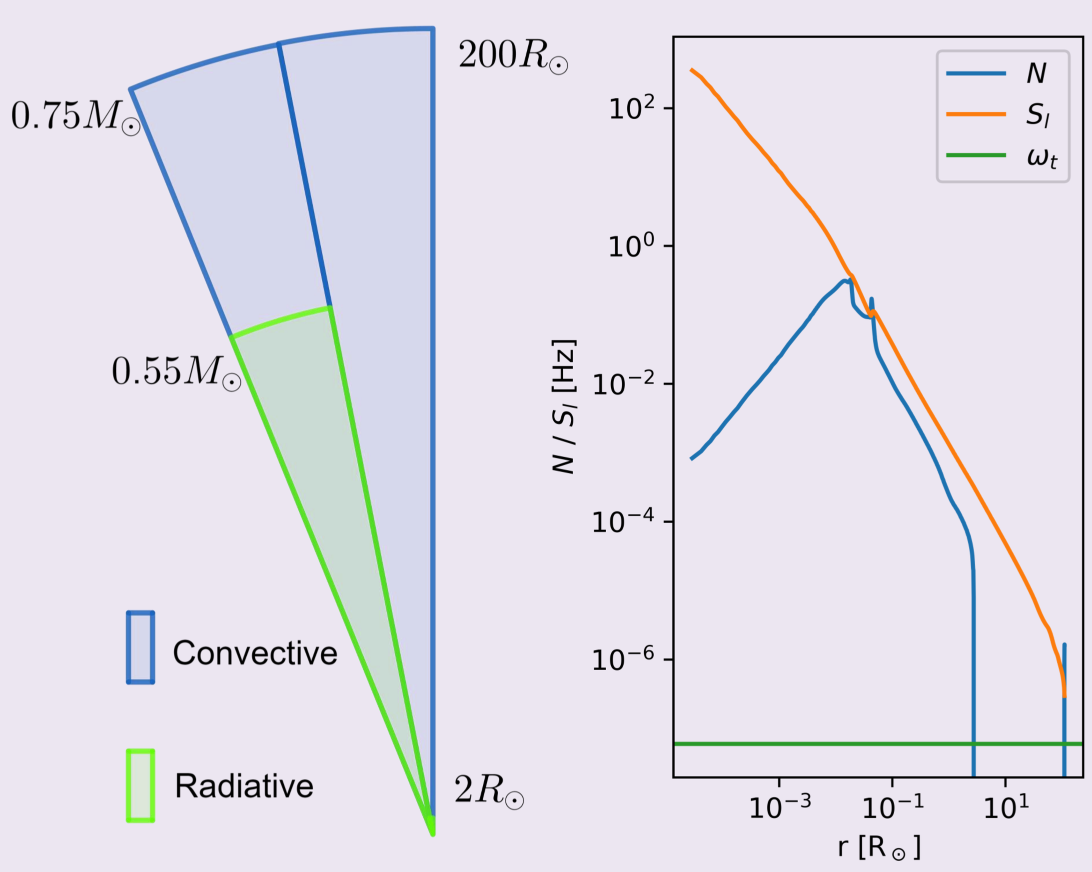
Towards a complete picture of the evolution of planetary systems around evolved stars

Mats Esselders[1], Stéphane Mathis[2], Leen Decin[1]

1 Instituut voor Sterrenkunde, KU Leuven, Celestijnenlaan 200D, 3001 Leuven, Belgium
2 Département d'Astrophysique, CEA, Université Paris-Saclay, 91191 Gif-sur-Yvette, France

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:

