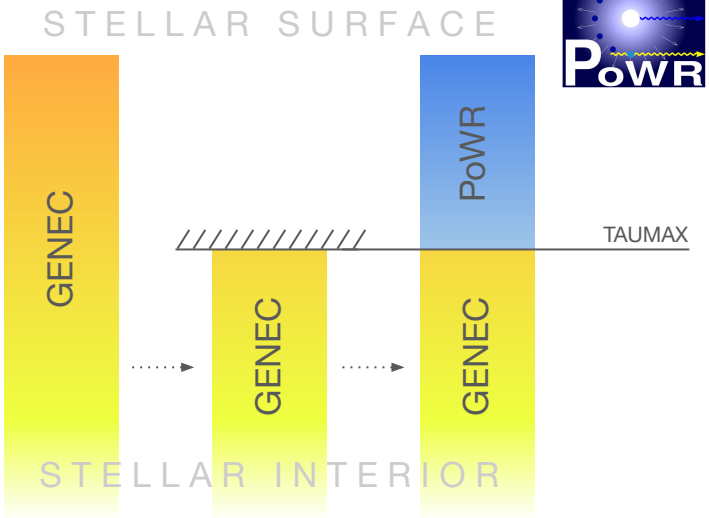

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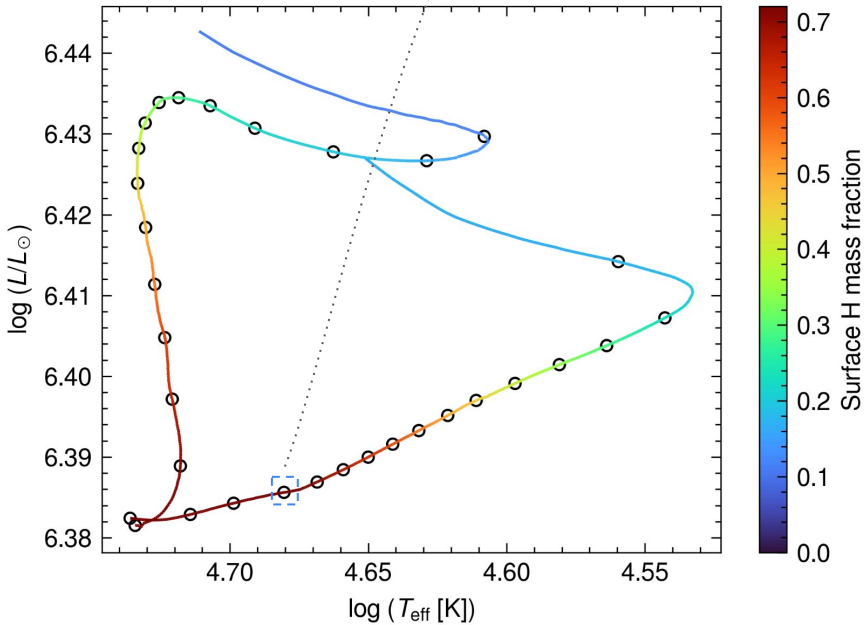

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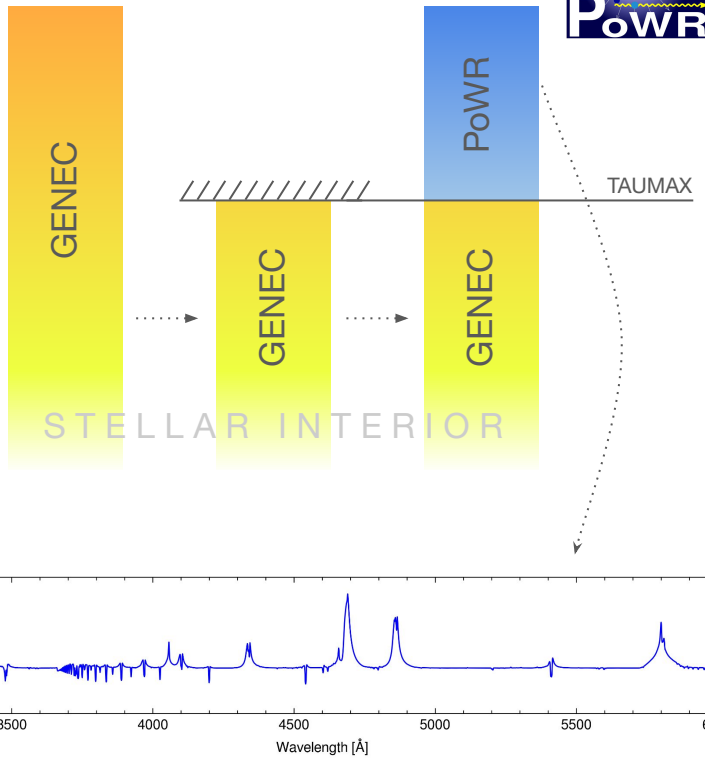

