HITS
Heidelberg Institute for Theoretical Studies

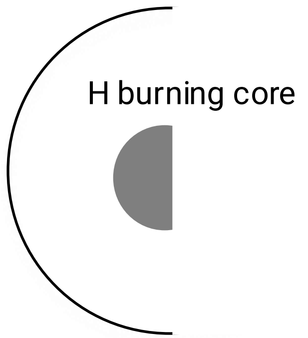
TOS
The quest for the ultimate stellar model

Red giants

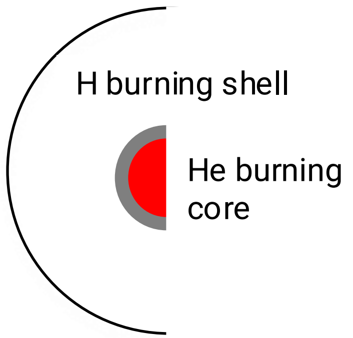
Saskia Hekker

TAs: Susmita Das; Noi Shitrit; Arthur Le Saux; Zhao Guo

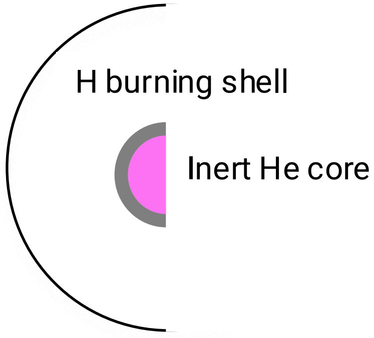
Stellar Structure & Evolution



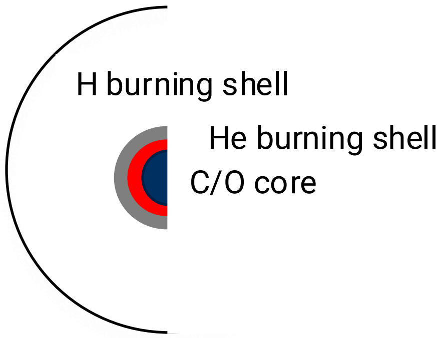
A-B main sequence



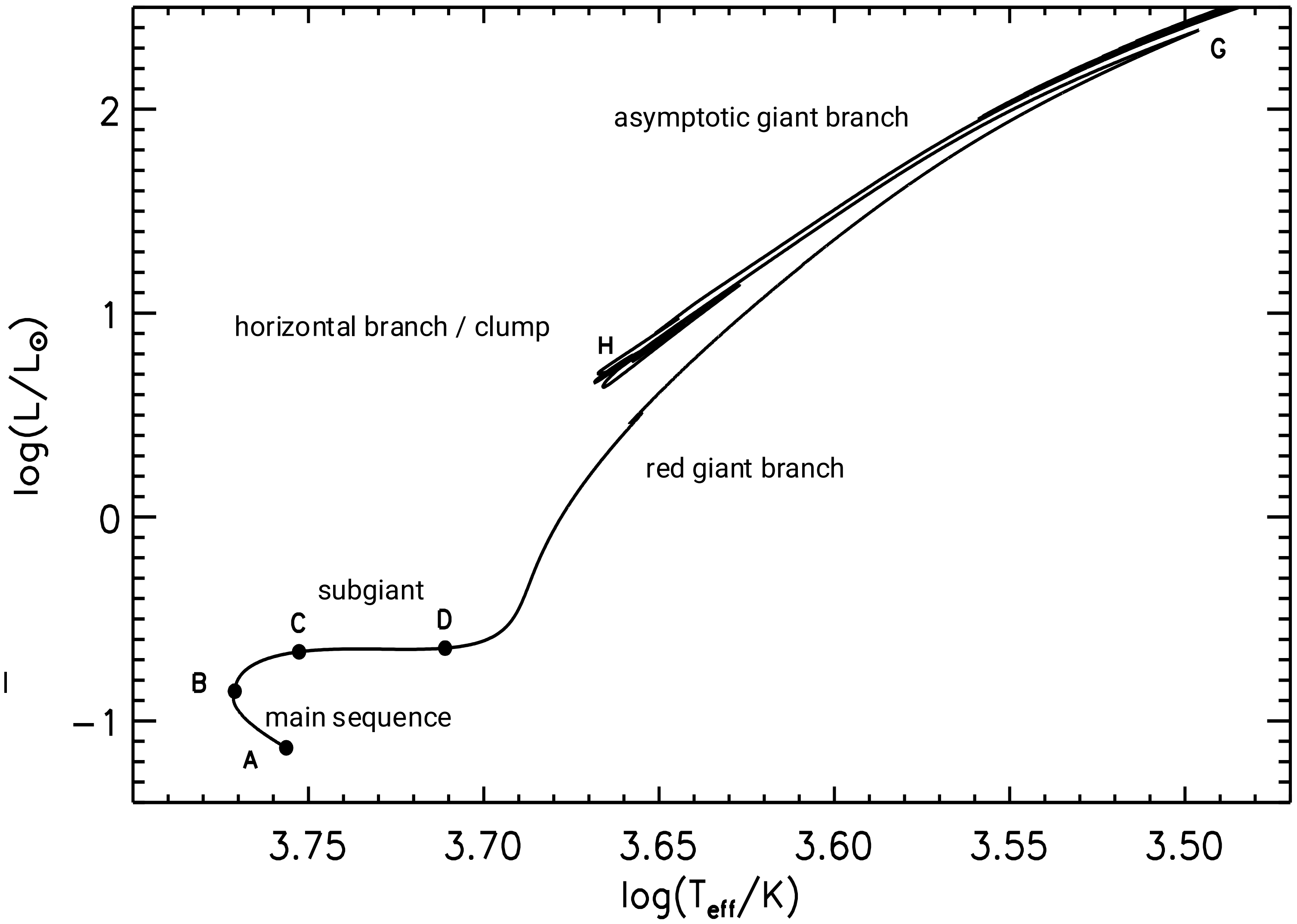
H horizontal branch / clump



B-G subgiant / red giant branch



> H asymptotic giant branch



