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

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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
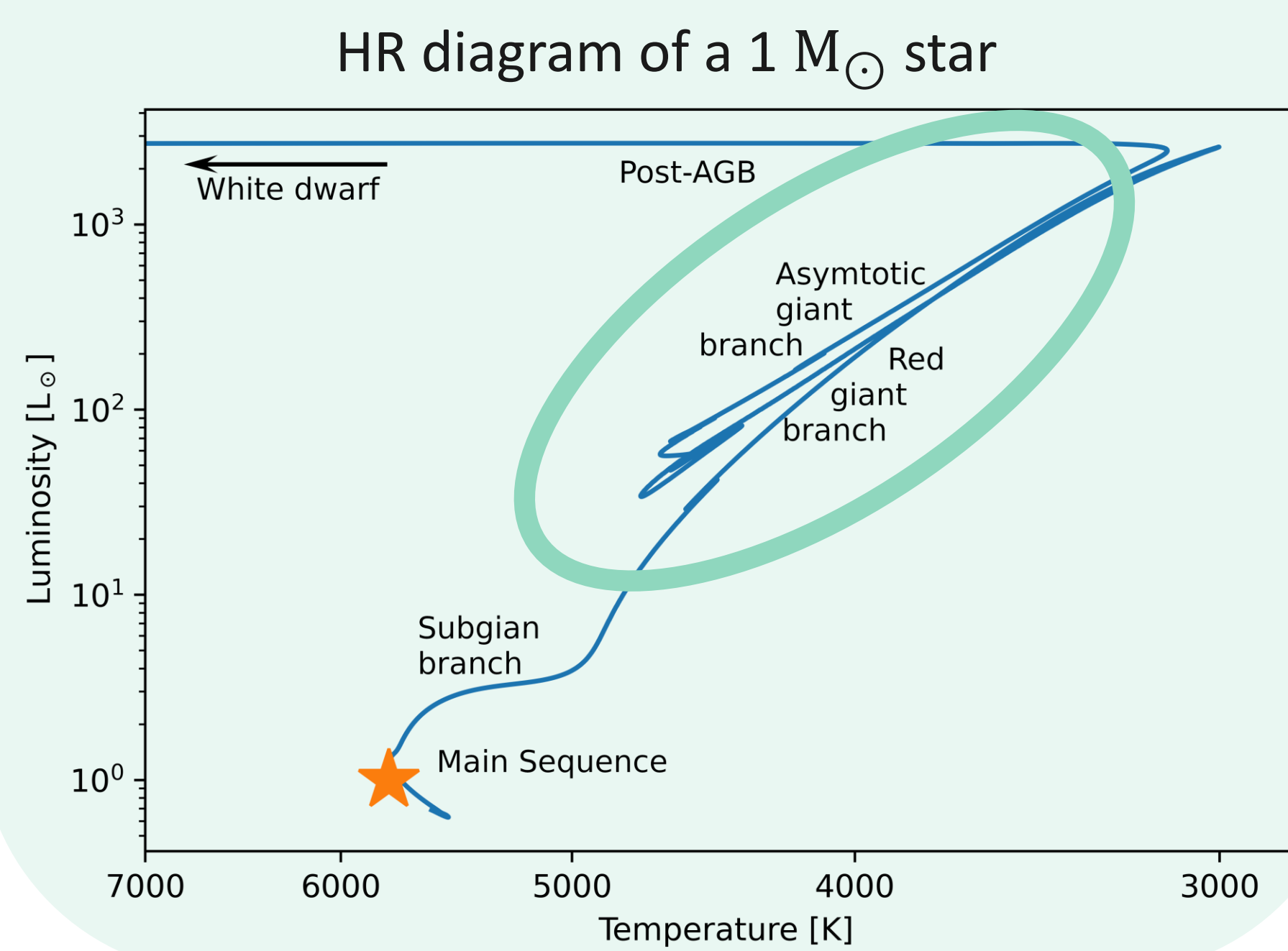Right: Important frequencies for tidal waves
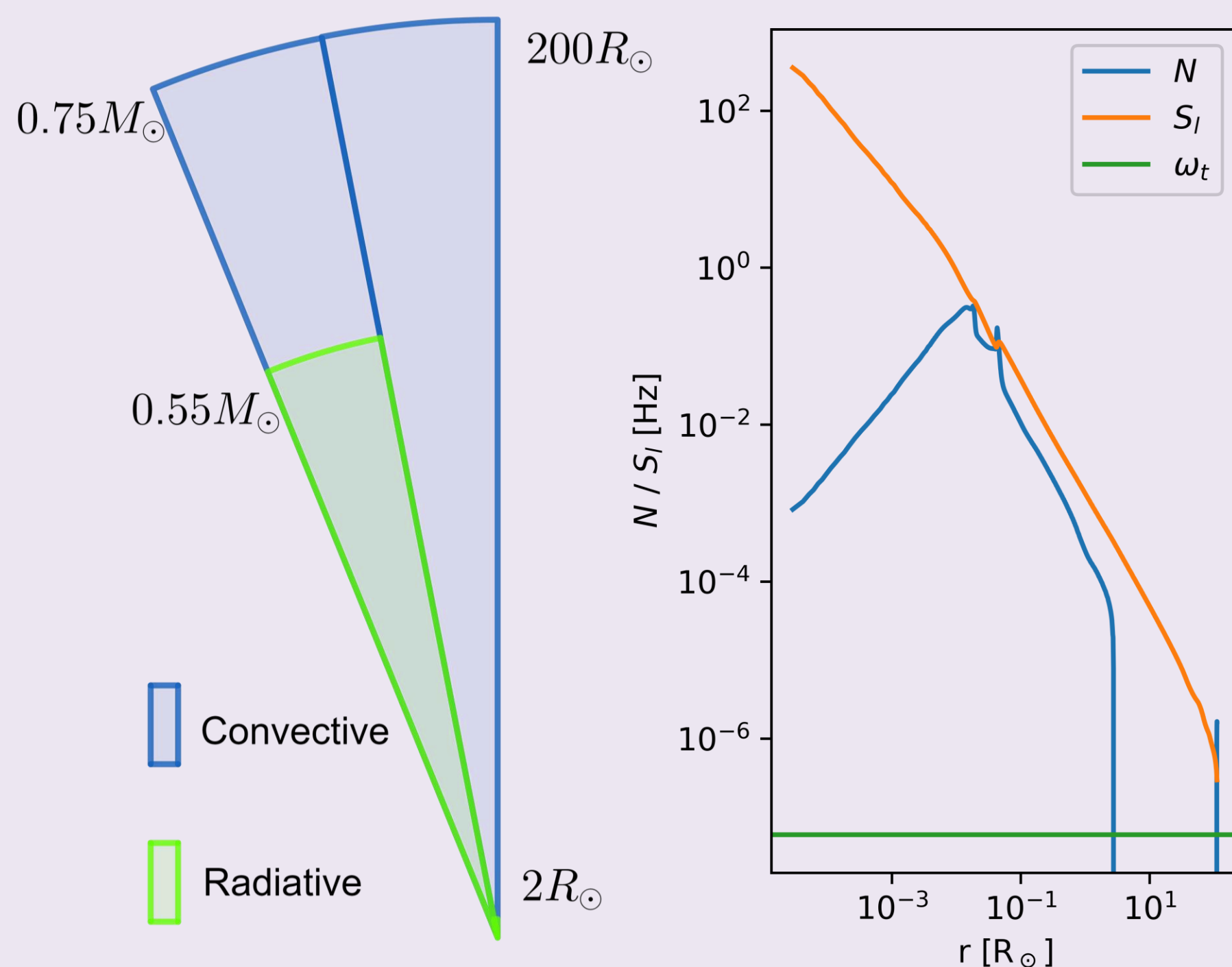
AGB Stars