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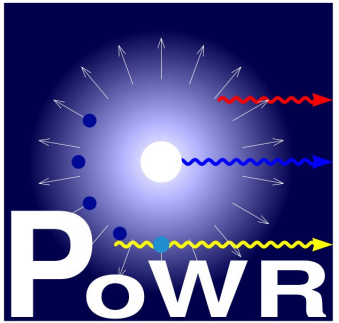
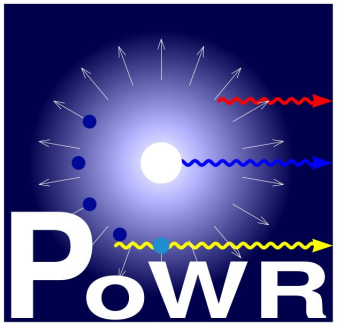


Atmosphere modeling

For preliminary modeling:

cut @ TAUMAX=20 (spectral line formation happens above this)



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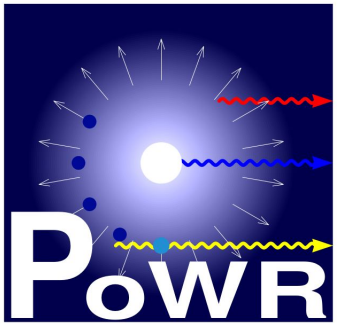
only include H, He, C, N, O, Fe



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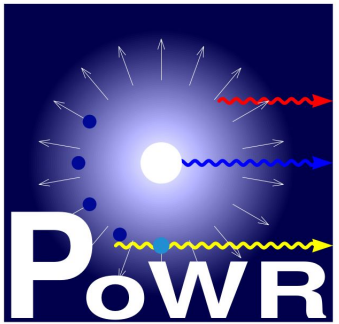

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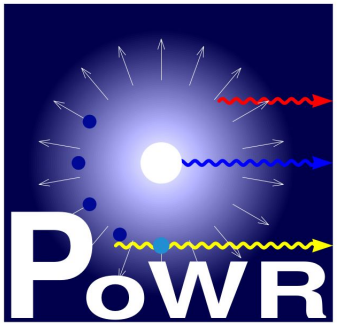
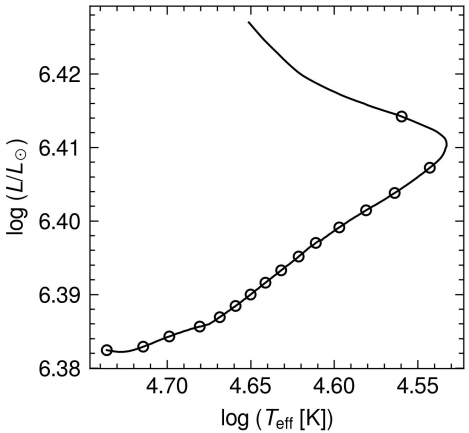
- stellar parameters taken from GENEC models



Spectral evolution of a non-rotating 150 $M_\odot$ star



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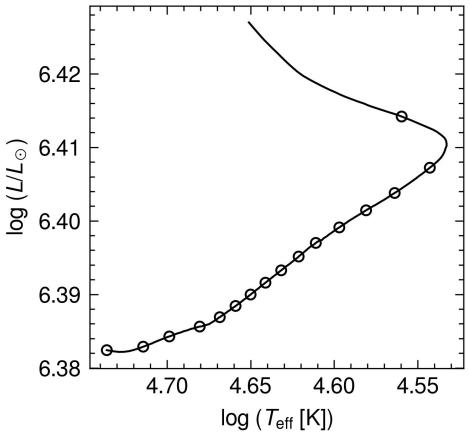