A&A, 683, A189 (2024)
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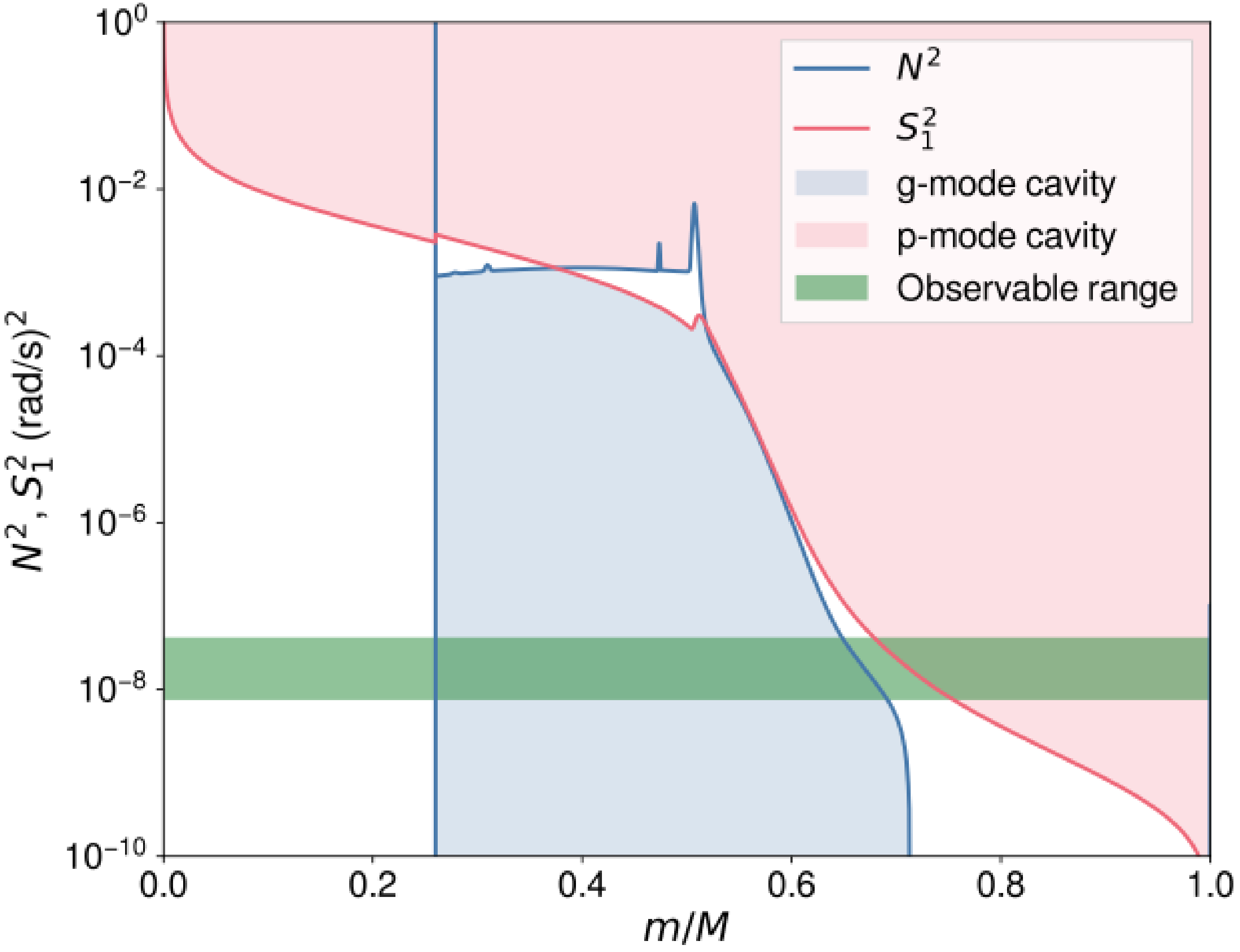
Astronomy & Astrophysics

Effect of nuclear reactions rates and core boundary mixing on the seismology of red clump stars

Anthony Noll[1], Sarbani Basu[2], and Saskia Hekker[1,3]

Core helium burning stars



$$\Delta\Pi_\ell = \frac{2\pi^2}{\sqrt{\ell(\ell+1)}}\left(\int_{r_0}^{r_1}\frac{N}{r}\mathrm{d}r\right)^{-1}$$

Core helium burning stars

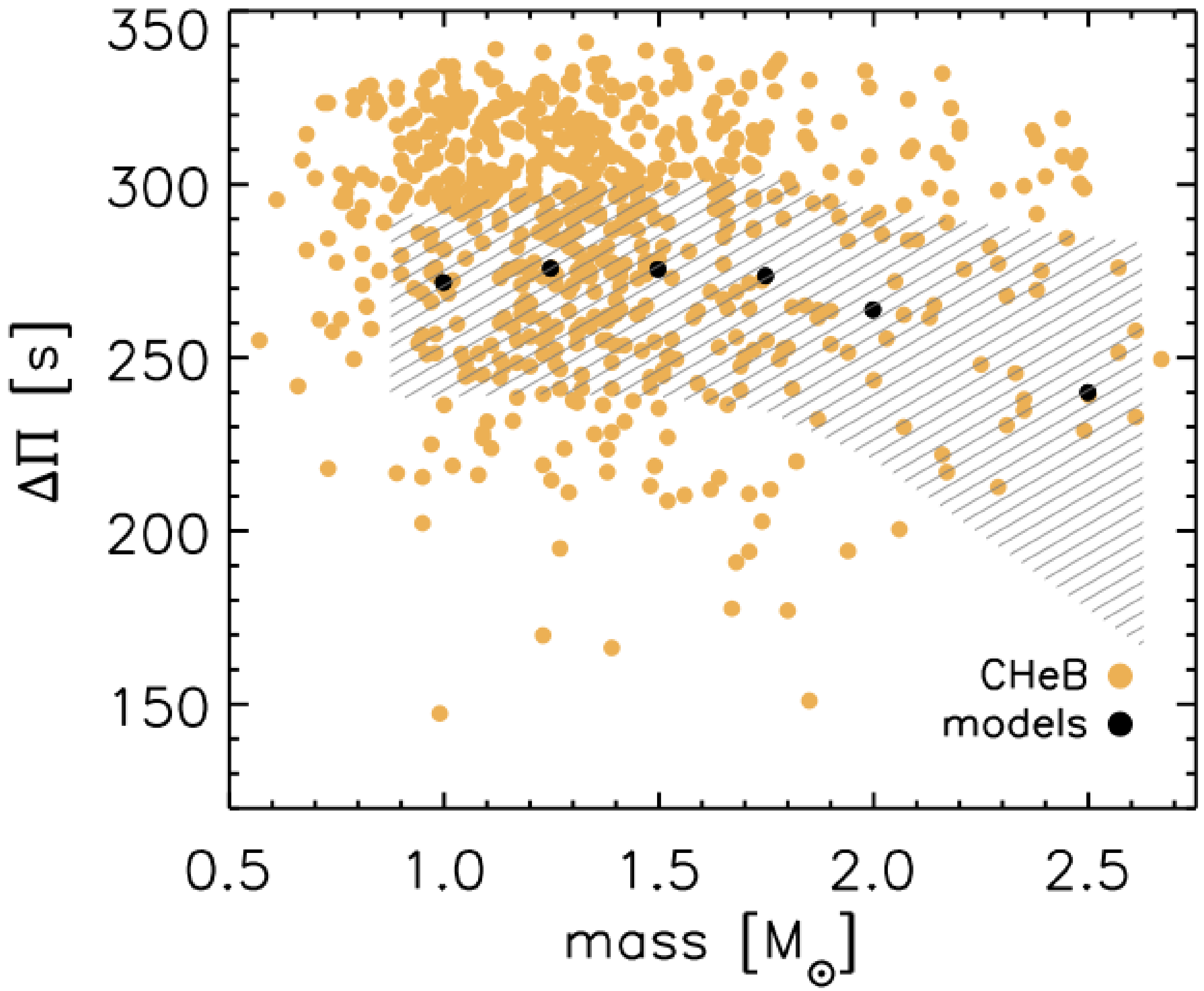
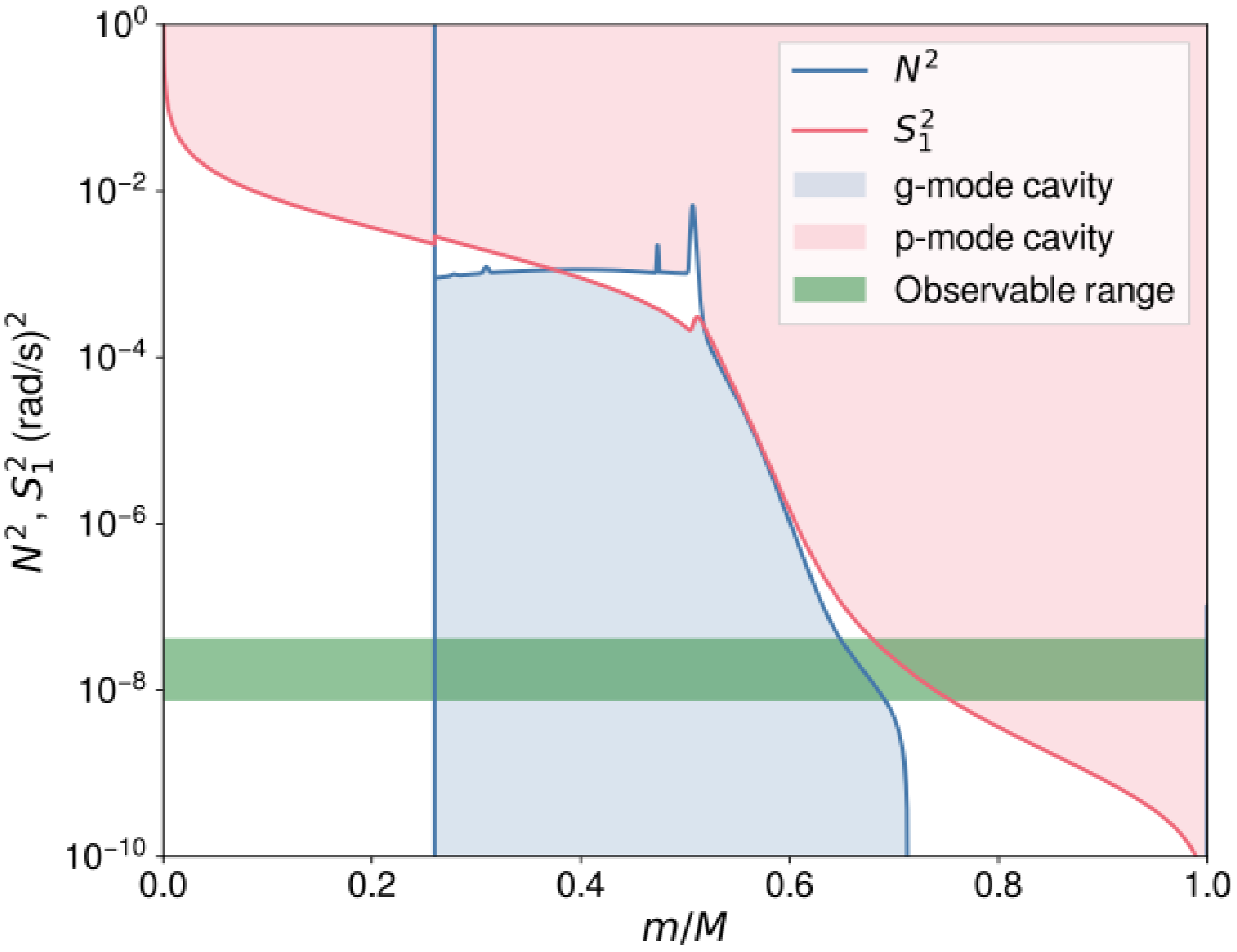


