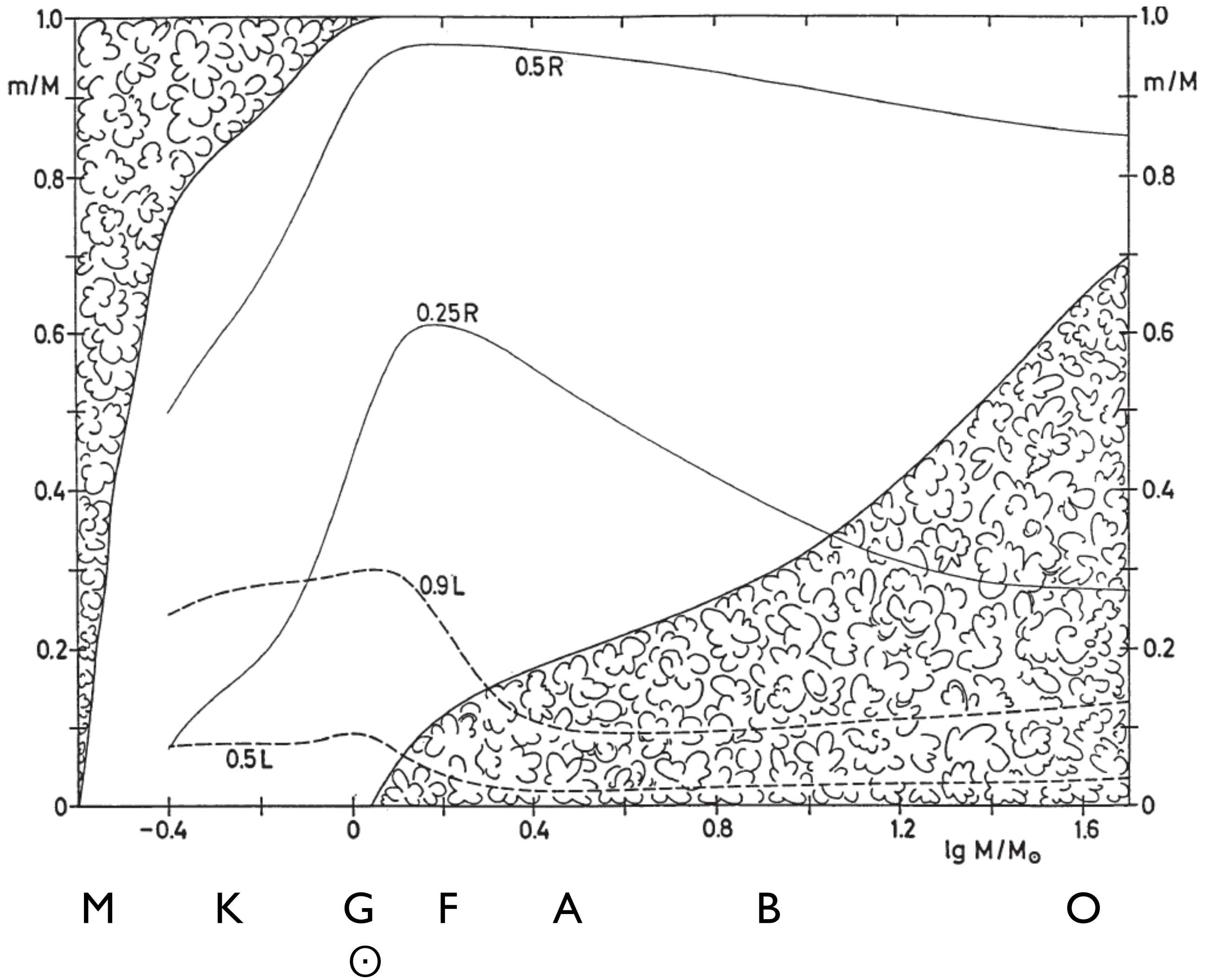
Quick notes on
Stellar Convection

Zach Meisel
Ohio University - ASTR4201 - Fall 2020

Where does convection occur?

- The temperature gradient from radiative transport is $\frac{dT}{dr} = \left(\frac{-3\rho\kappa}{4acT^3}\right)\left(\frac{L(r)}{4\pi r^2}\right)$
  - Steep temperature gradients (relative to the Schwarzschild criterion) occur for:
    - high opacity
    - high luminosity
- Cool regions (e.g. extended stellar envelopes) host partial ionization & therefore lots of photon absorption will occur (i.e. high opacity)
- Hot regions (e.g. high-temperature cores with CNO burning) have a high luminosity from nuclear burning