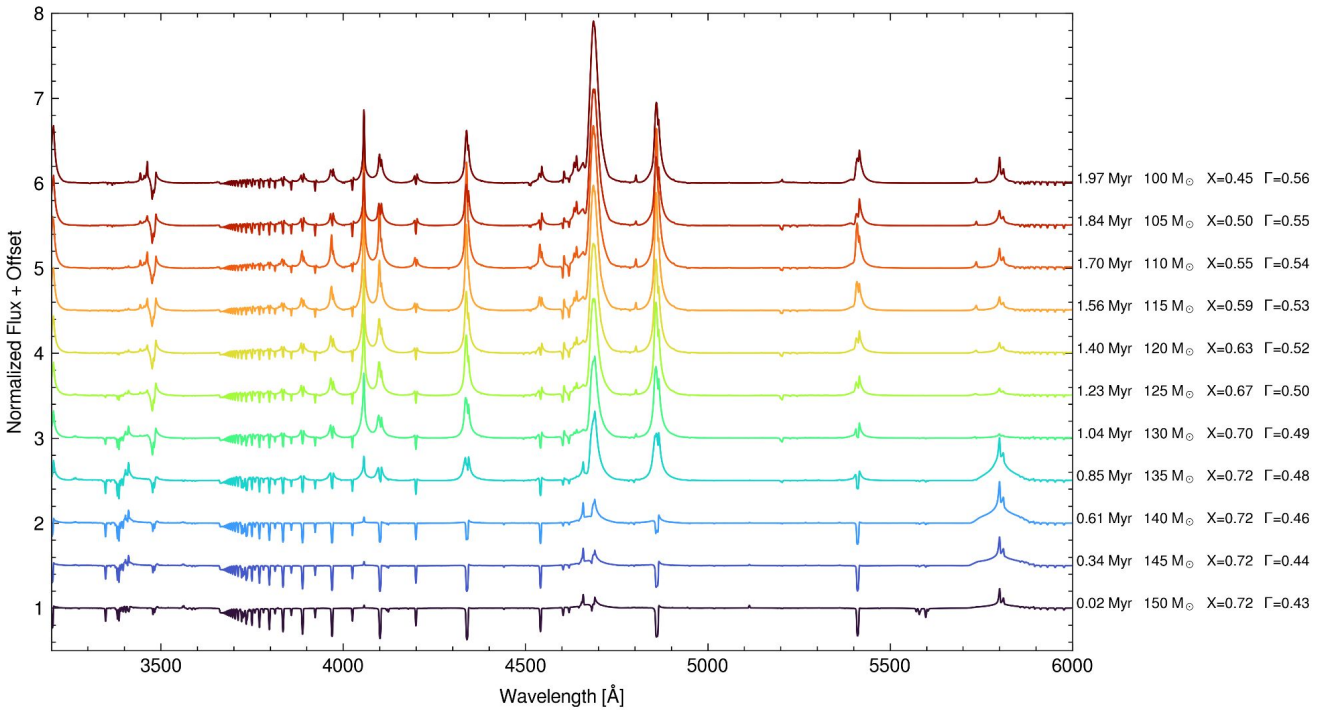

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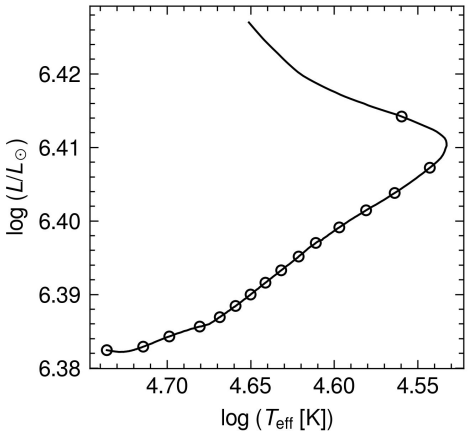