Figure from ERC Consolidator Grant proposal ‘DipolarSound’, PI Hekker

Range in ΔΠ <u>NOT</u> matched by models with canonical physics!

Core helium burning stars



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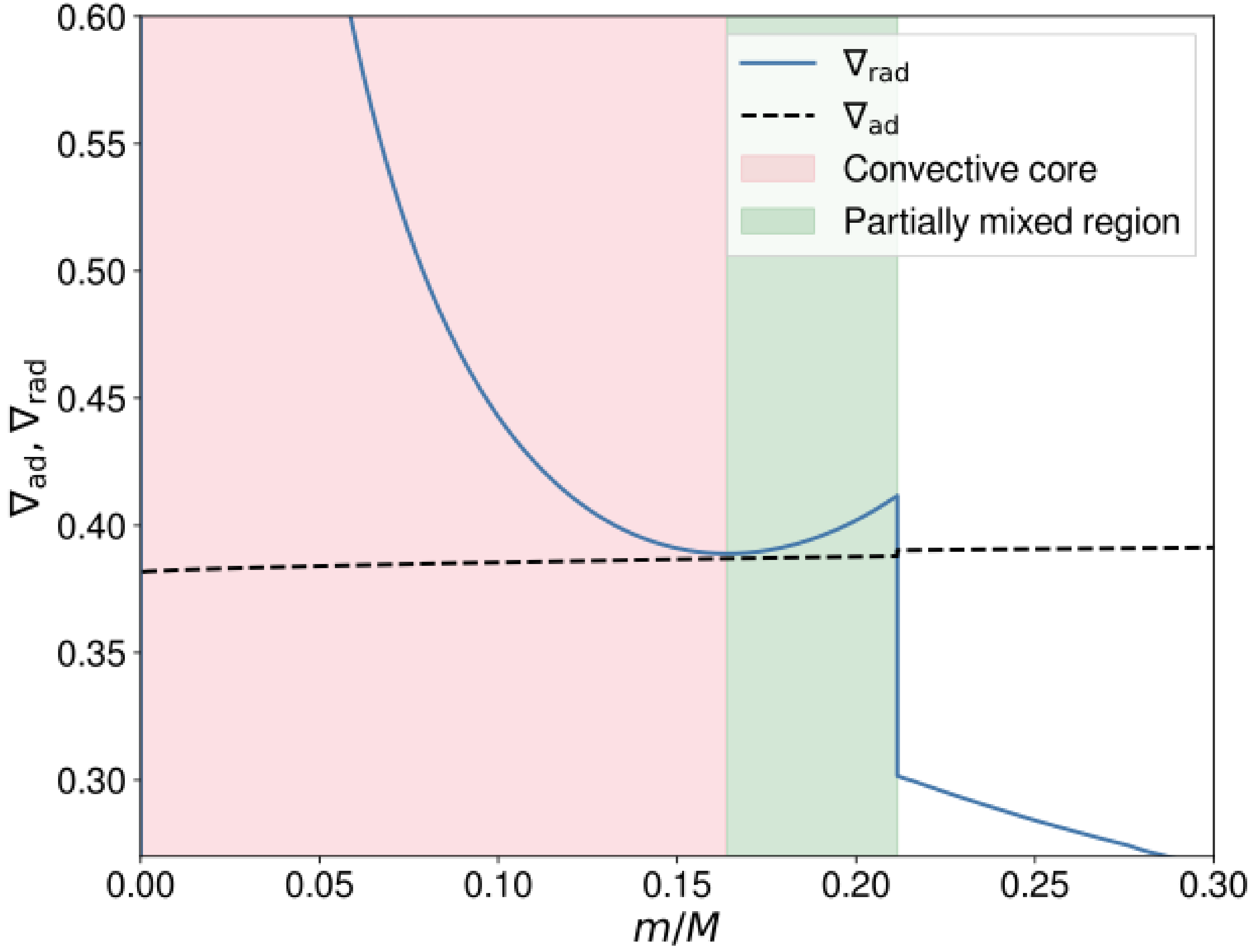
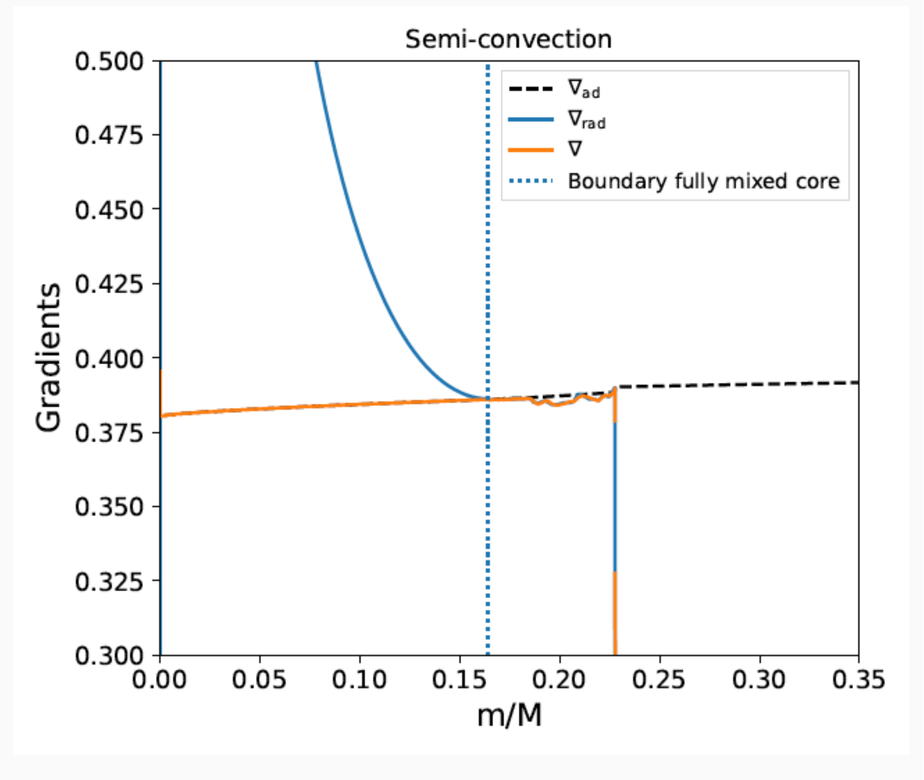
Core boundary mixing



