



The Orbital Evolution of (Sub)Stellar Companions to Asymptotic Giant Branch Stars

Mats Esseldeurs¹, Stéphane Mathis², Leen Decin¹

¹ Instituut voor Sterrenkunde, KU Leuven, Celestijnenlaan 200D, 3001 Leuven, Belgium

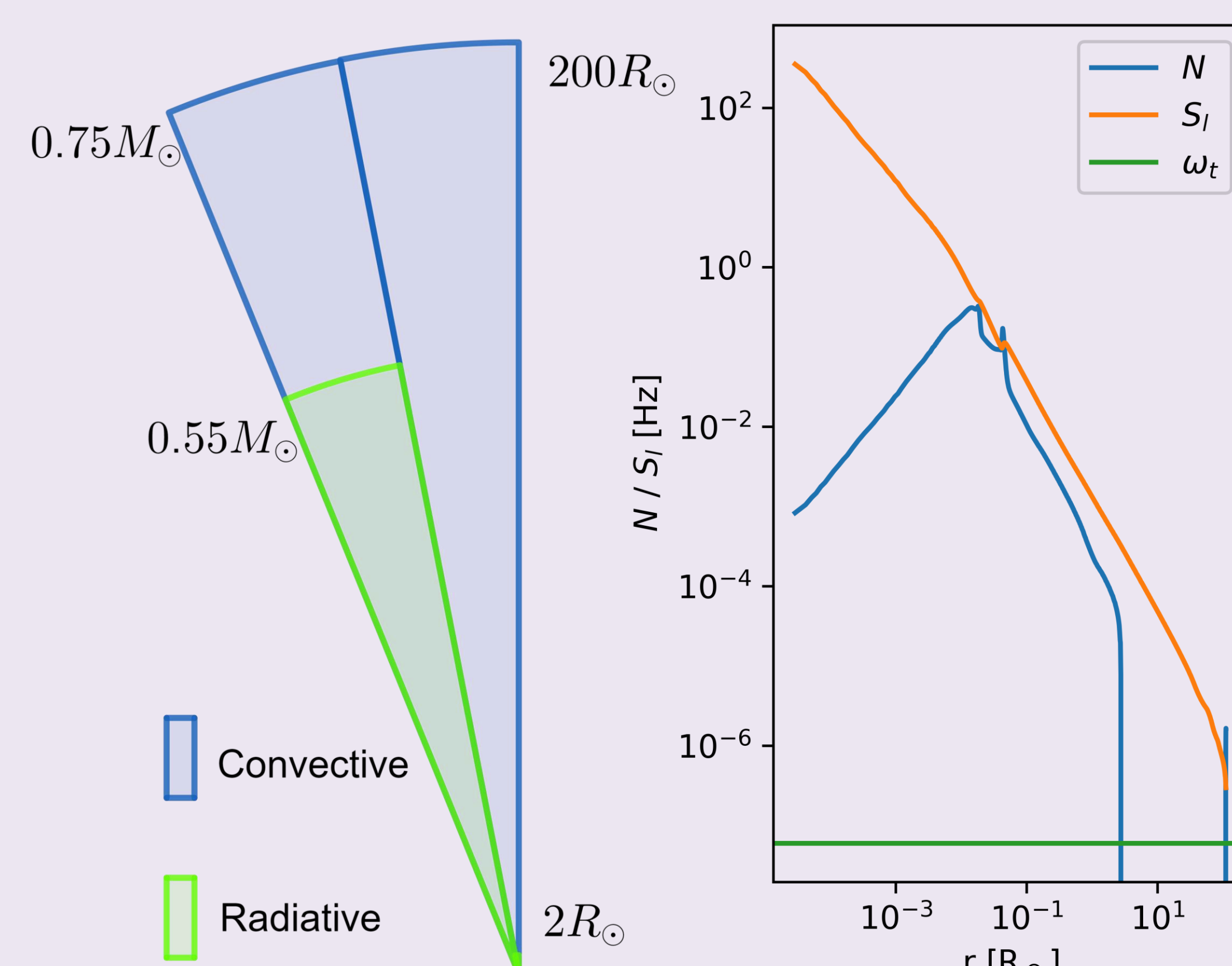
² Département d'Astrophysique, CEA, Université Paris-Saclay, 91191 Gif-sur-Yvette, France



matsesseldeurs.github.io/talks/EAS2023

Solar-like stars evolve through the **Asymptotic Giant Branch (AGB)** phase. This phase is characterized by increased radii, high luminosities, intense **pulsations**, and significant **mass loss**. In order to understand the **survival of planetary** or stellar companions during this phase and explain the presence of **planets orbiting white dwarfs**, it is essential to examine the **orbital evolution** of these systems. Several physical mechanisms come into play for AGB stars, such as the **stellar mass-loss rate** and the **tidal interactions** between the star and its companion.