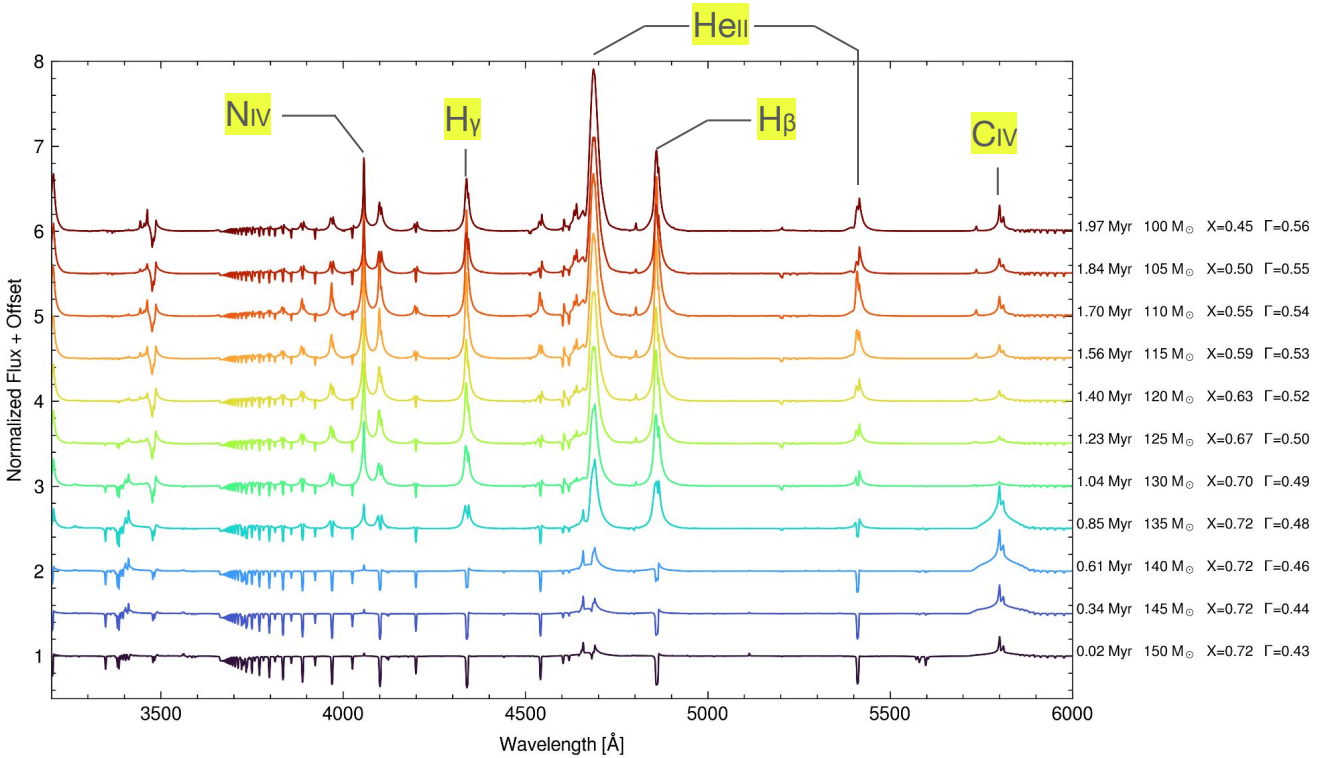

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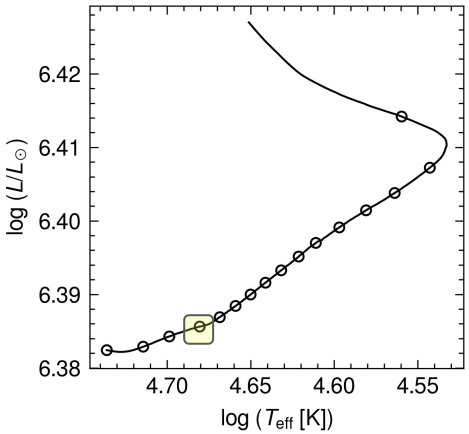
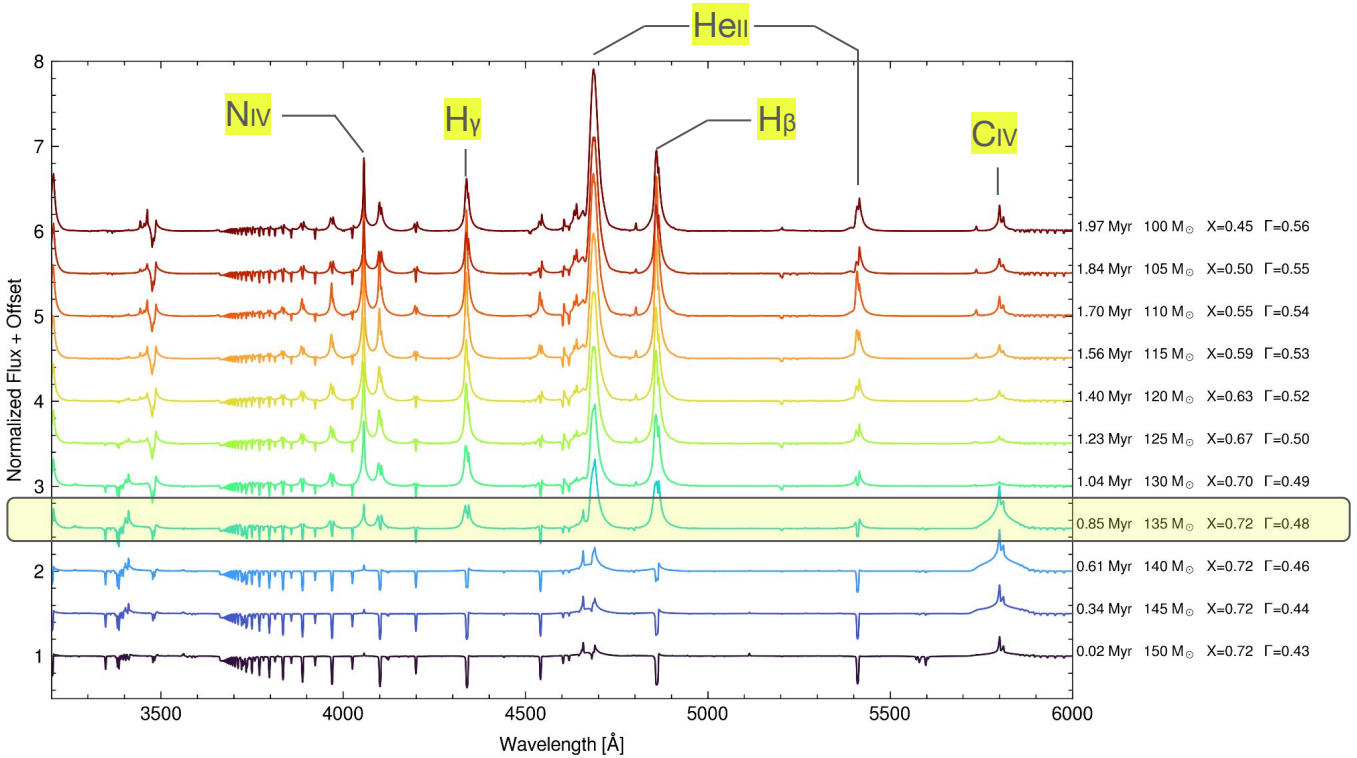
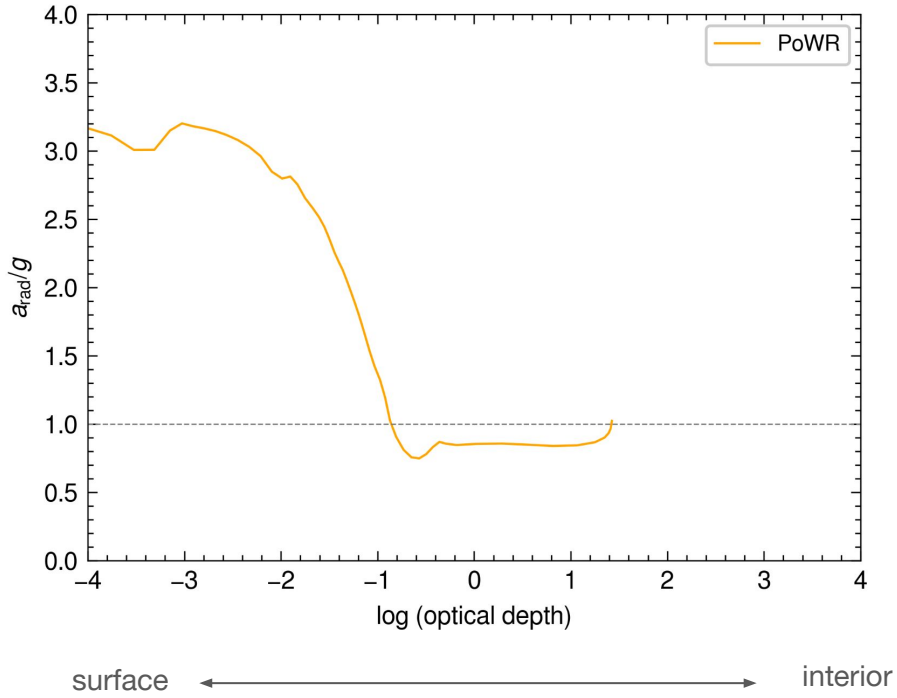