Core boundary mixing: different prescriptions

- semi convection: partially mixed region is buoyantly neutral, i.e. $\nabla_{\mathrm{rad}} = \nabla_{\mathrm{ad}}$



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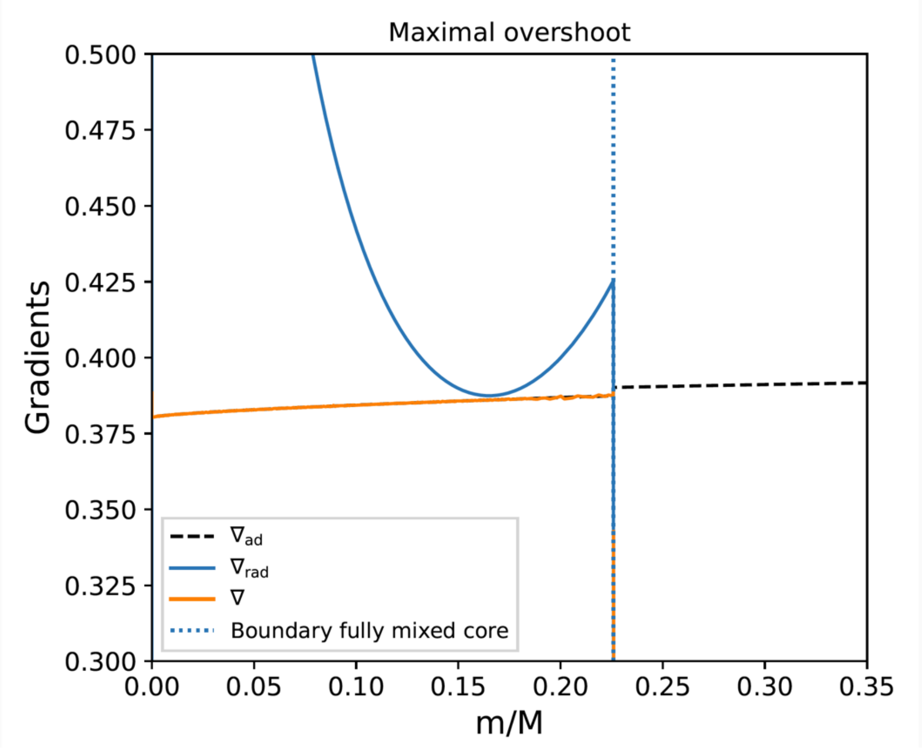
- maximal overshoot: largest core possible by including the ‘partially mixed region’



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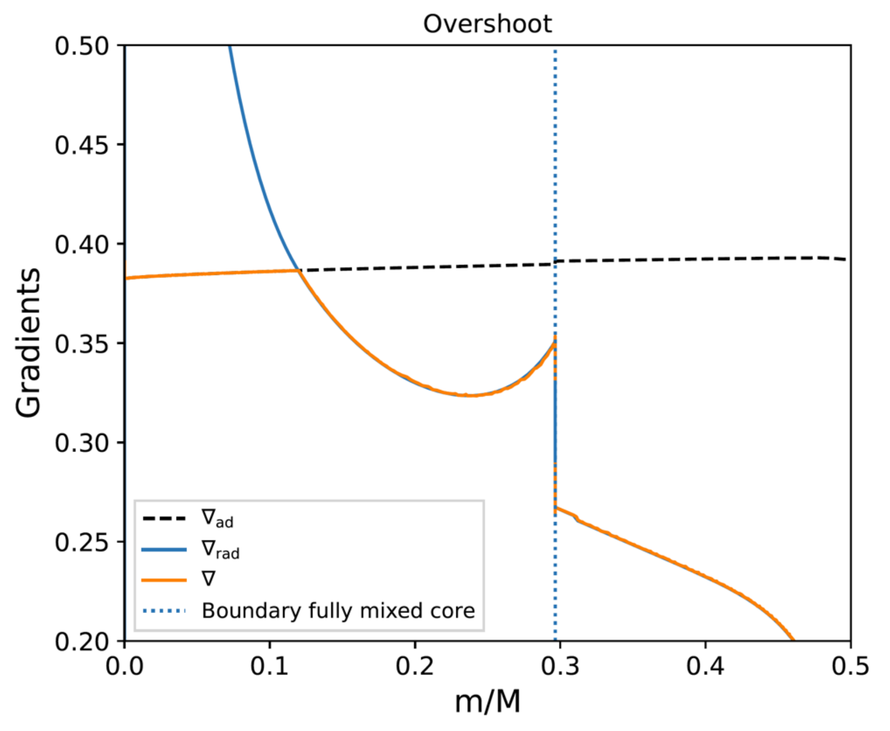

Core boundary mixing: different prescriptions

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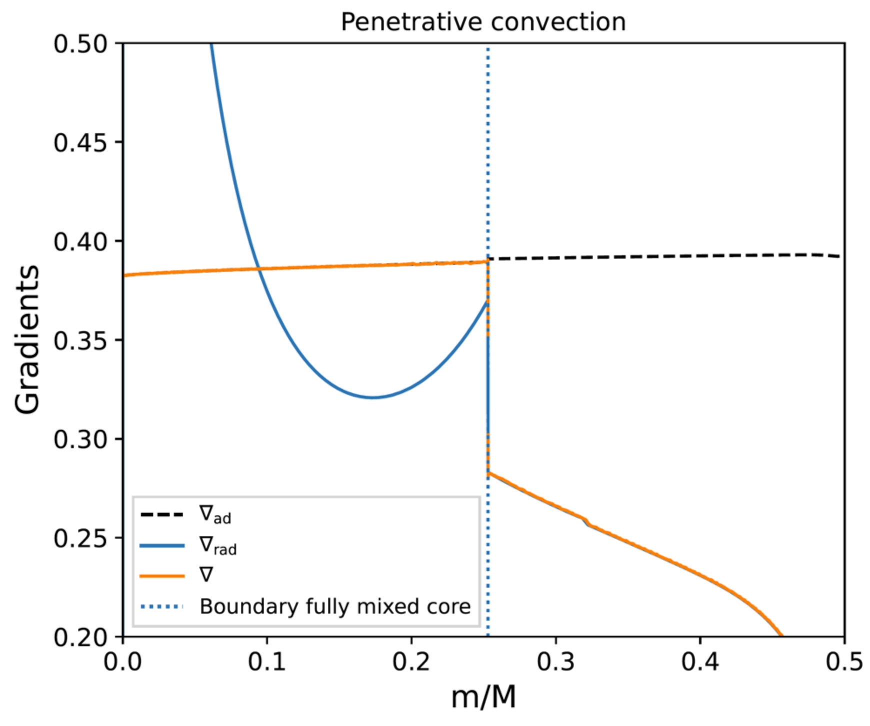
- overmixing: overshoot with $d_{ov} = \alpha_{ov} H_p$ and thermal stratification in extended region radiative ($\nabla = \nabla_{\mathrm{rad}}$)
- penetrative convection: overshoot with $d_{ov} = \alpha_{ov} H_p$ and thermal stratification in extended region adiabatic ($\nabla = \nabla_{\mathrm{ad}}$)