Kippenhan & Weigert "Stellar Structure and Evolution" 1990



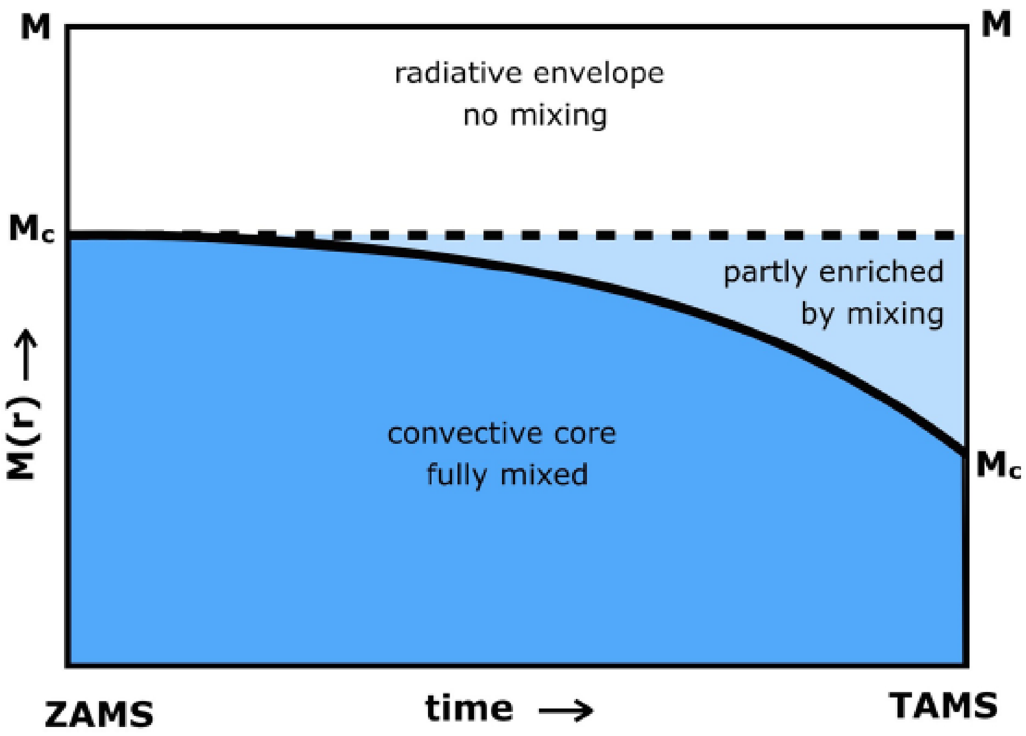
Convection During the Main Sequence

- During main sequence evolution, core hydrogen is fused into helium
- Recall from the Photons and Matter Quick Notes that electron scattering is the dominant contribution to the opacity at high-Temperature and high-density conditions of the core
  - Electron scattering per unit mass:

$$\sigma_e = N_e \sigma_{\text{Thomson}} = \frac{1}{\mu m_u} \sigma_{\text{T}} \approx 0.2(1 + X) \frac{\text{cm}^2}{g}$$

- H-burning reduces X, reducing σ_e and therefore κ

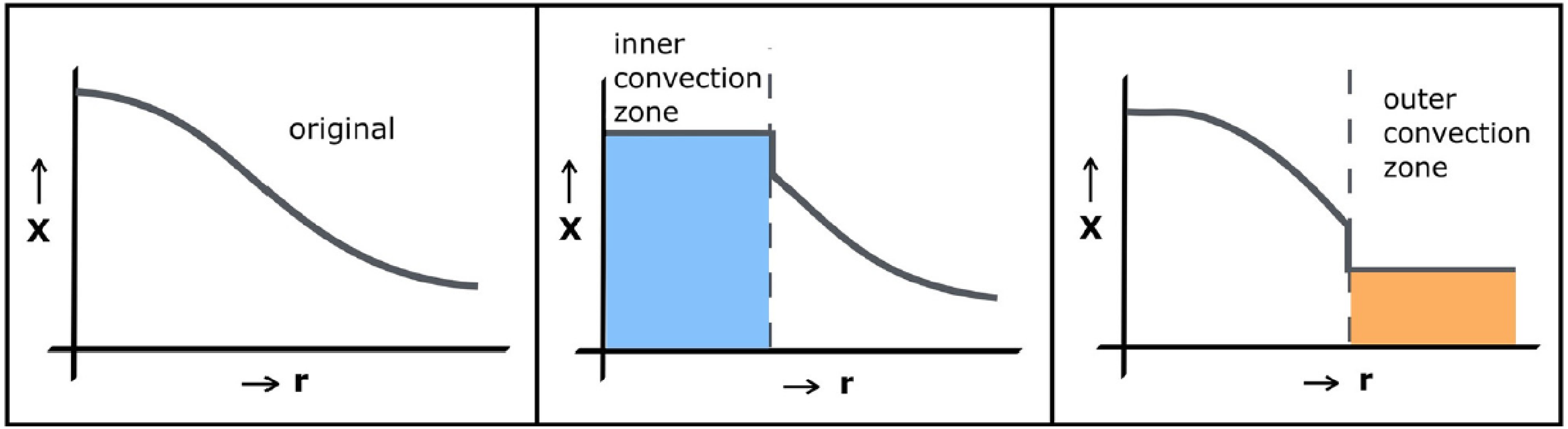
Lamers & Levesque "Understanding Stellar Evolution" 2018



Consequences of Convective Mixing

- The region hosting convection becomes chemically homogeneous due to mixing

Lamers & Levesque "Understanding Stellar Evolution" 2018



- Therefore, the Ledoux criterion will essentially become irrelevant for stellar structure once convection sets-in, as the composition gradient will have been removed
- Convection in the core will mix-in surround material containing un-burned helium
  - This substantially extends the life of high-mass main sequence stars
  - Rather than processing ~10% of the stellar H-content, as in the sun, (see TBS exercise 5.4) a ~60 $M_{\odot}$ star will process ~75% of its H-content