Left: Internal structure of an AGB star
Right: Important frequencies for tidal waves



Tidal Dissipation

Equilibrium Tide:

- Hydrostatic displacement due to deformation from companion's gravity
- Its energy is dissipated because of turbulent friction in convective layers

Dynamical Tide:

- Inertial modes in convective envelope (only stellar companions)
- Low-frequency gravity waves in radiative core
- Considering dynamical (mass losing) outer boundary

AGB Stars

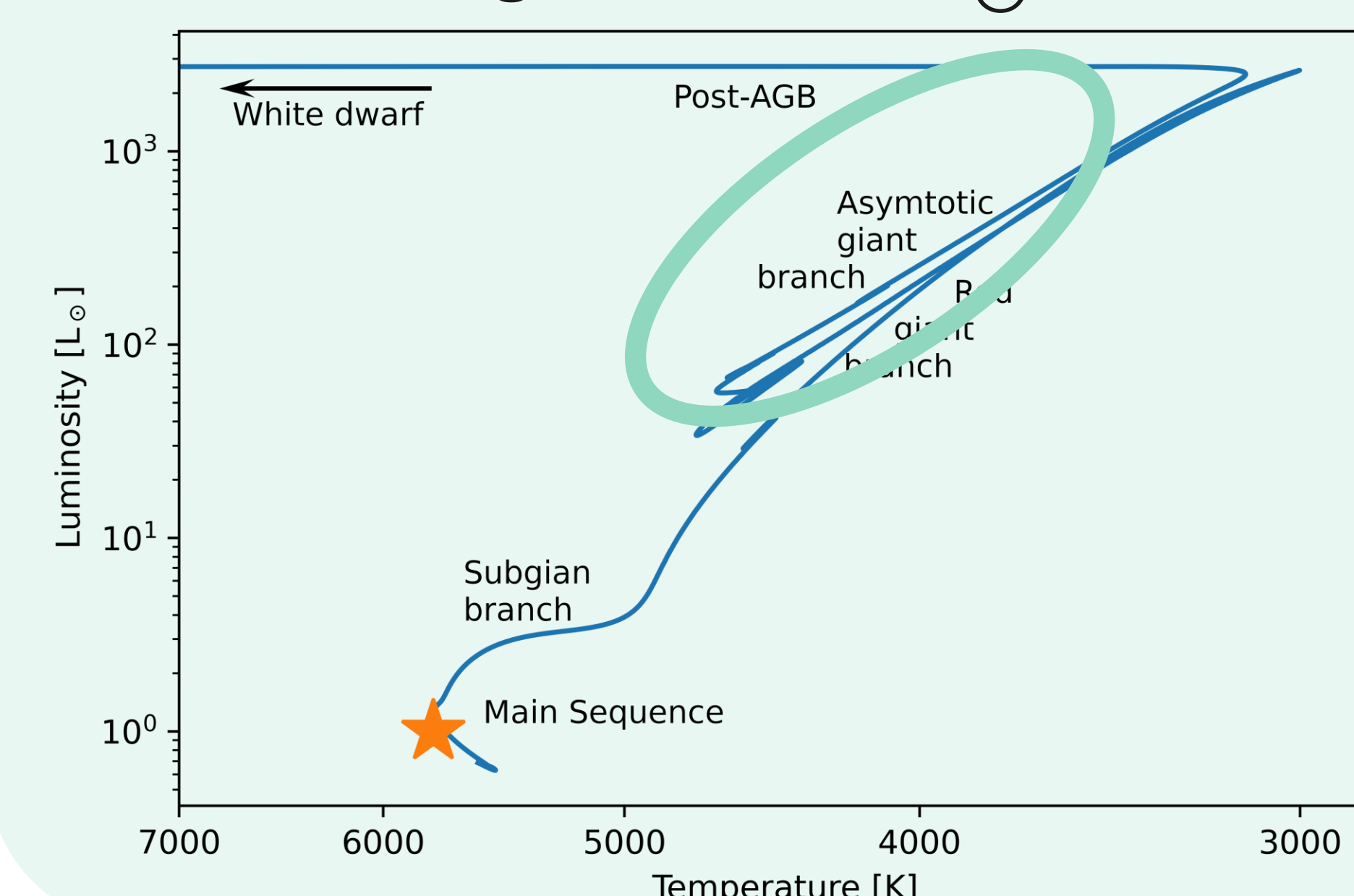
Typical parameters for AGB stars

$$R \approx 1.3 \text{ AU}$$

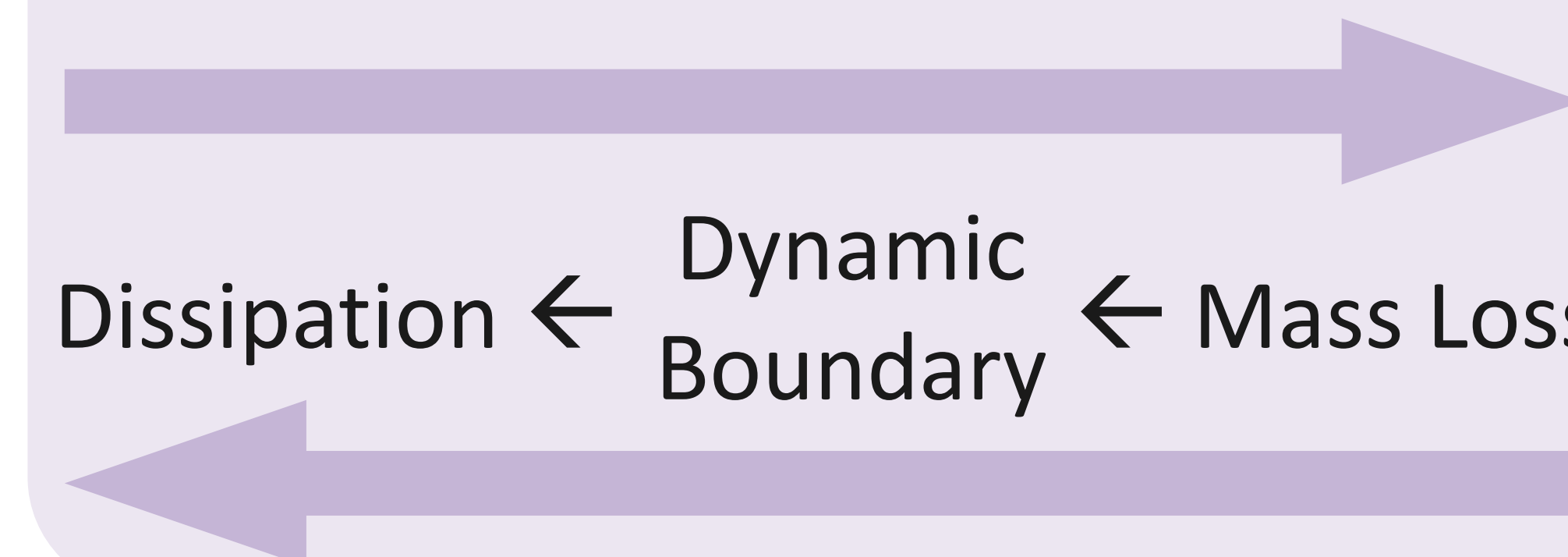
$$L \approx 10^2 - 10^5 L_\odot$$