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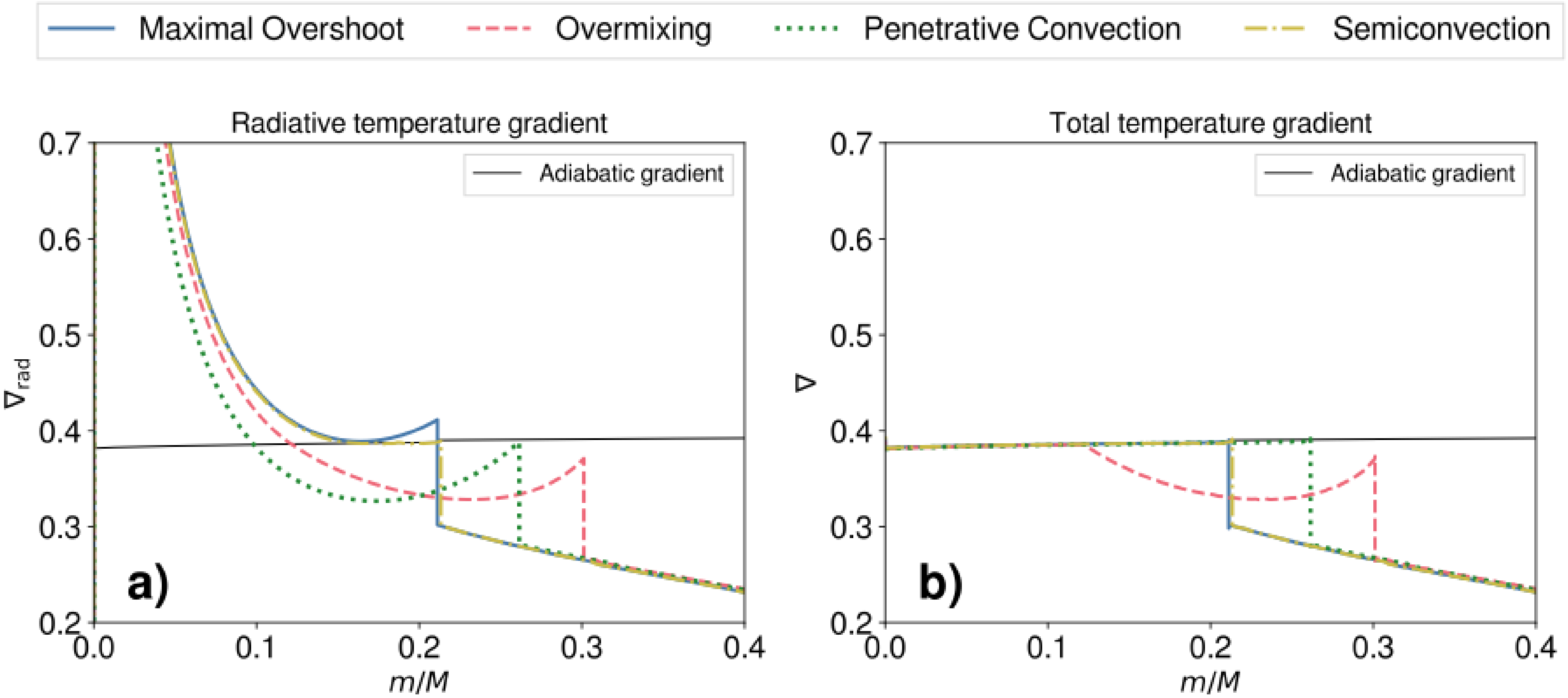
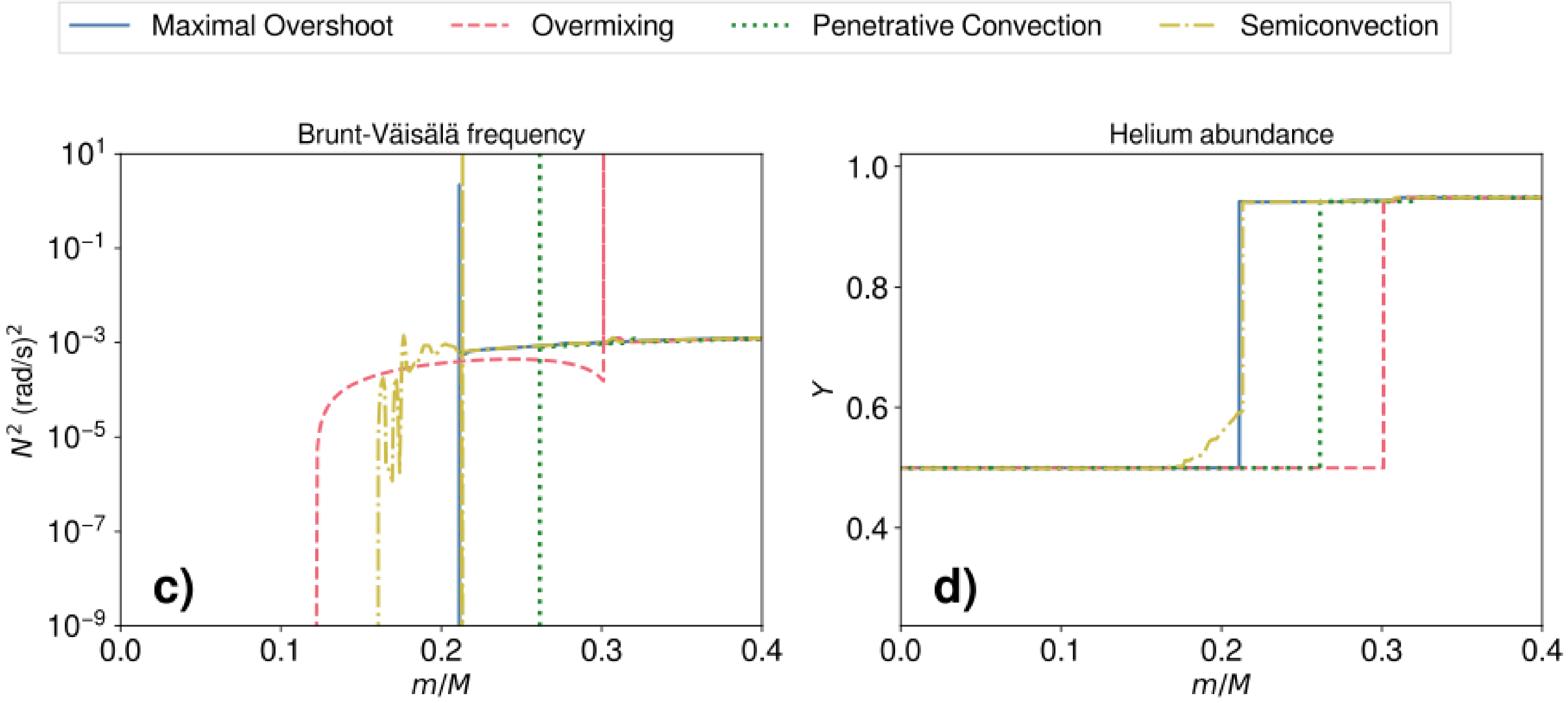
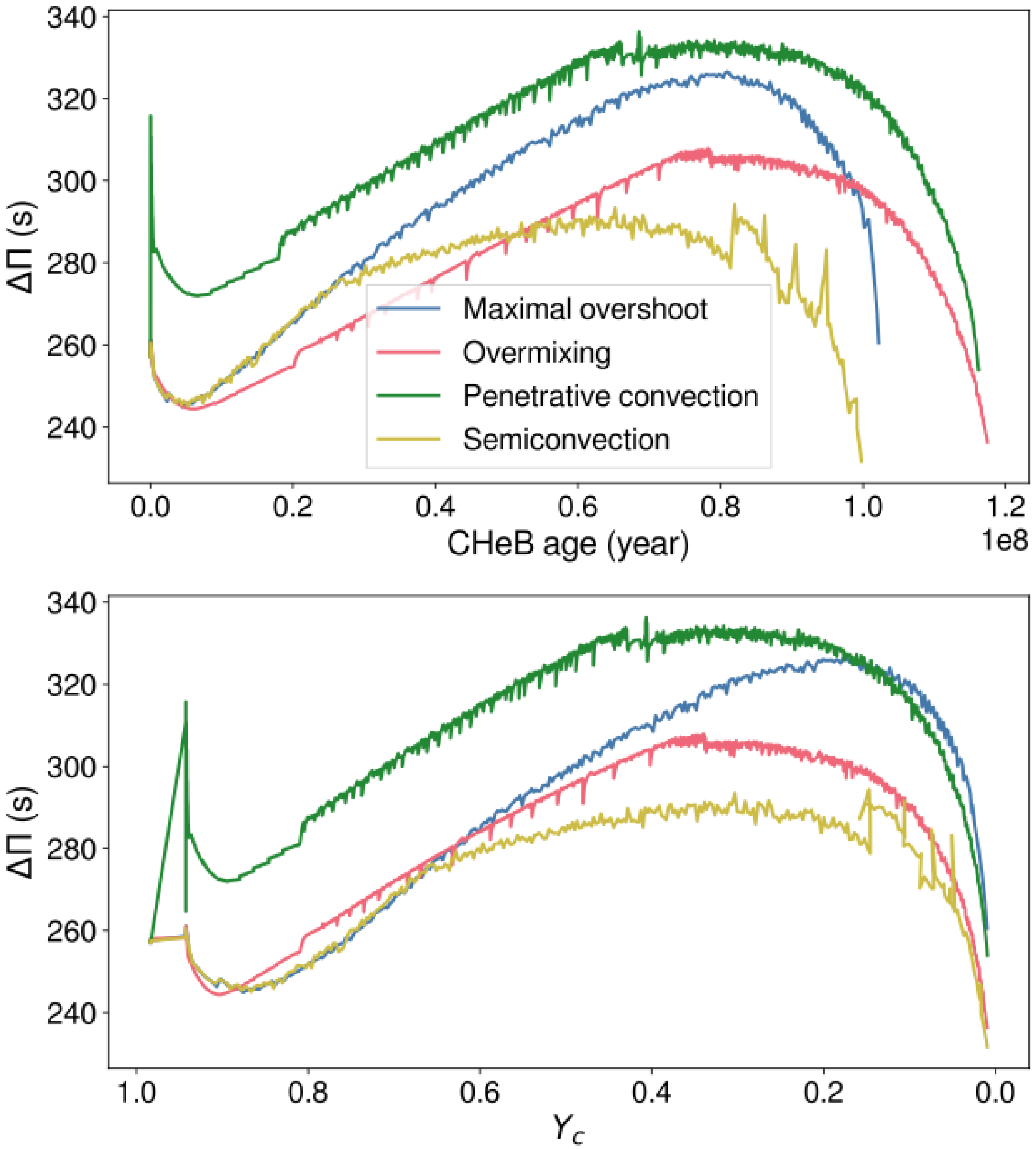