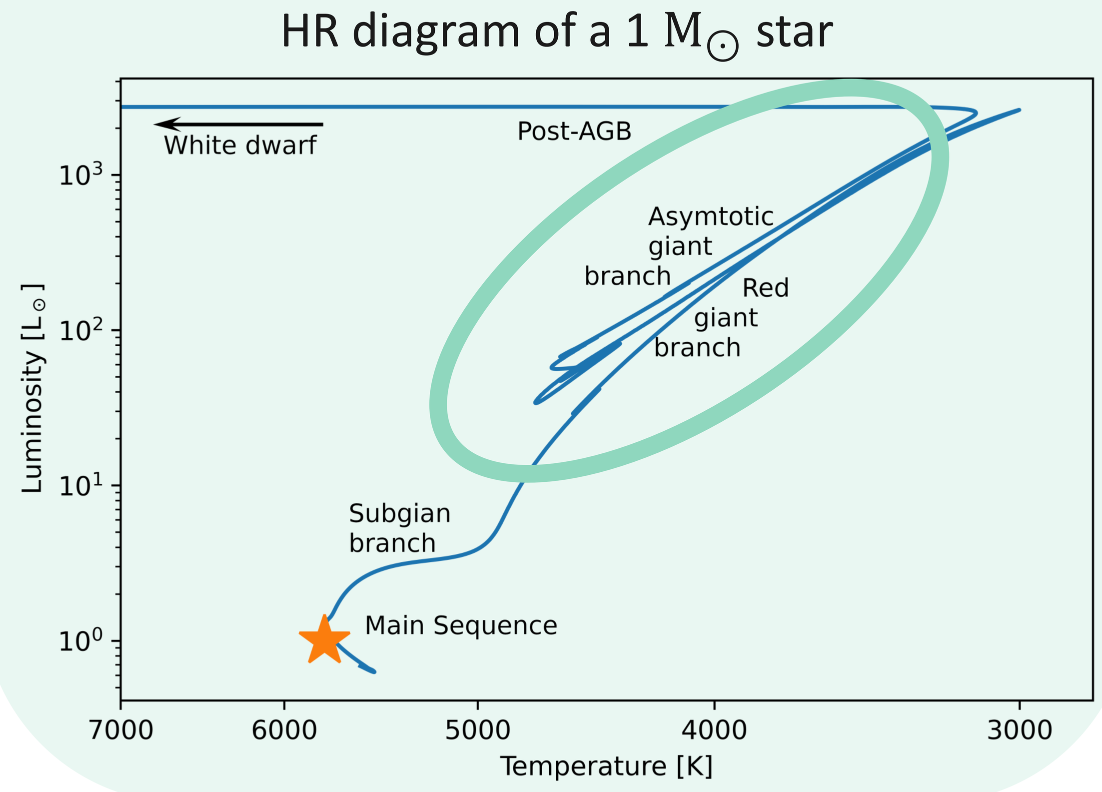
- Inertial modes in convective envelope (only stellar companions)
- Low-frequency gravity waves in radiative core
- Considering dynamical (mass losing) outer boundary

