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SEIT 1386

Spectral evolution of Very Massive Stars on the Main Sequence

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Very Massive Stars

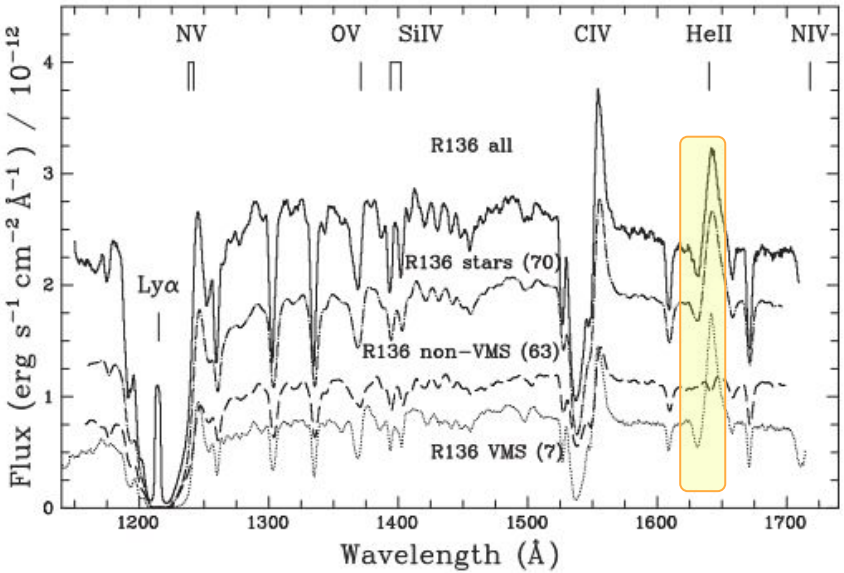
$M \gtrsim 100\ M_\odot$

$L \gtrsim 10^6\ L_\odot$

$T_{eff} \gtrsim 10\,000$ K

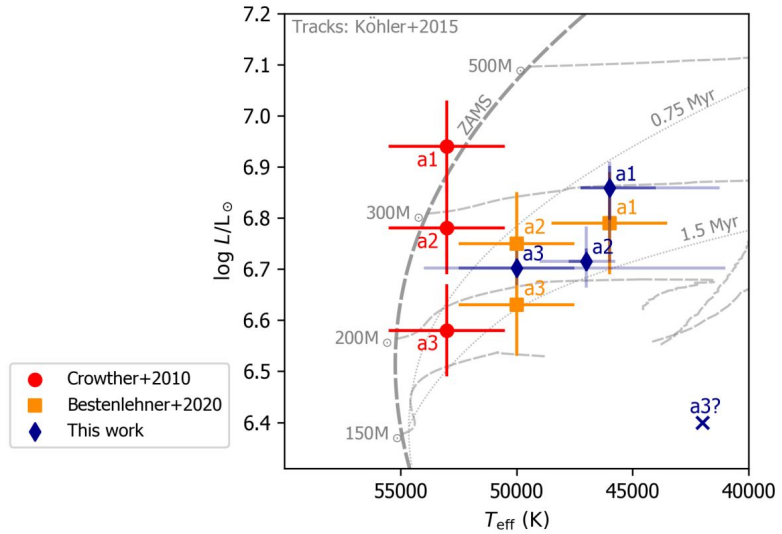
R136 spectrum + VMS contribution

Crowther et al. (2016)



VMS in the R136 cluster (LMC)

Brands et al. (2022)



Evolution modeling — a broad overview

Codes: MESA, GENEC, BEC, PARSEC, …

Procedure

1. Solve stellar structure equations
2. Evolve over a small timestep
   (mass loss, nuclear reactions, …)

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

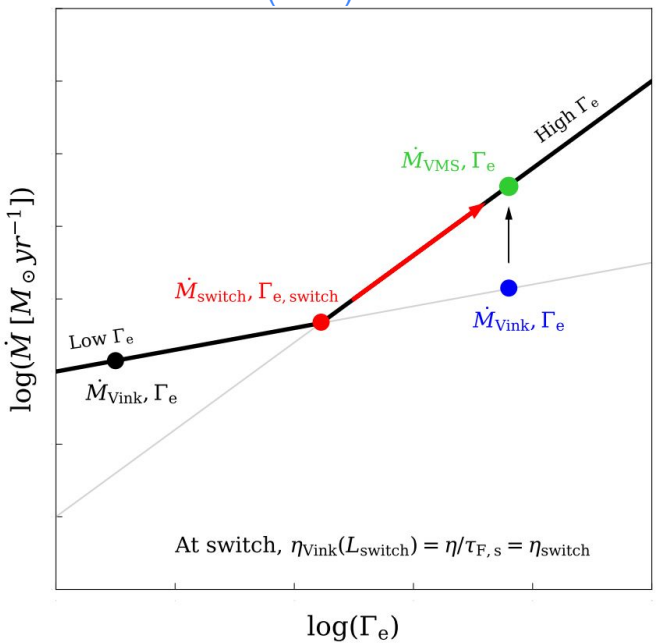
Dedicated mass-loss scheme (Sabhahit et al. 2022)