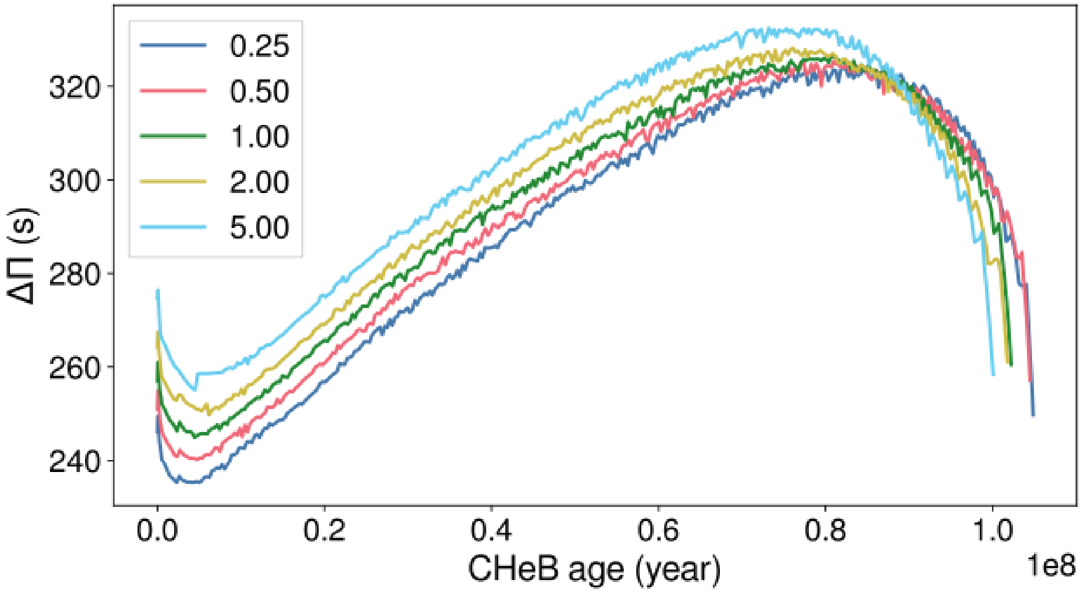
Core boundary mixing: Brunt-Väisälä frequency