$$\dot{M} \approx 10^{-8} - 10^{-5} M_\odot/\text{yr}$$

HR diagram of a $1 M_\odot$ star



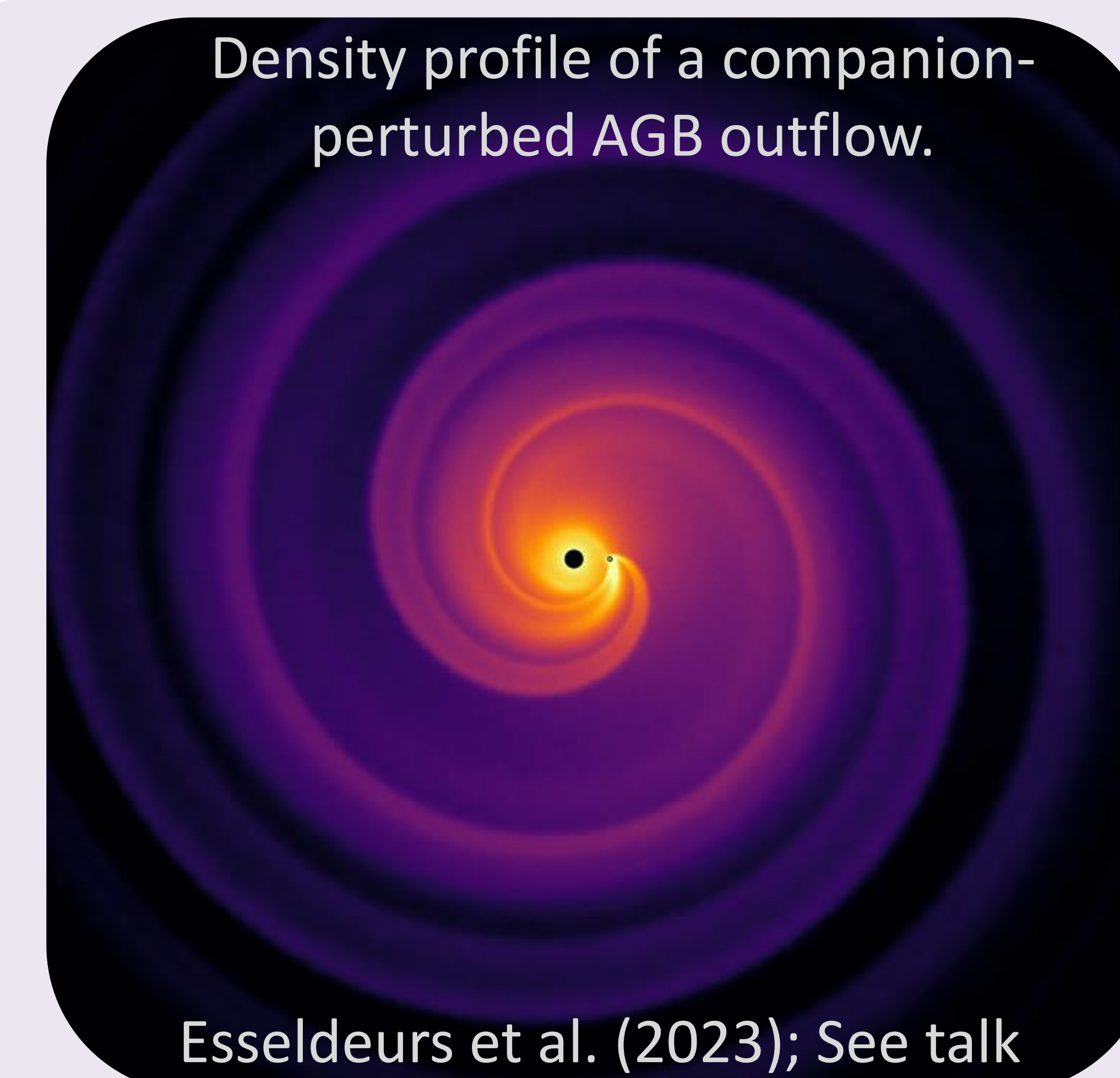
Tides \rightarrow Pulsations \rightarrow Mass Loss



Goal: Orbital Evolution

$$\left(\frac{\dot{a}}{a}\right) = \left(\frac{\dot{a}}{a}\right)_{\text{tide}} - \frac{\dot{M}_* + \dot{M}_p}{M_* + M_p}$$

Density profile of a companion-perturbed AGB outflow.



Esseldeurs et al. (2023); See talk

Mass Loss

- Mass loss via dust-driven wind
- Pulsations + Radiation on dust grains
- Observations show intricate shapes often caused by unseen companion
- Requires complex 3D radiation-hydro-chemical simulations
- Investigate the impact of the companion on:
 - Stars' mass-loss rate
 - Companions' efficiency of accretion
- Enhancing computational speed

To investigate **the orbital evolution of companions around AGB stars**, both mass loss and tidal dissipation play crucial roles. **Complex simulations** are essential for understanding how companions impact the star's mass loss rate, and the accretion onto the companion. Tidal dissipation, relying on **internal structure and boundary conditions**, requires additional studies. The interplay between winds, pulsations, and tides signifies a mutual influence on mass loss and tidal dissipation, presenting **a complex problem demanding a dedicated investigation**.