Initial masses: 100–350 $M_\odot$

Metallicity: Solar

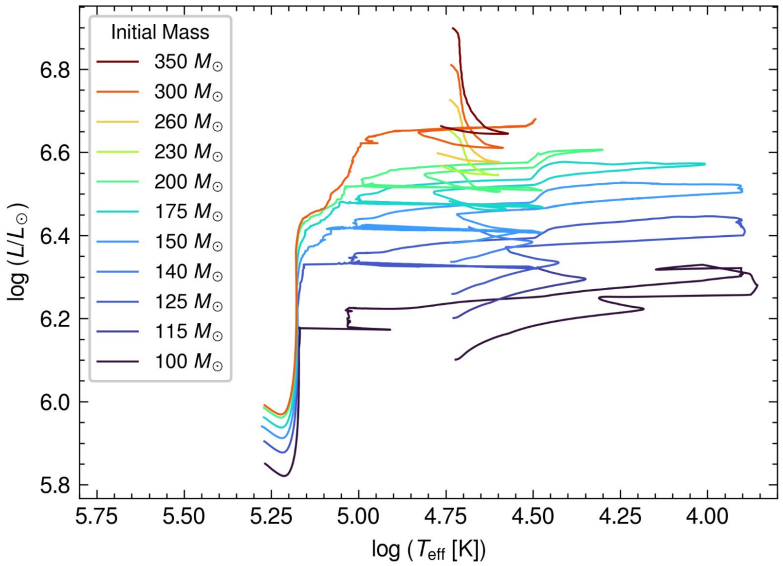
Rotation: 0; 10% V_{crit}

Sabhahit et al. (2023)

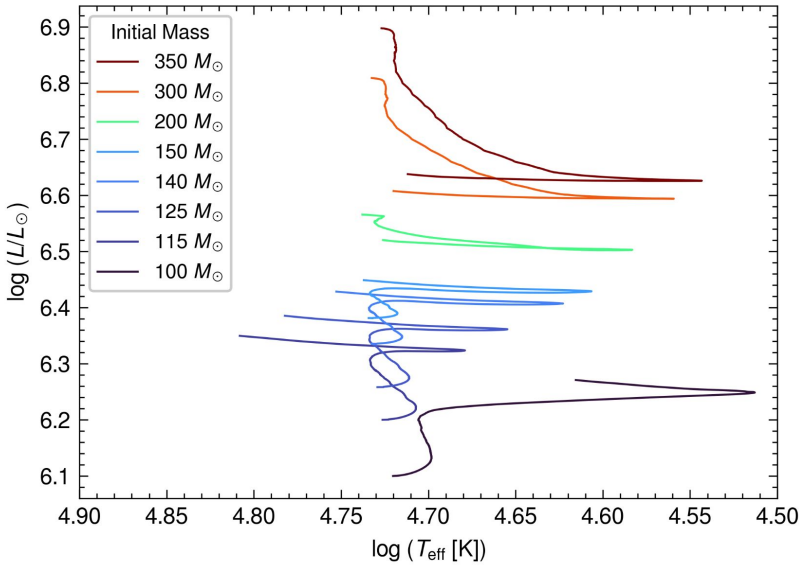


Evolution grid

Non-rotating



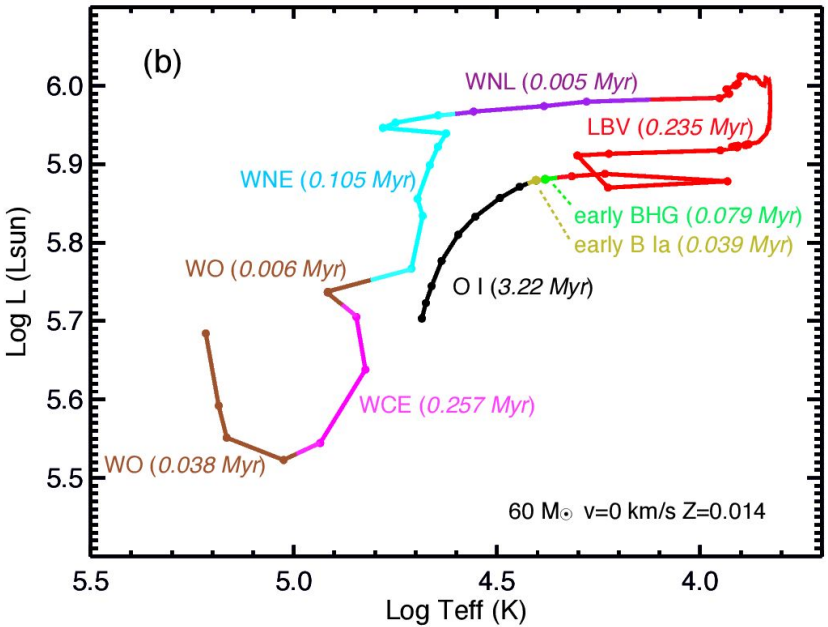
Rotating (Main sequence only)