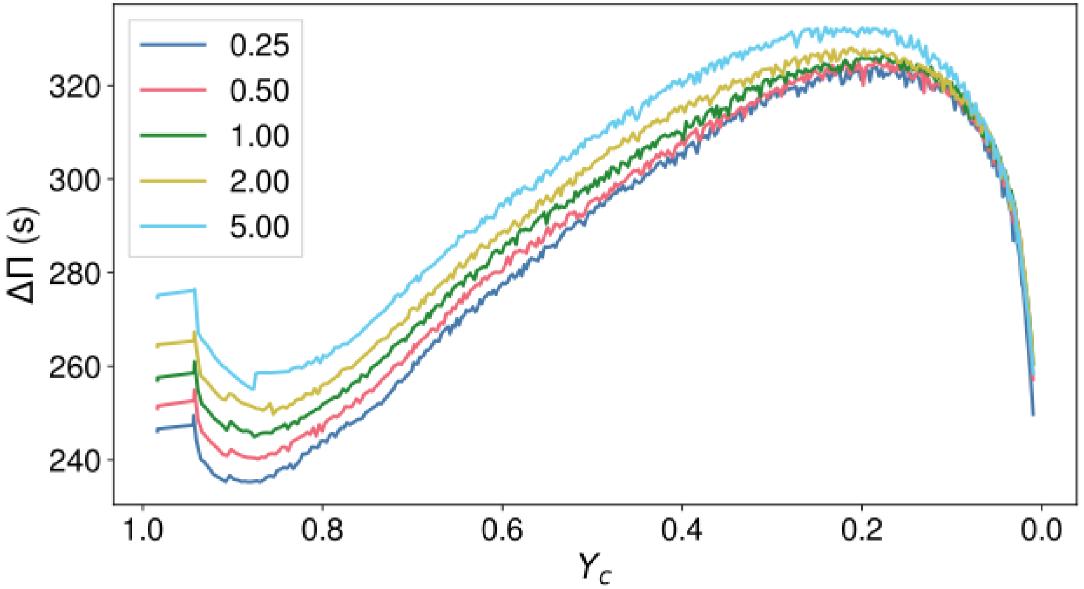


Effect of core boundary mixing on period spacing

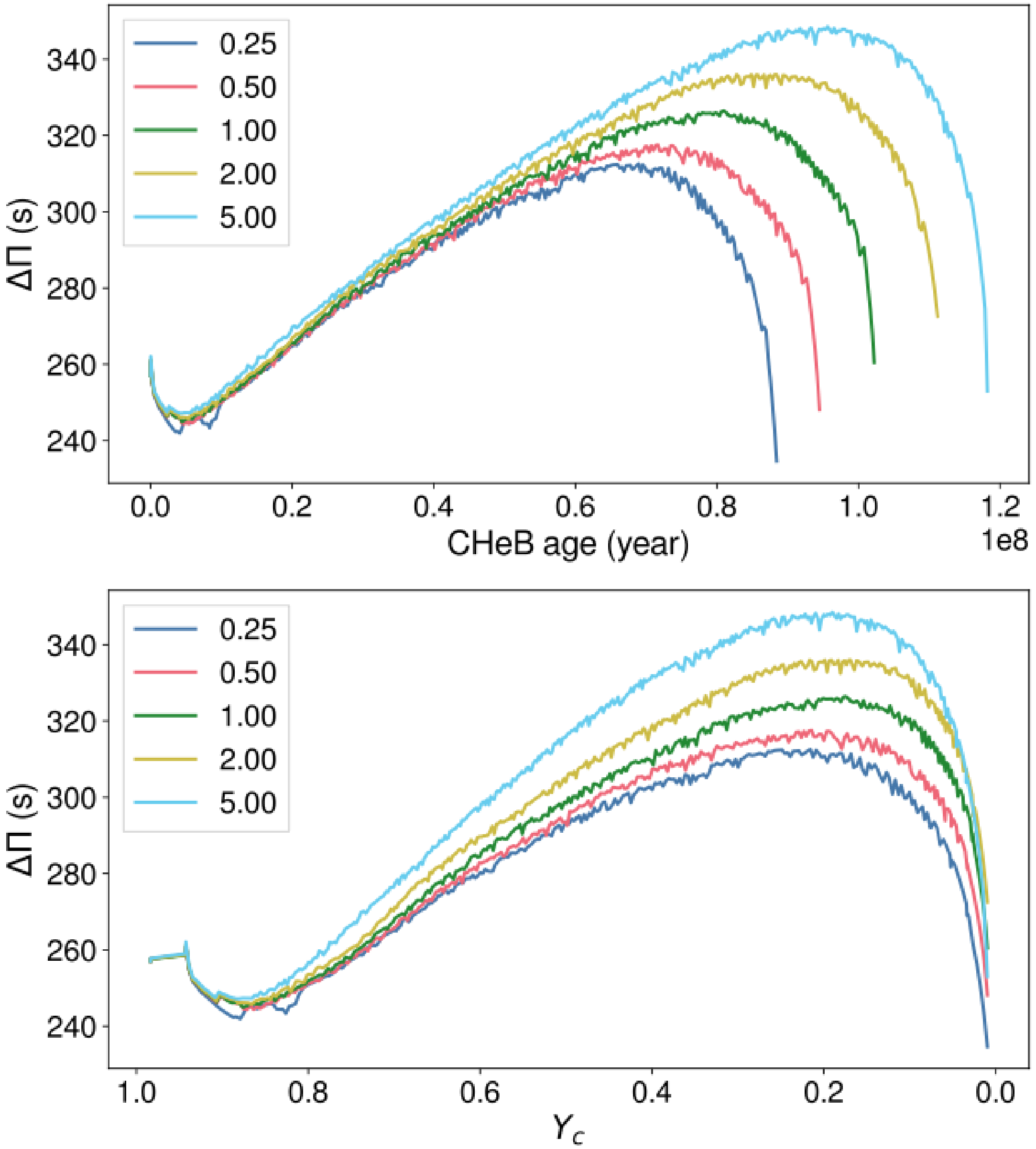


Nuclear reaction rates: 3α

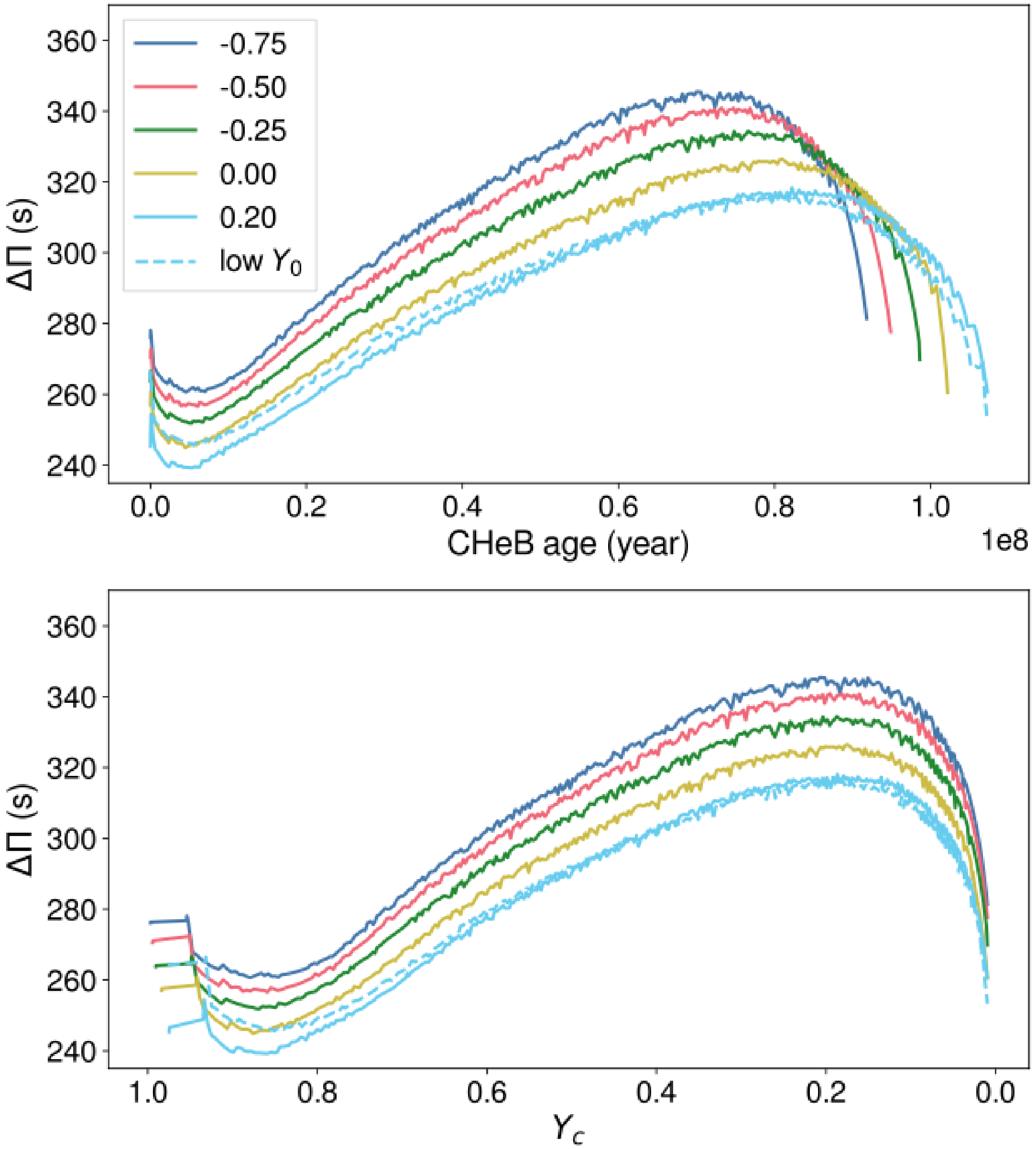




Nuclear reaction rates: $^{12}C(\alpha,\gamma)^{16}O$



Nuclear reaction rates: [Fe/H]



After Lab slides

Cause of change in period spacing

- 3α:
  1. higher 3α -> He-flash @ lower T (earlier in the RGB) -> He-core less massive = smaller convective core -> lower period spacing
  2. higher 3α -> same L at lower ρ -> decreases local gravity -> decreases Brunt-Väisälä frequency -> higher period spacing

  ➔ 2. dominates 1. leading to higher period spacings

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  1. at early ages not much difference as $^{12}\mathrm{C}(\alpha,\gamma)^{16}\mathrm{O}$ produces neglibile part of L
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- [Fe/H]:
  1. a metal poor star ignites He at a more massive core -> higher period spacing
  2. decreasing metallicity shortens CHeB phase