Acceleration structure



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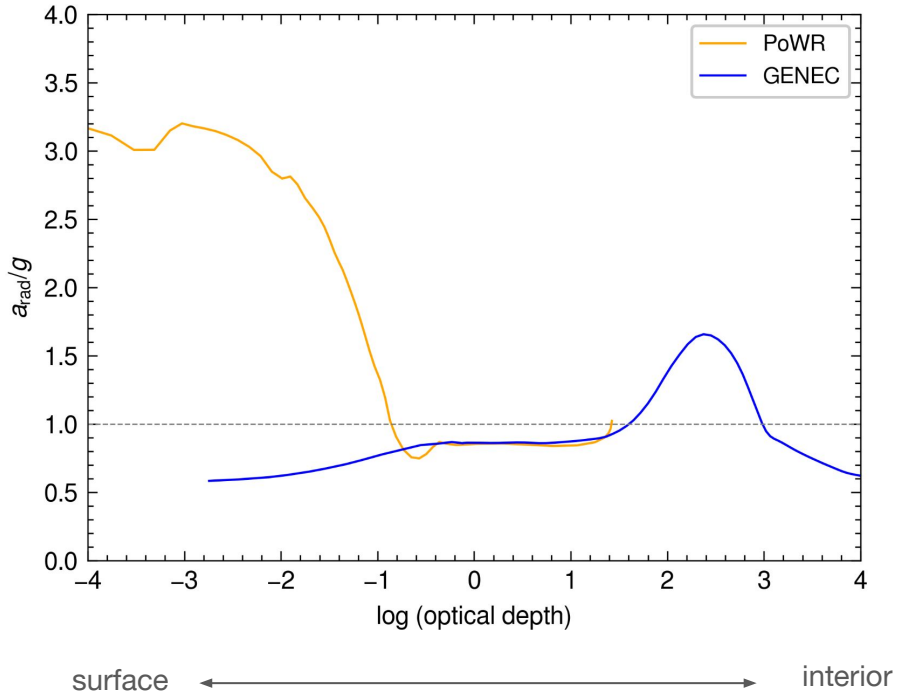