AGB Stars

Typical stellar parameters for AGB stars

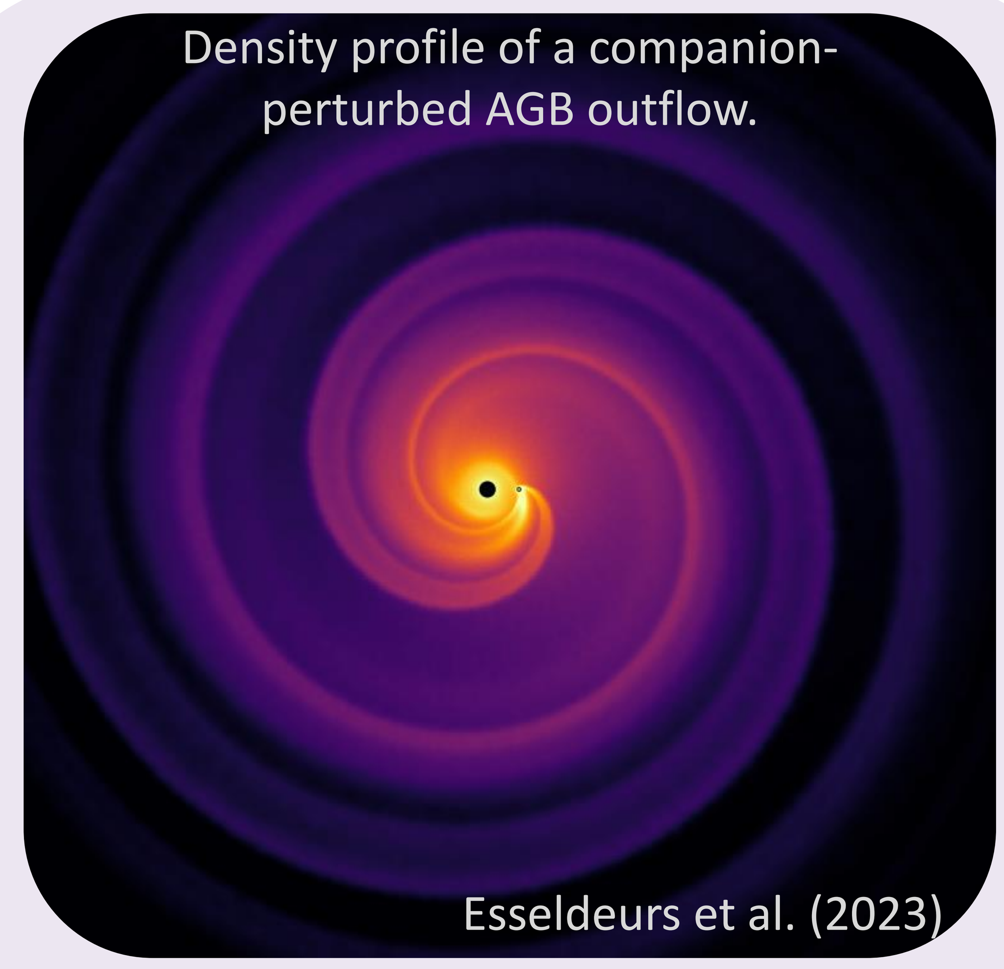
$R \approx 1.3$ AU
$L \approx 10^2 - 10^5\ L_\odot$
$\dot{M} \approx 10^{-8} - 10^{-5} M_\odot/yr$