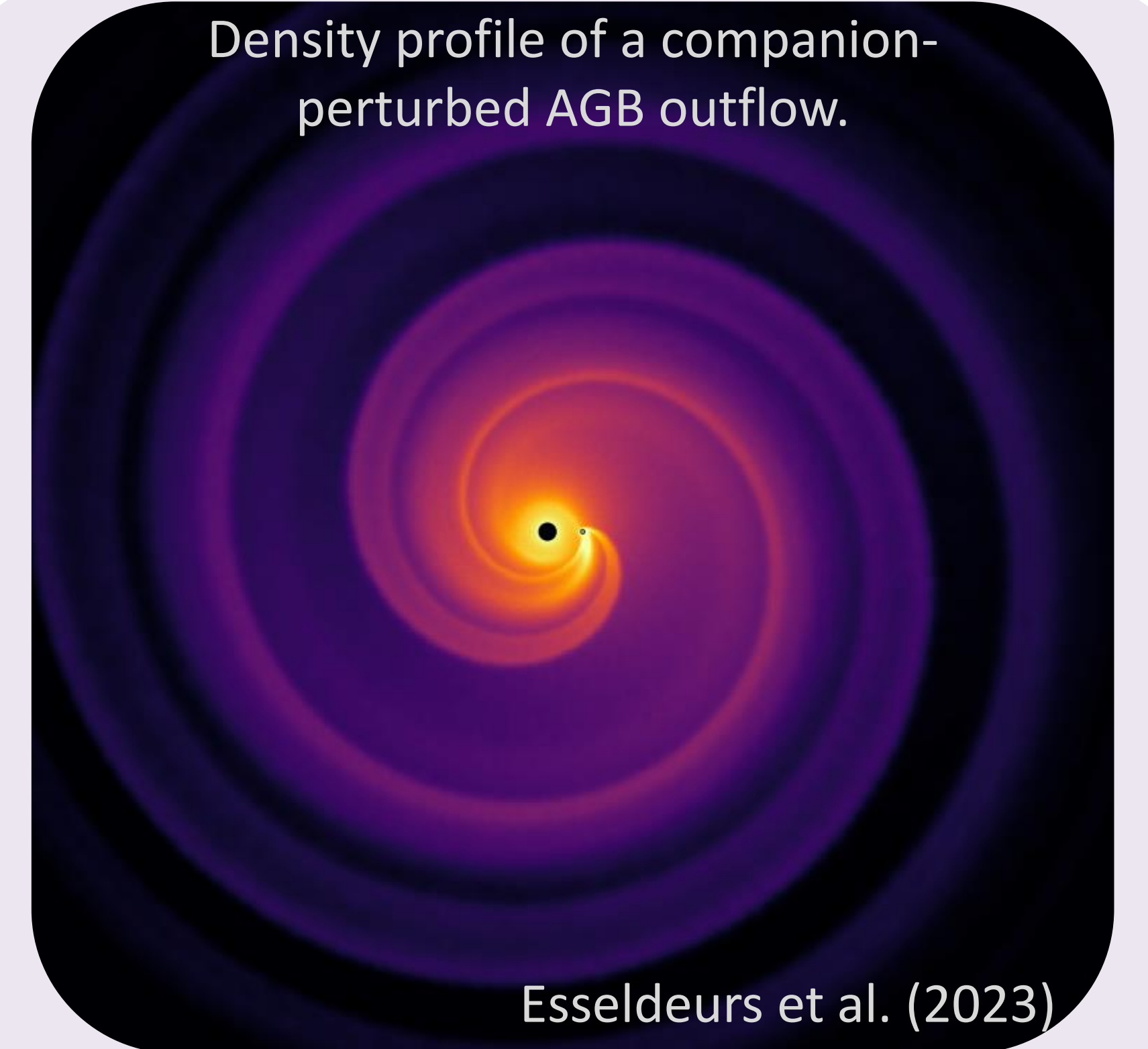Typical stellar parameters for AGB stars

$R \approx 1.3$ 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

Density profile of a companion-perturbed AGB outflow.