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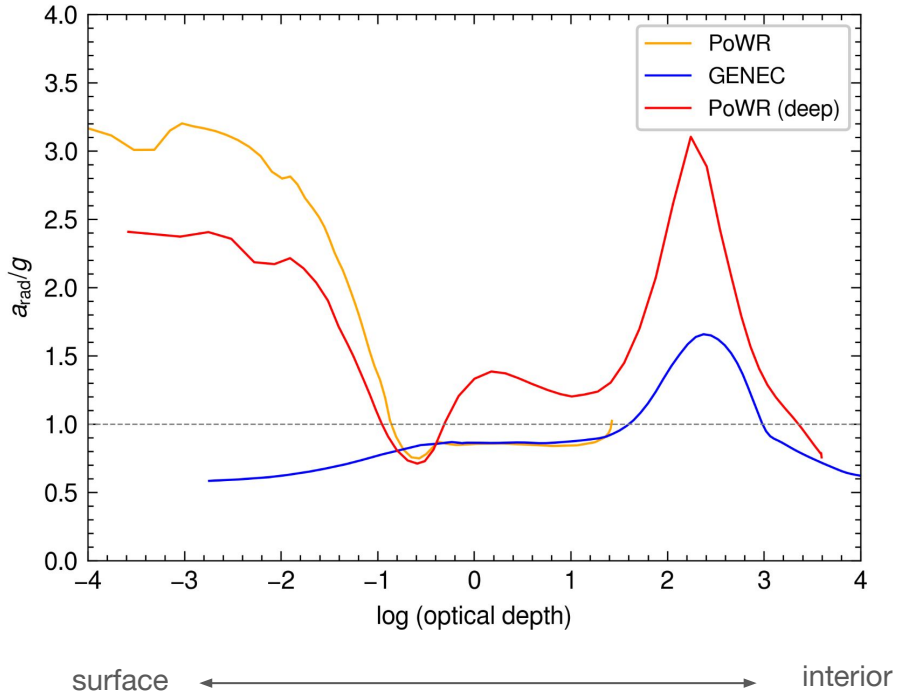
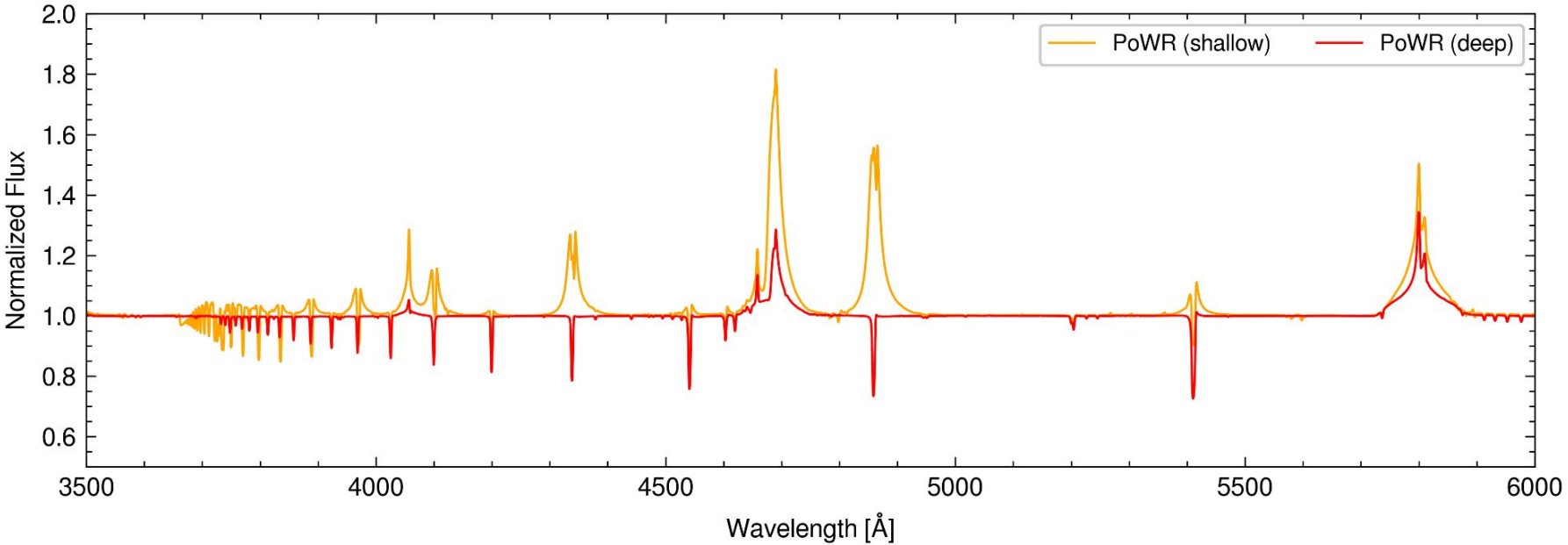