Atmosphere models on evolution tracks

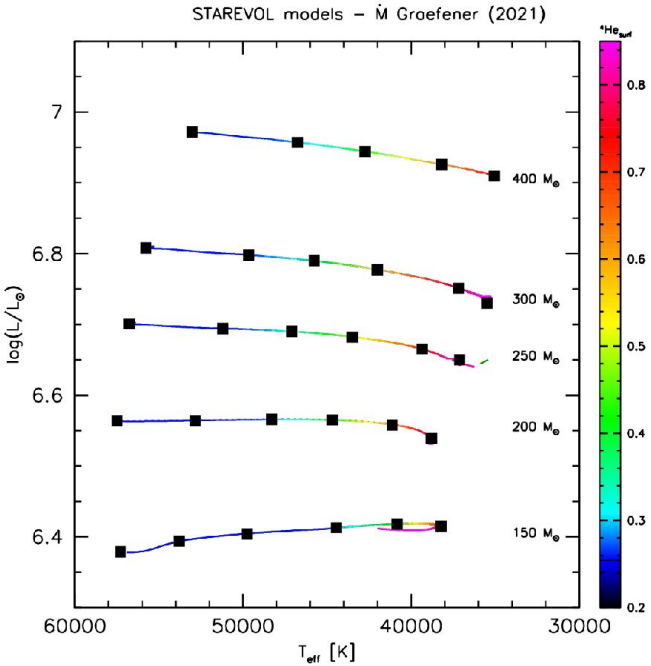
Non-rotating 60$M_\odot$ model

Groh et al. (2014)

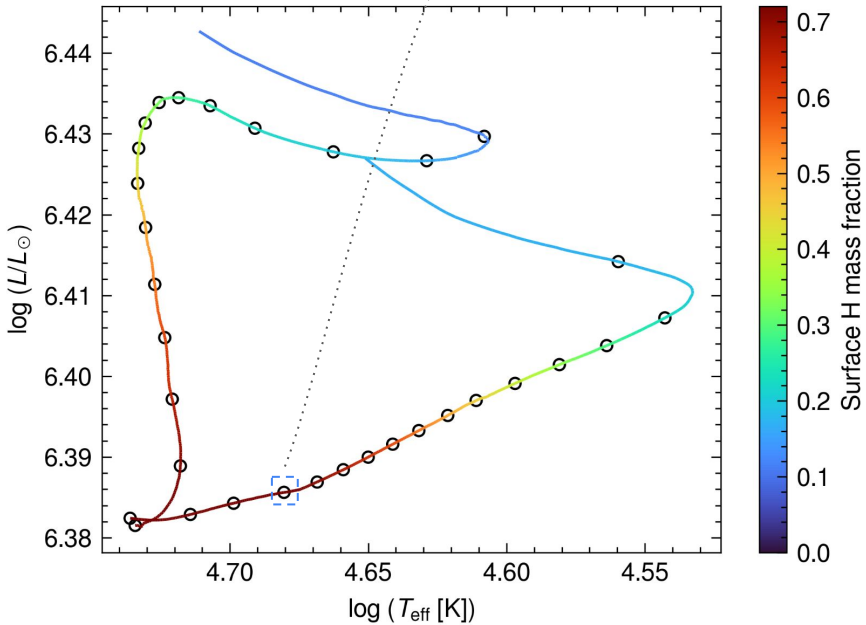


Very massive stars in LMC

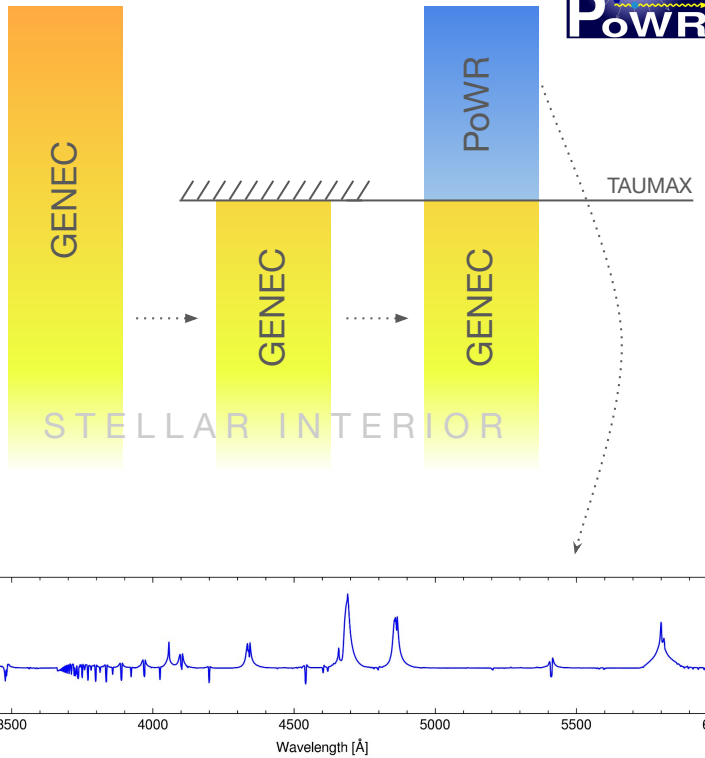
Martins & Palacios (2022)