HR diagram of a 1 $M_\odot$ star



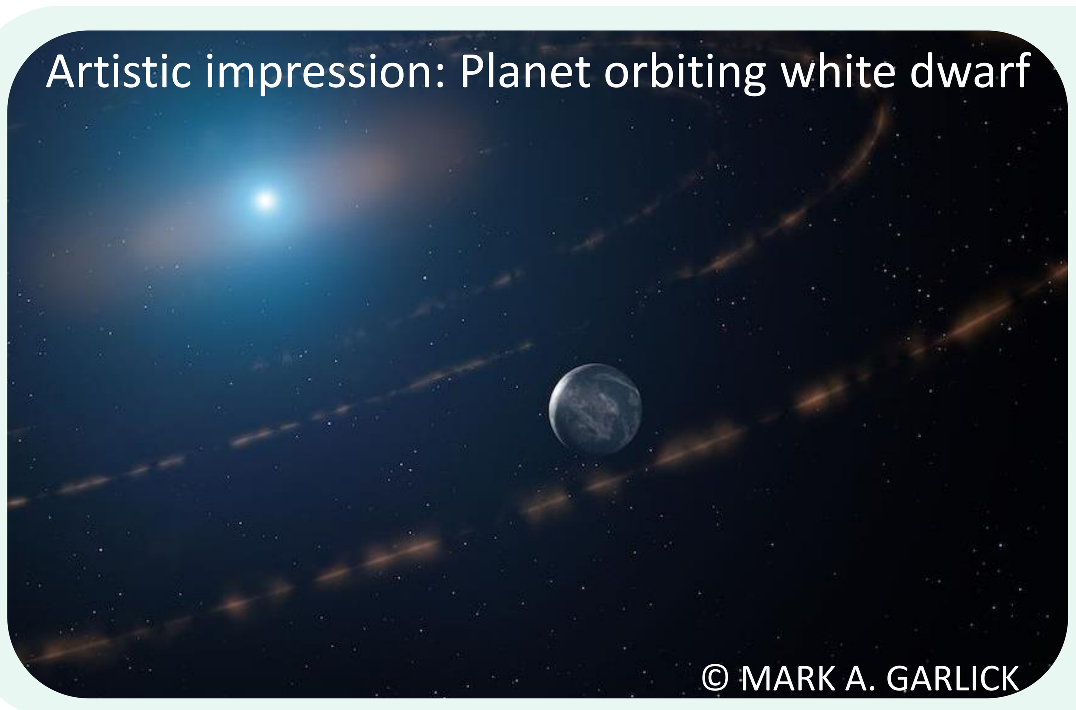
Tides → Pulsations → Mass Loss

Dissipation ← Dynamic Boundary ← Mass Loss



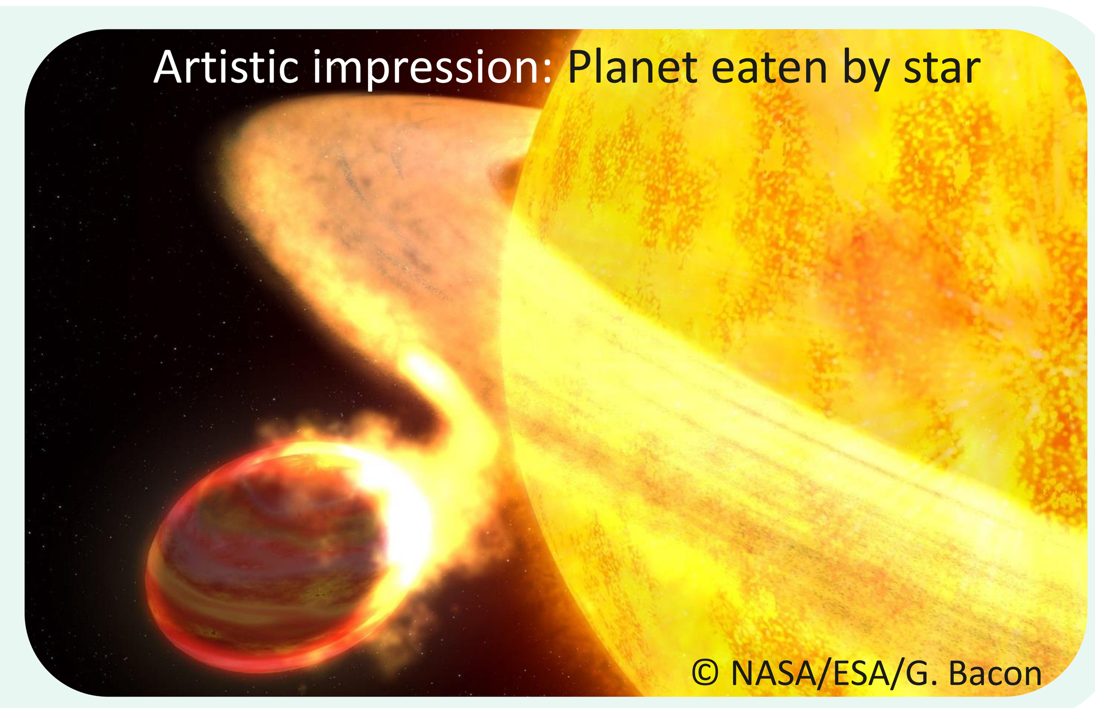
Mass Loss

- 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
- Efforts to enhance computational speed

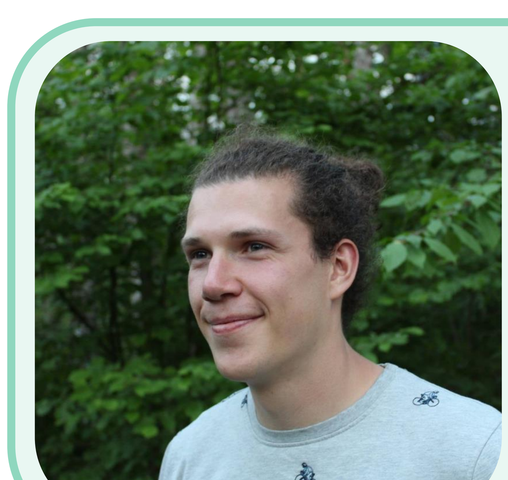


Goal: Orbital Evolution

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



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***.



Get in Touch!

Mats Esselders
PhD student at KU Leuven

mats.esseldeurs@kuleuven.be

More info →