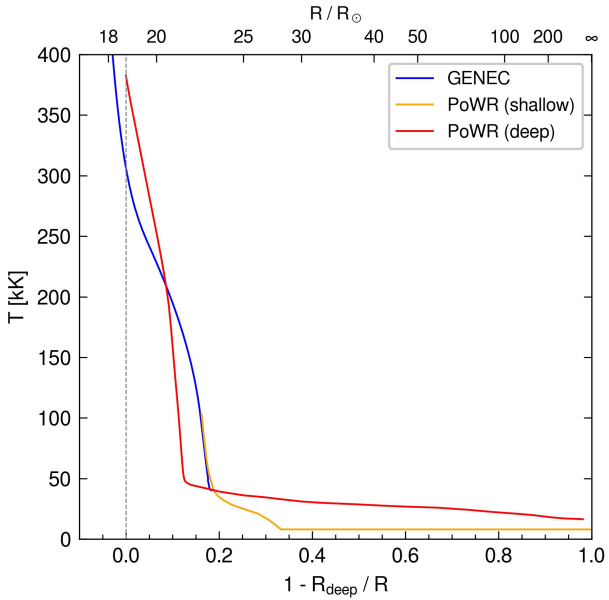
Does the atmosphere depth change spectra? YES!

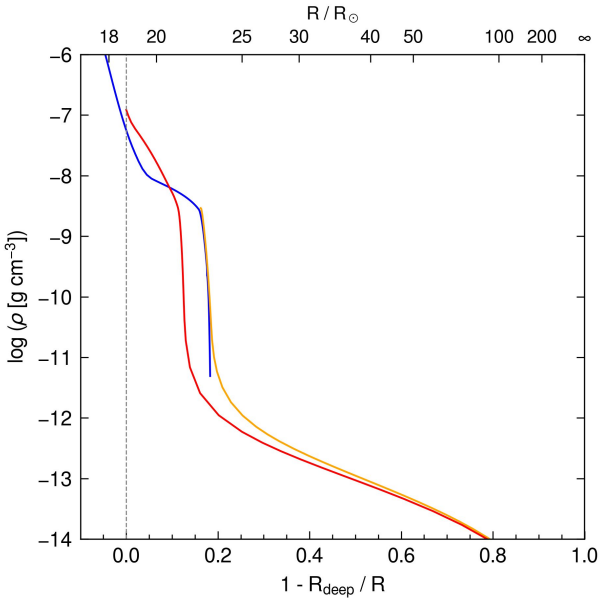


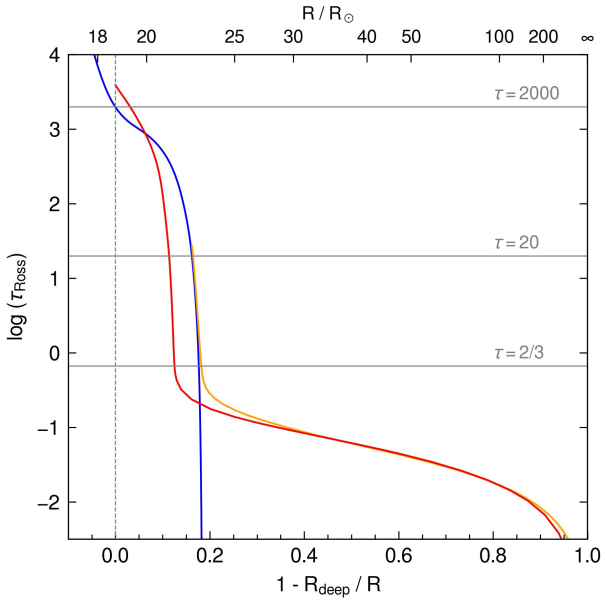
Structure comparison

Shallow cutoff: TAUMAX = 20

Deep cutoff: TAUMAX = 2000







Stellar evolution parameters

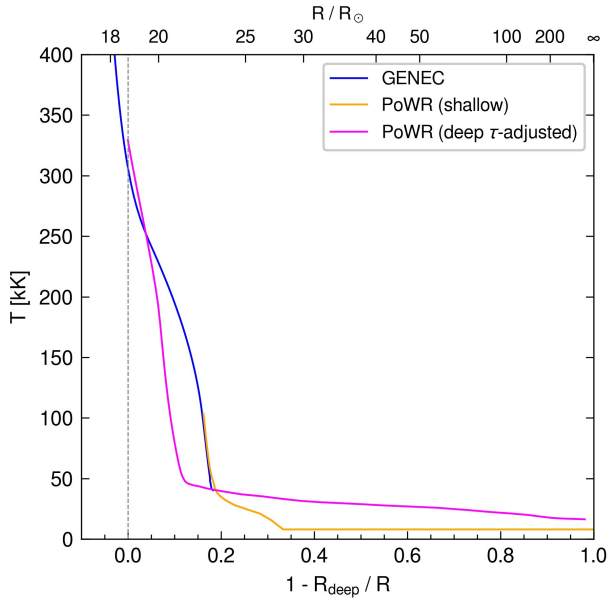
M_{ini} = 150 $M_\odot$ M =135 $M_\odot$ logL = 6.39 R_{deep} = 18.68 $R_\odot$ t_{evol} = 0.85 Myr log $\dot{M}$ = –4.63 v_∞ = 3992 km/s