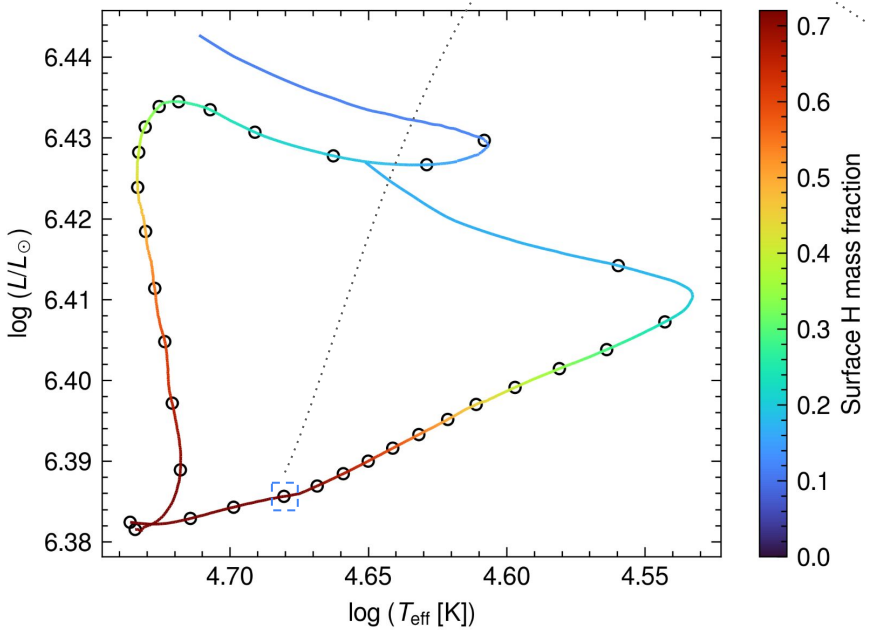


Atmosphere grid



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





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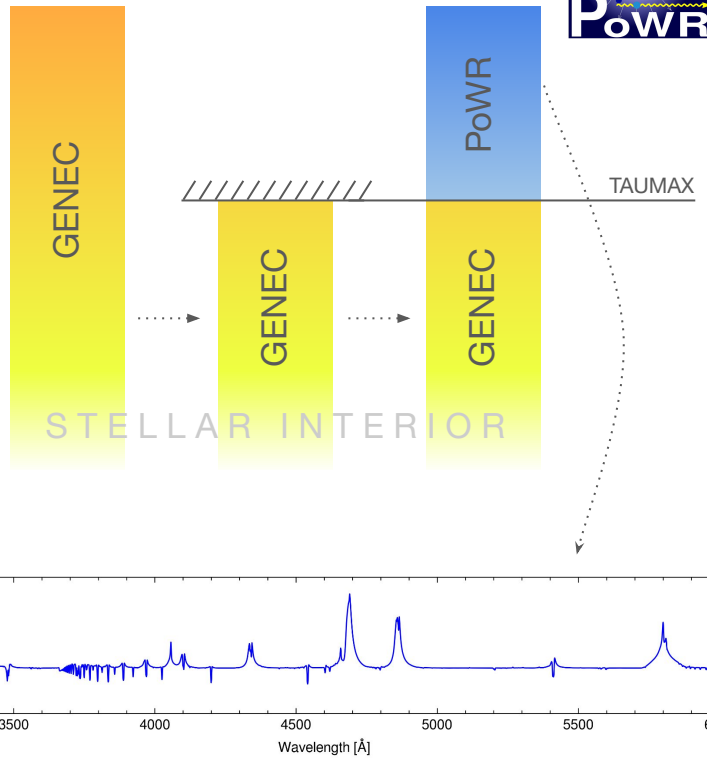
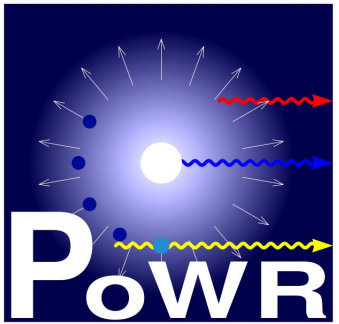