Combined effects: 3α + $^{12}C(\alpha,\gamma)^{16}O$ + [Fe/H]

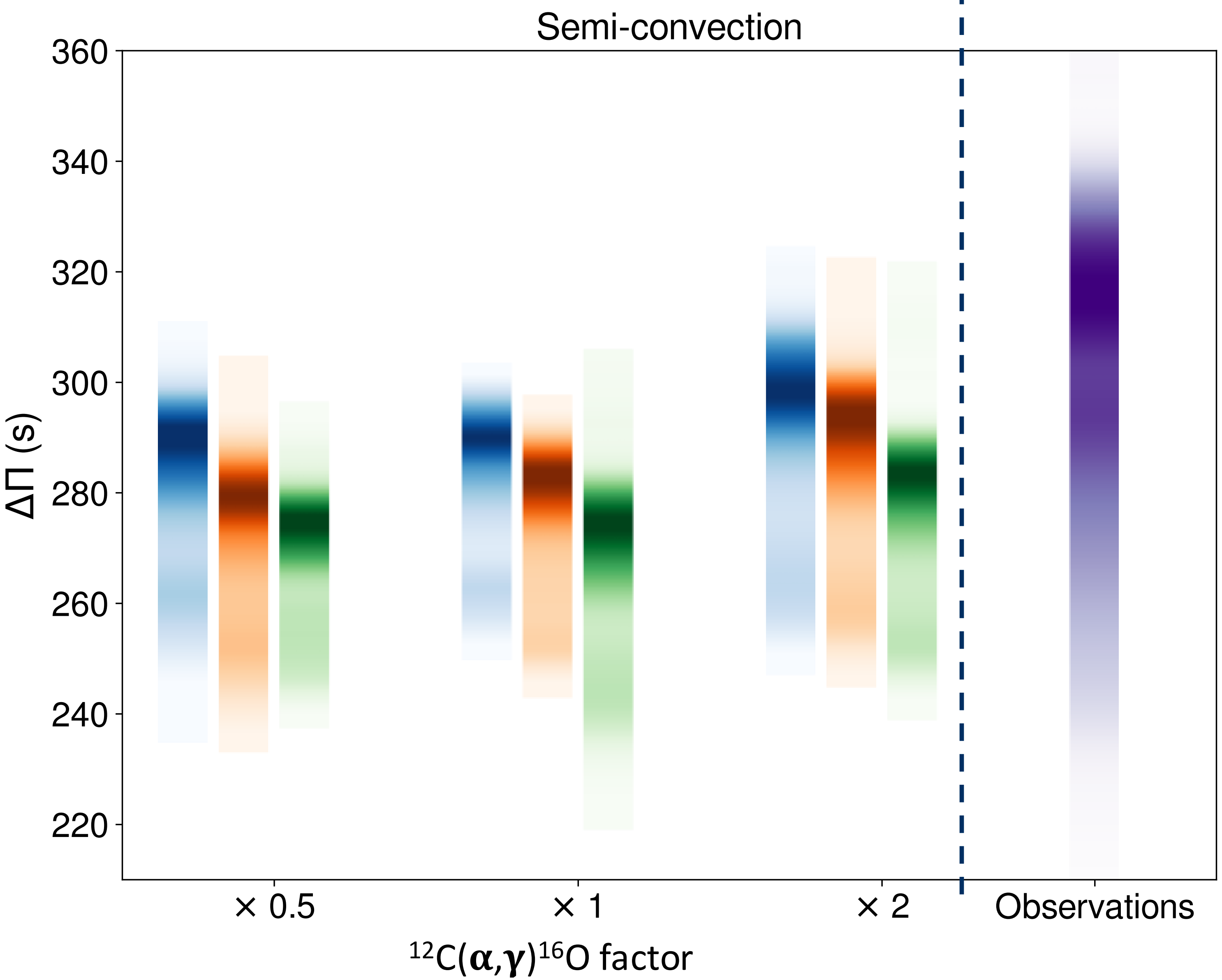
[Fe/H]:

- 0.5

0.0

+0.2

➢ opacity of bar indicates time of model spend at that **ΔΠ**



Observations of ensemble

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+0.2

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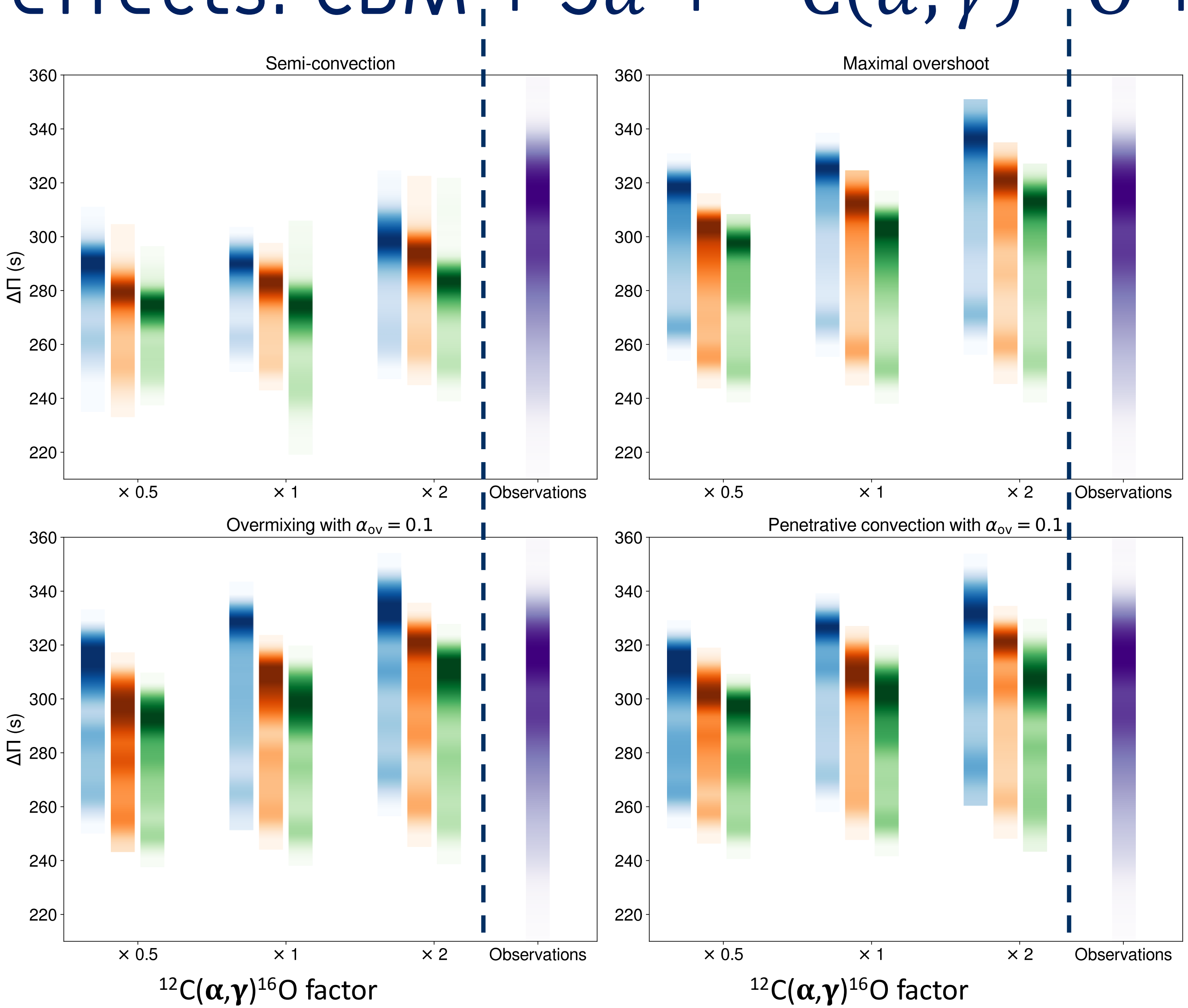

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