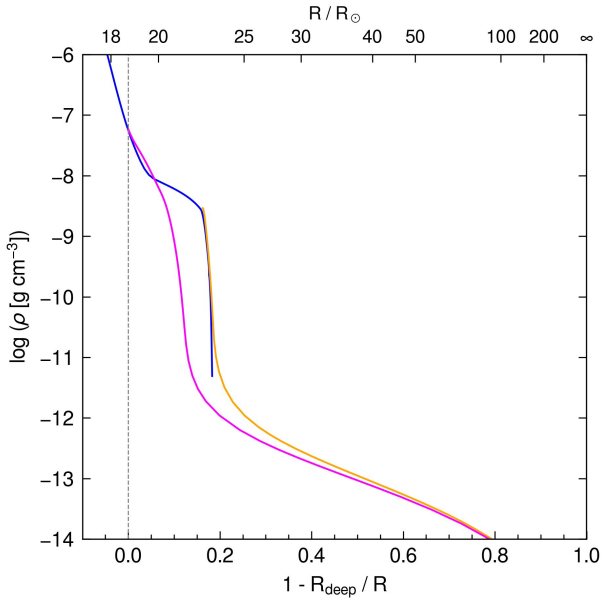
Structure comparison

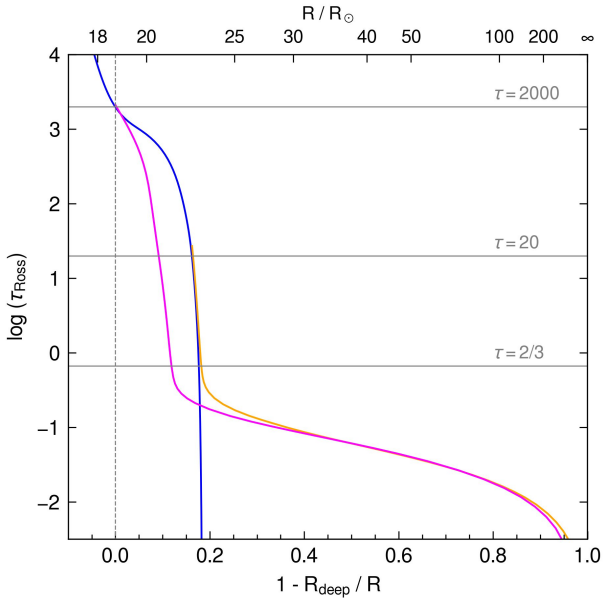
Shallow cutoff: TAUMAX = 20

Deep cutoff: TAUMAX = 911

(corresponds to τ≈2000 with lines)







Stellar evolution parameters

M_{ini} = 150 $M_\odot$ M =135 $M_\odot$ logL = 6.39 R_{deep} = 18.68 $R_\odot$ t_{evol} = 0.85 Myr log $\dot{M}$ = –4.63 v_∞ = 3992 km/s

Further work…

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evolution of VMS atmosphere structure

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deep vs. shallow atmosphere models

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deep vs. shallow atmosphere models

connection to stellar structure models

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physical origin of VMS features in spectra

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spectral classification of VMS from evolution codes

Summary

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1. GENEC stellar evolution grid with new mass-loss scheme for 100-350 Msol

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(To be applied to the whole grid in the future)

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2. PoWR atmosphere models on 150 $M_{\odot}$, connect at different optical depths
   (To be applied to the whole grid in the future)

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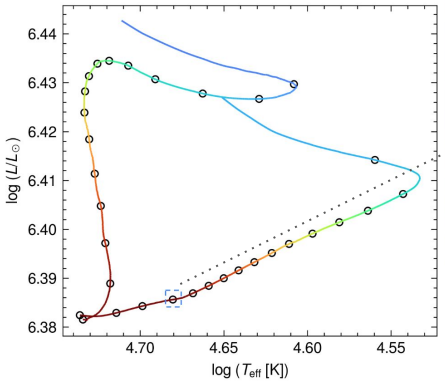
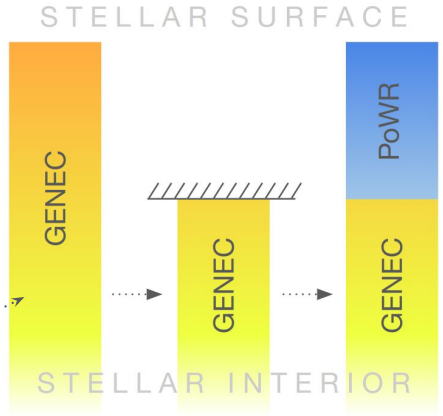
   e.g. spectral classification at 0.85 Myr unclear (WR or O?)

4. Quantitative analysis + interpretation to be done in future

GENEC Evolution models





Structure & spectra from PoWR atmosphere models →