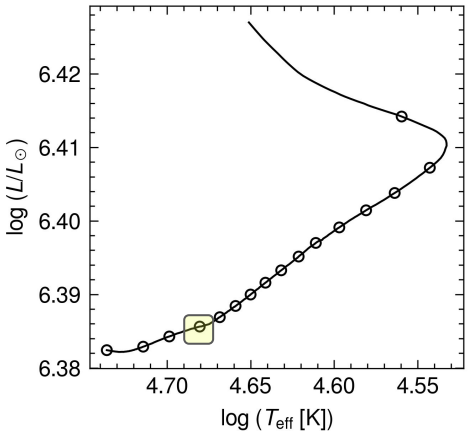
Atmosphere modeling

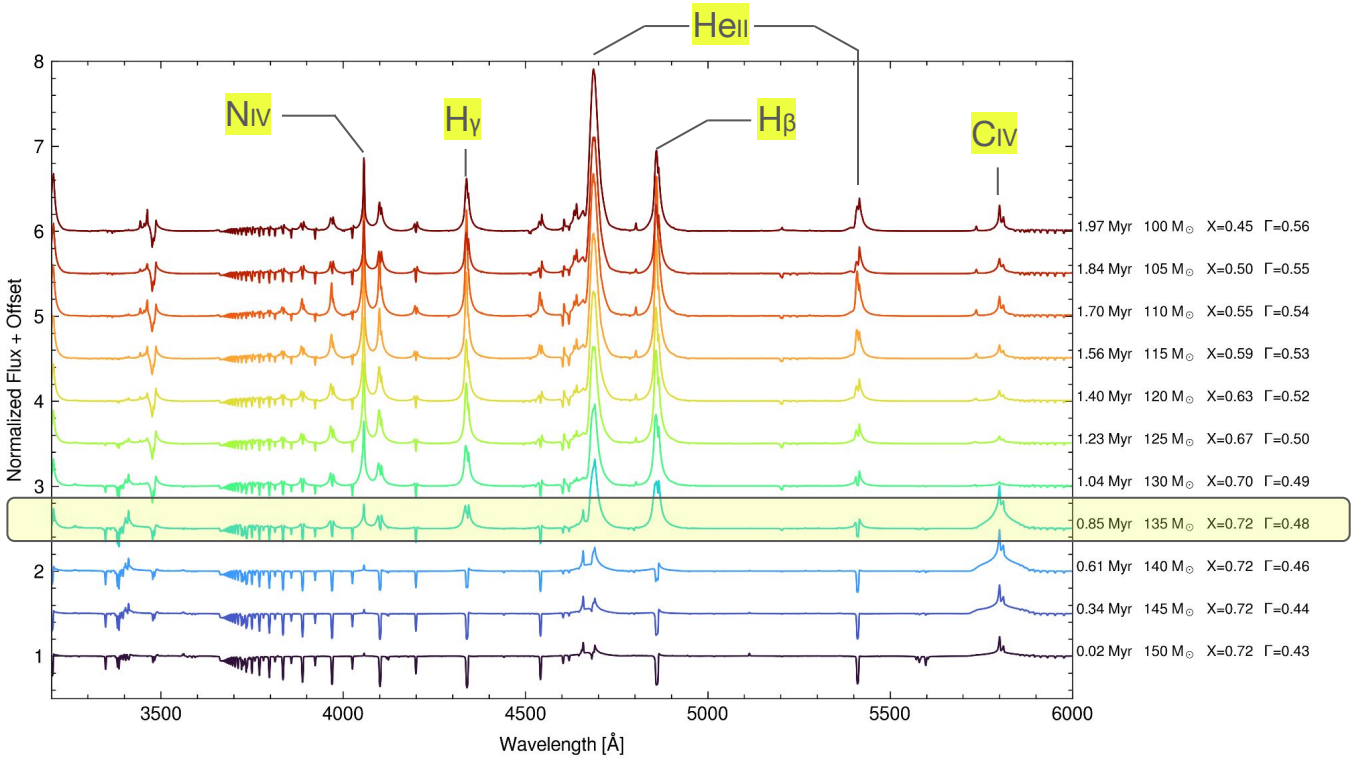
For preliminary modeling:

- cut @ TAUMAX=20 (spectral line formation happens above this)
- only include H, He, C, N, O, Fe
- hydrostatic integration + beta-law
- stellar parameters taken from GENEC models