Esseldeurs et al. (2023)

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

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
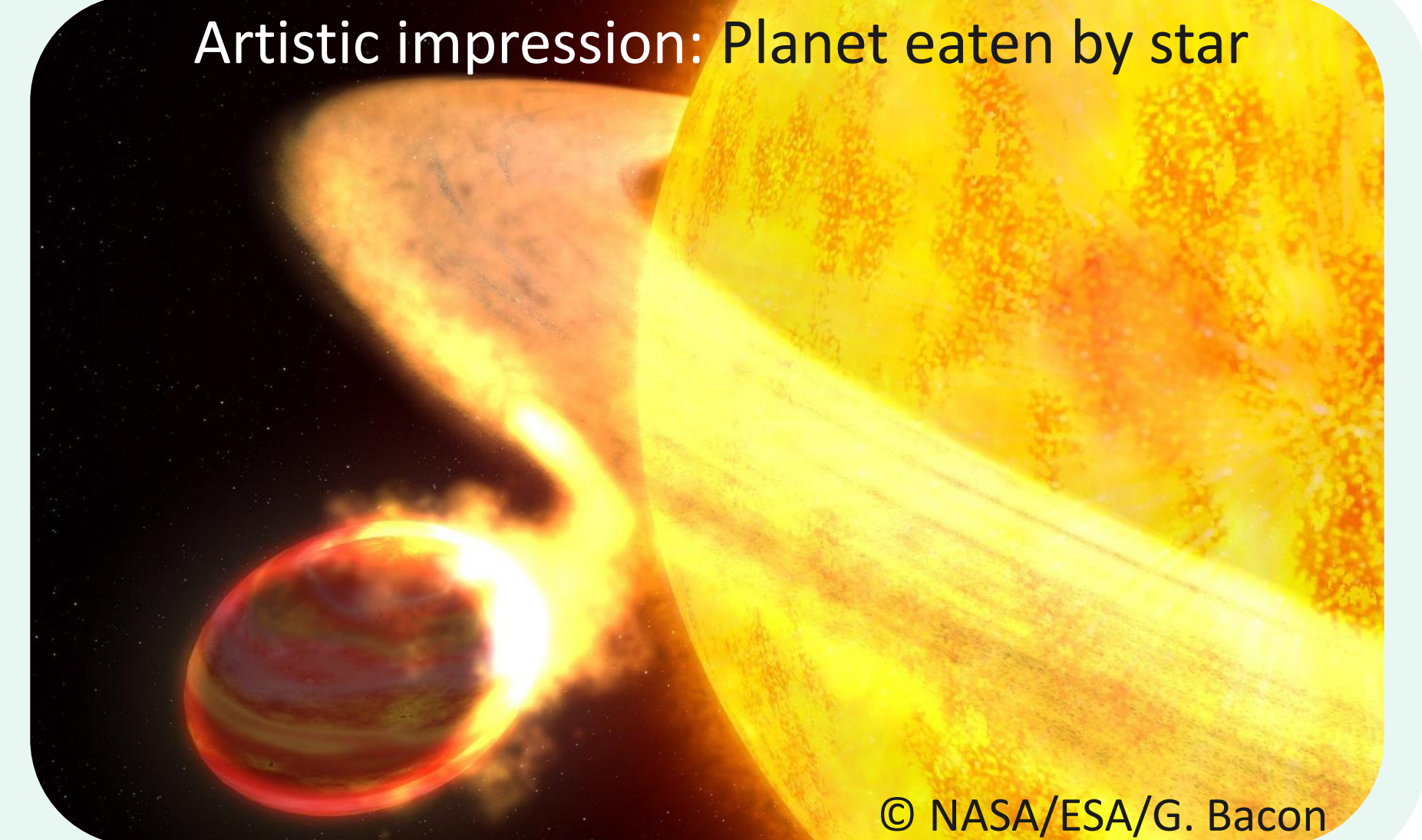- Efforts to enhance computational speed

Artistic impression: Planet orbiting white dwarf

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Goal:
Orbital Evolution

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

Artistic impression: Planet eaten by star

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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!

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More info →