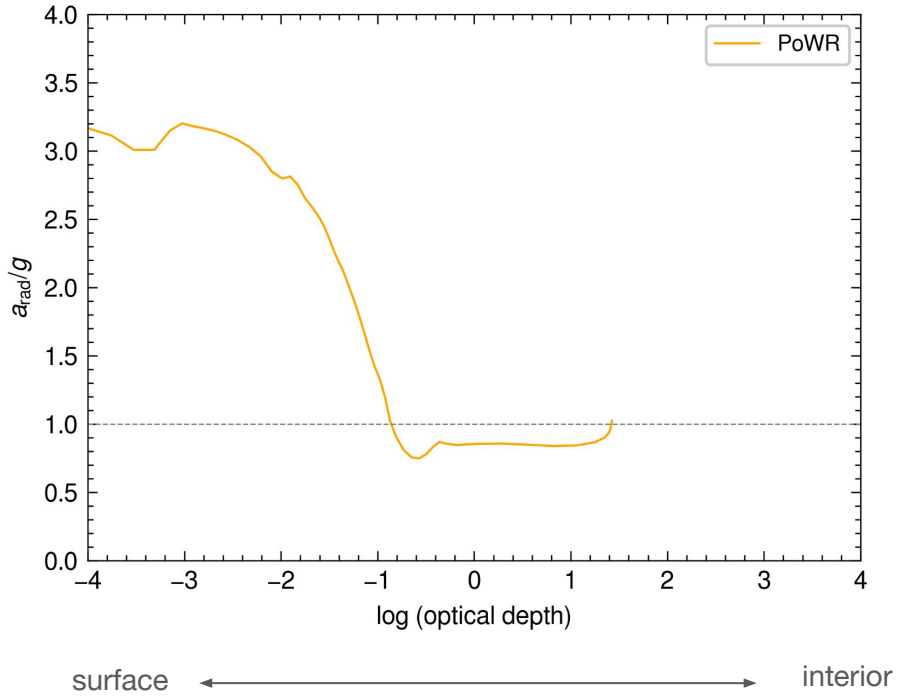


Spectral evolution of a non-rotating 150 $M_\odot$ star





Acceleration structure



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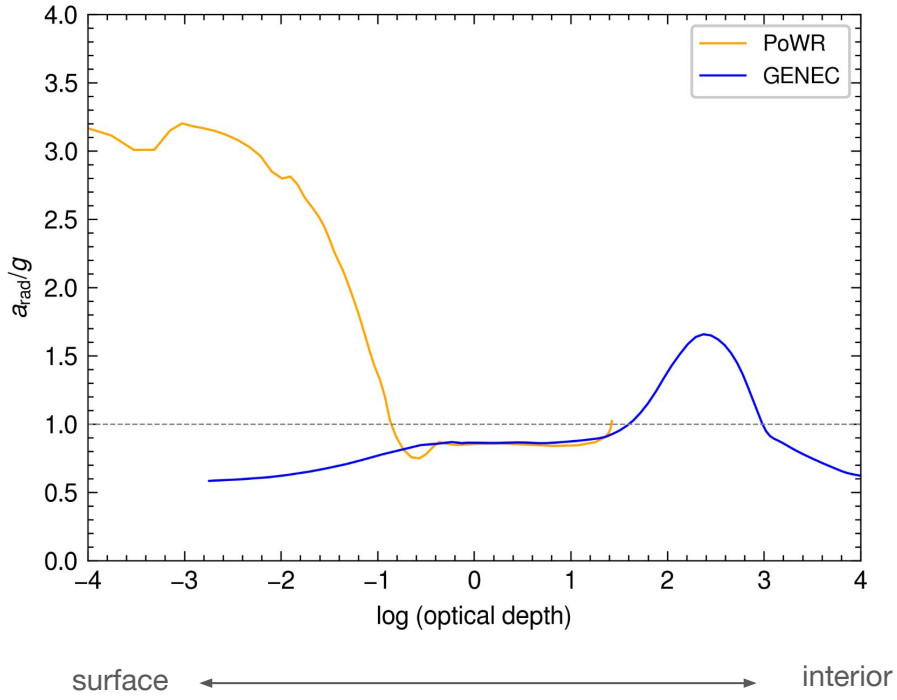
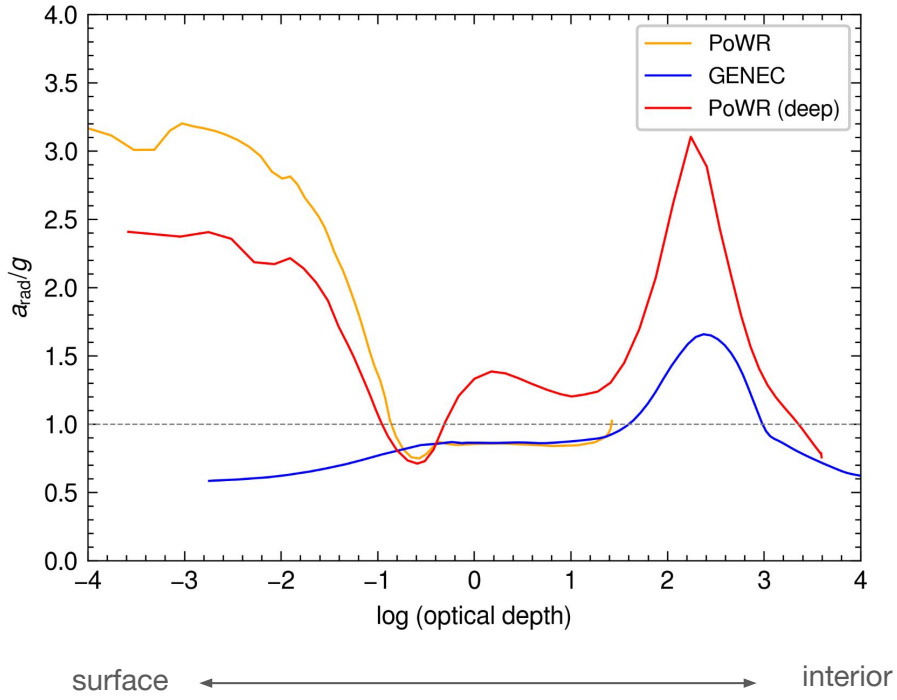
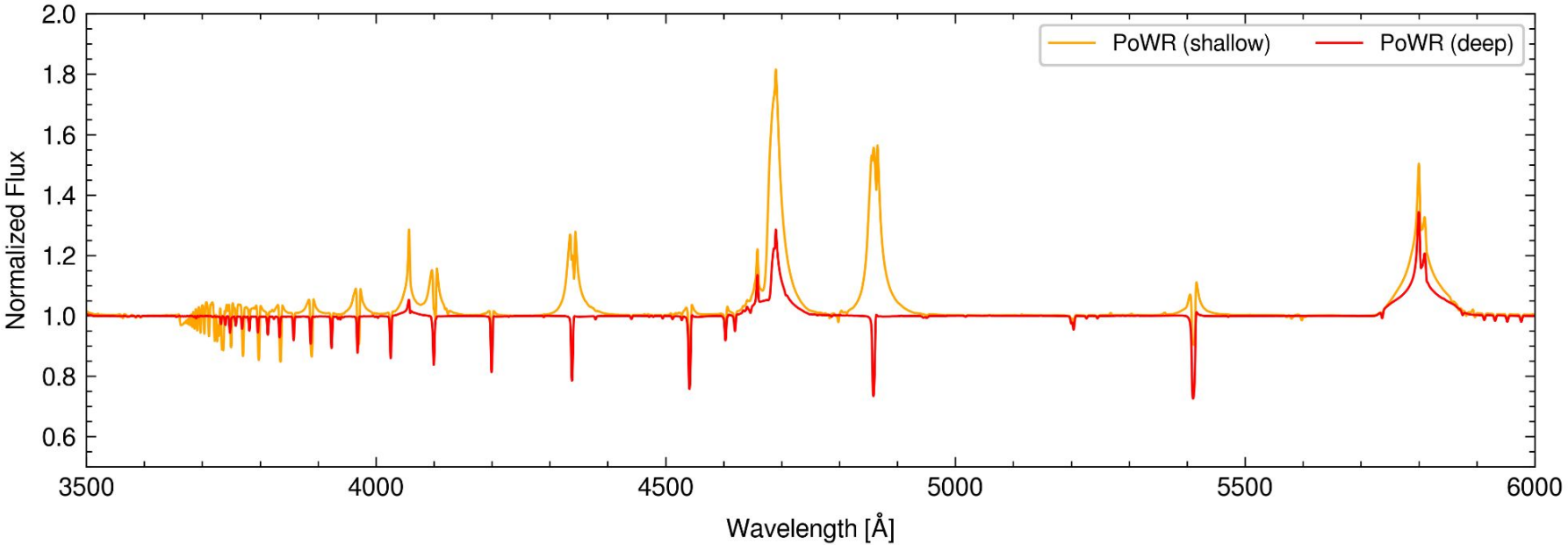


Acceleration structure



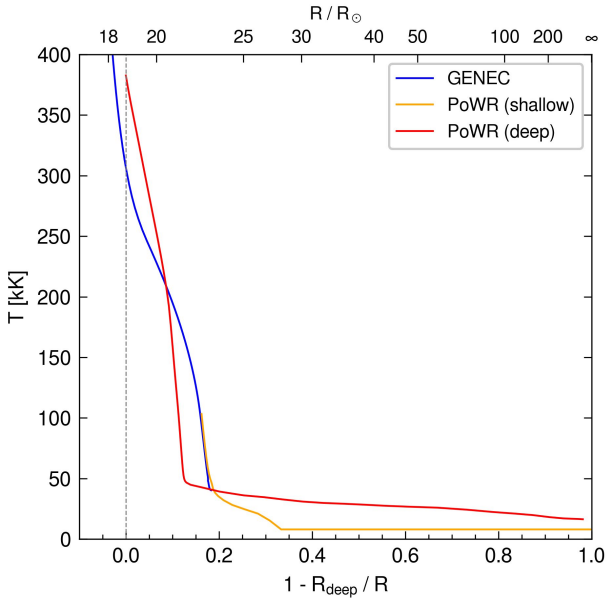
Does the atmosphere depth change spectra? YES!

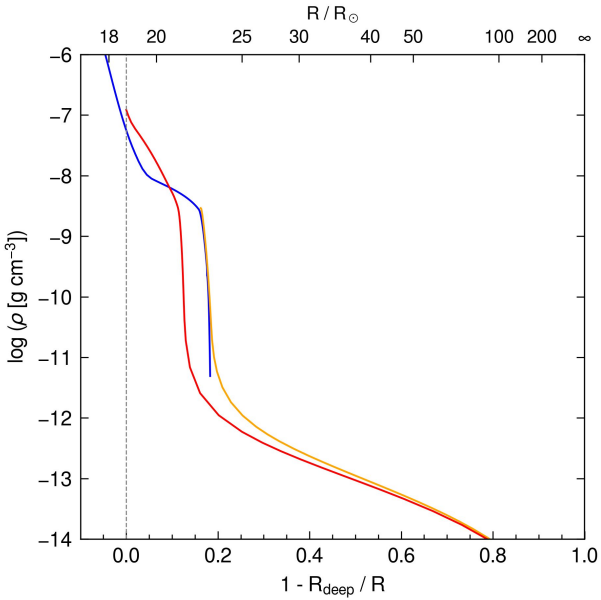


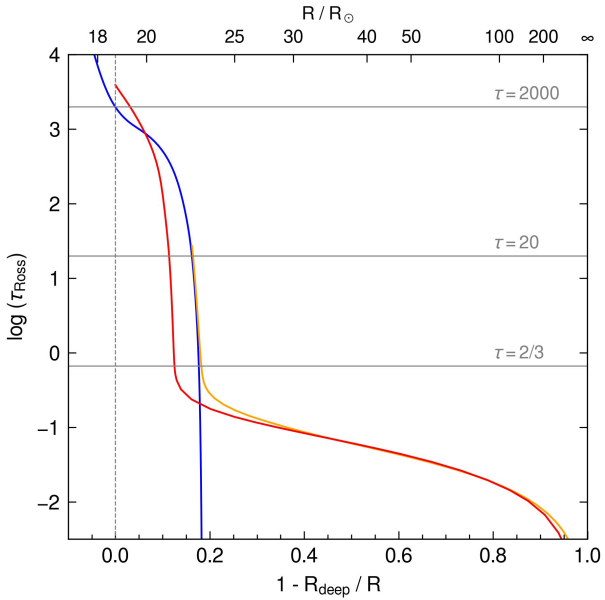
Structure comparison

Shallow cutoff: TAUMAX = 20

Deep cutoff: TAUMAX = 2000







Stellar evolution parameters

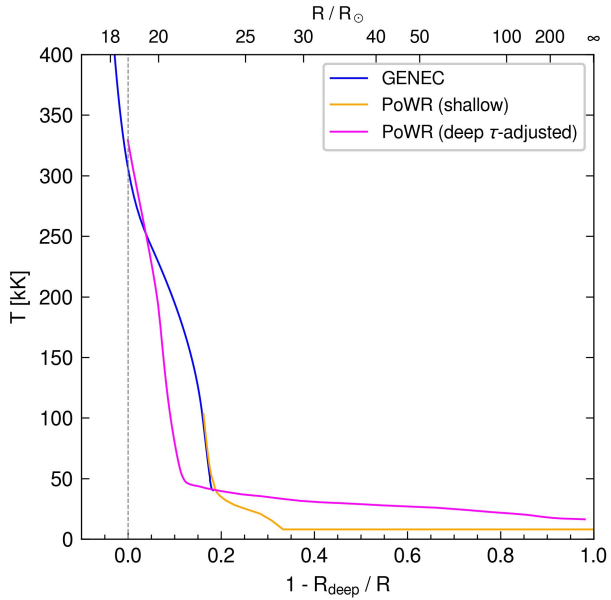
M_{ini} = 150 $M_\odot$ M =135 $M_\odot$ logL = 6.39 R_{deep} = 18.68 $R_\odot$ t_{evol} = 0.85 Myr log $\dot{M}$ = –4.63 v_∞ = 3992 km/s

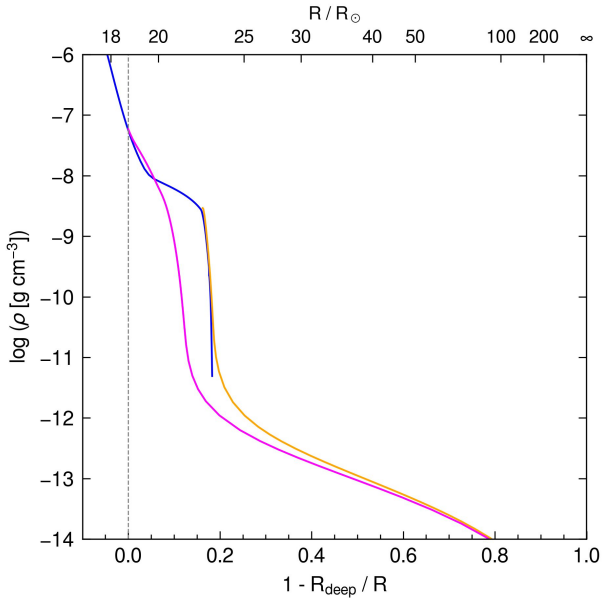
Structure comparison

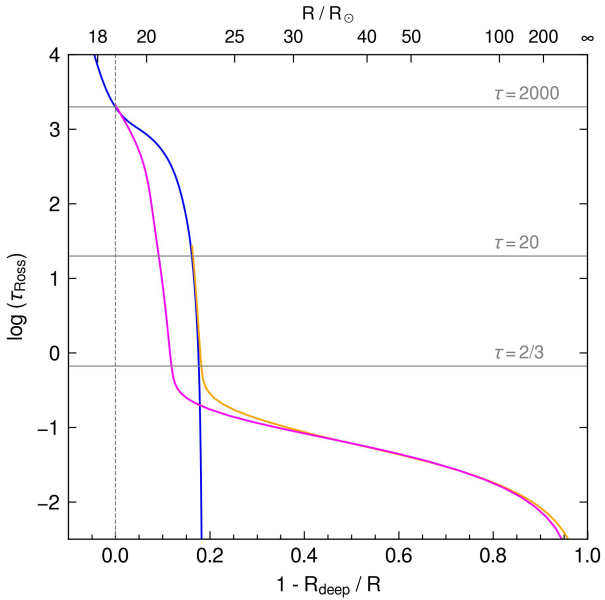
Shallow cutoff: TAUMAX = 20

Deep cutoff: TAUMAX = 911

(corresponds to τ≈2000 with lines)







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Further work…

evolution of VMS atmosphere structure

deep vs. shallow atmosphere models

connection to stellar structure models

physical origin of VMS features in spectra

spectral classification of VMS from evolution codes

Summary

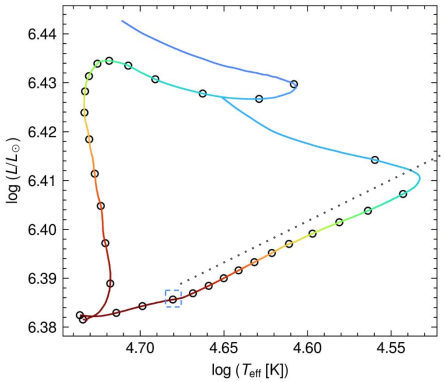
1. GENEC stellar evolution grid with new mass-loss scheme for 100-350 Msol

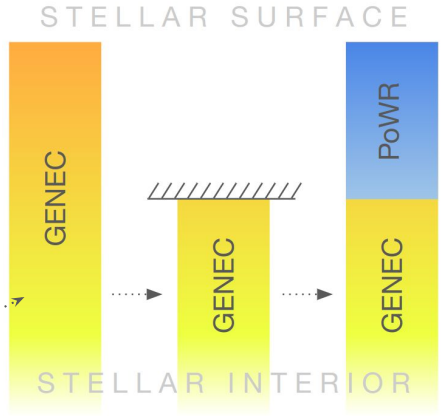
2. PoWR atmosphere models on 150 $M_{\odot}$, connect at different optical depths
   (To be applied to the whole grid in the future)

3. Connection depth significantly impacts atmosphere structure + spectra
   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 →