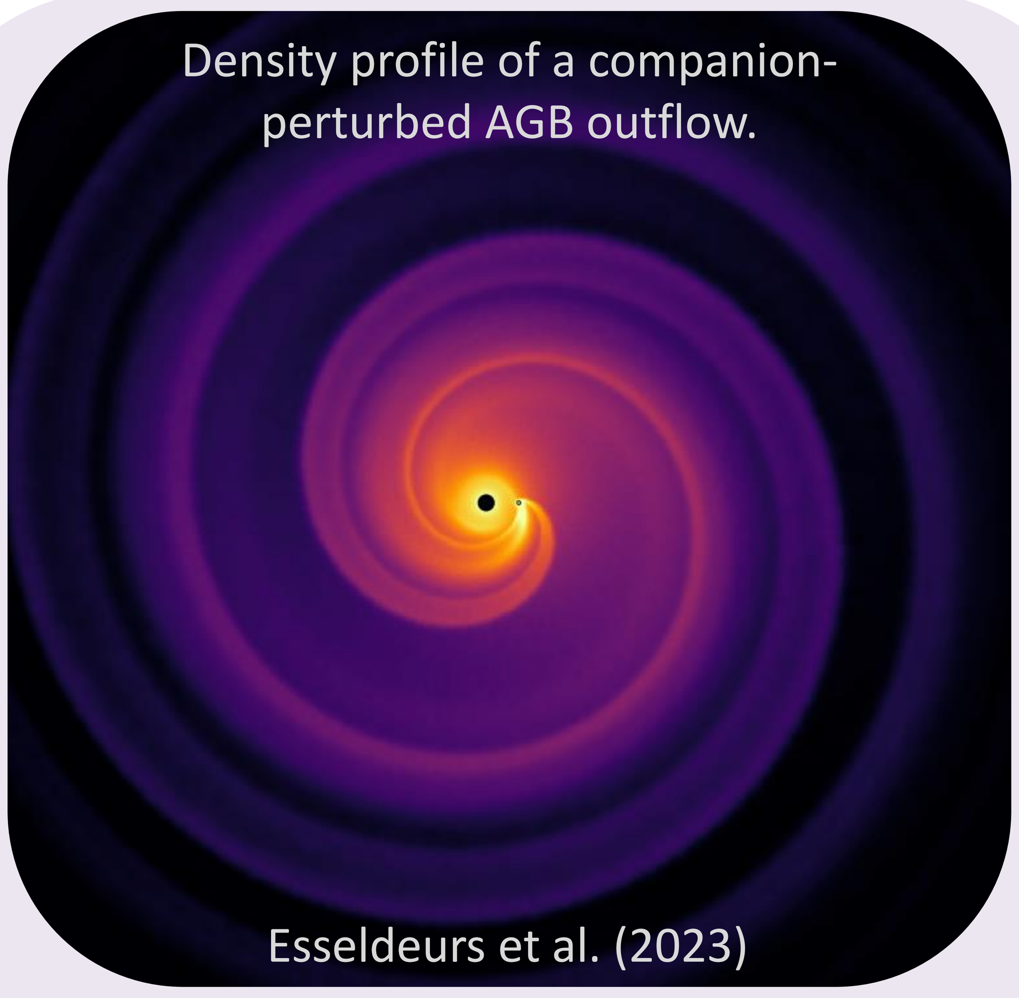
Orbital Evolution of AGB binary systems

Mats Esseldeurs[1], Stéphane Mathis[2], Leen Decin[1] et al.

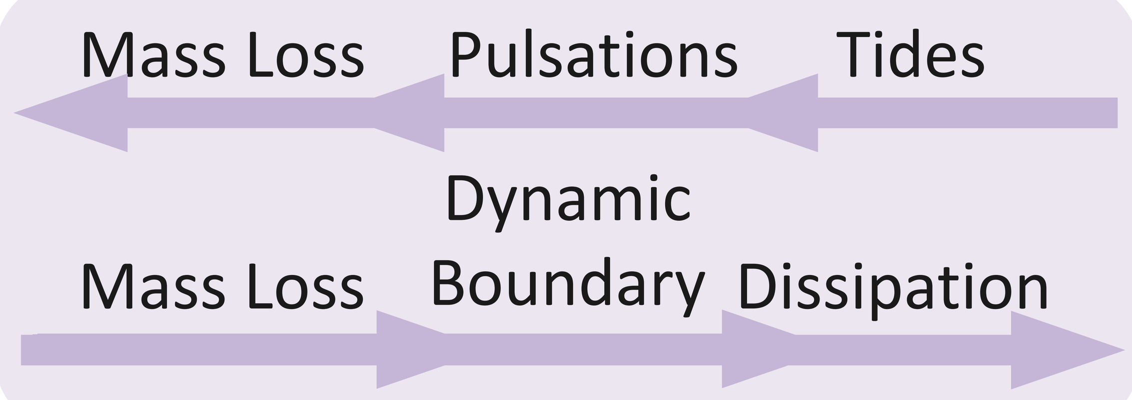
1 Instituut voor Sterrenkunde, KU Leuven, Celestijnenlaan 200D, 3001 Leuven, Belgium
2 Département d'Astrophysique, CEA, Université Paris-Saclay, 91191 Gif-sur-Yvette, France

The ***orbital evolution*** of binary systems with an AGB star is crucial because it determines whether the system will survive as a ***wide binary, undergo mass transfer, or merge entirely***. During the AGB phase, strong ***stellar winds*** and ***tidal interactions*** can drastically alter the ***orbital separation*** and ***eccentricity***. These processes shape the future evolution of both stars and determine the population statistics of ***close AGB and white dwarf binaries***, as well as predicting the fate of planetary systems around evolving stars like our Sun.



Mass Loss

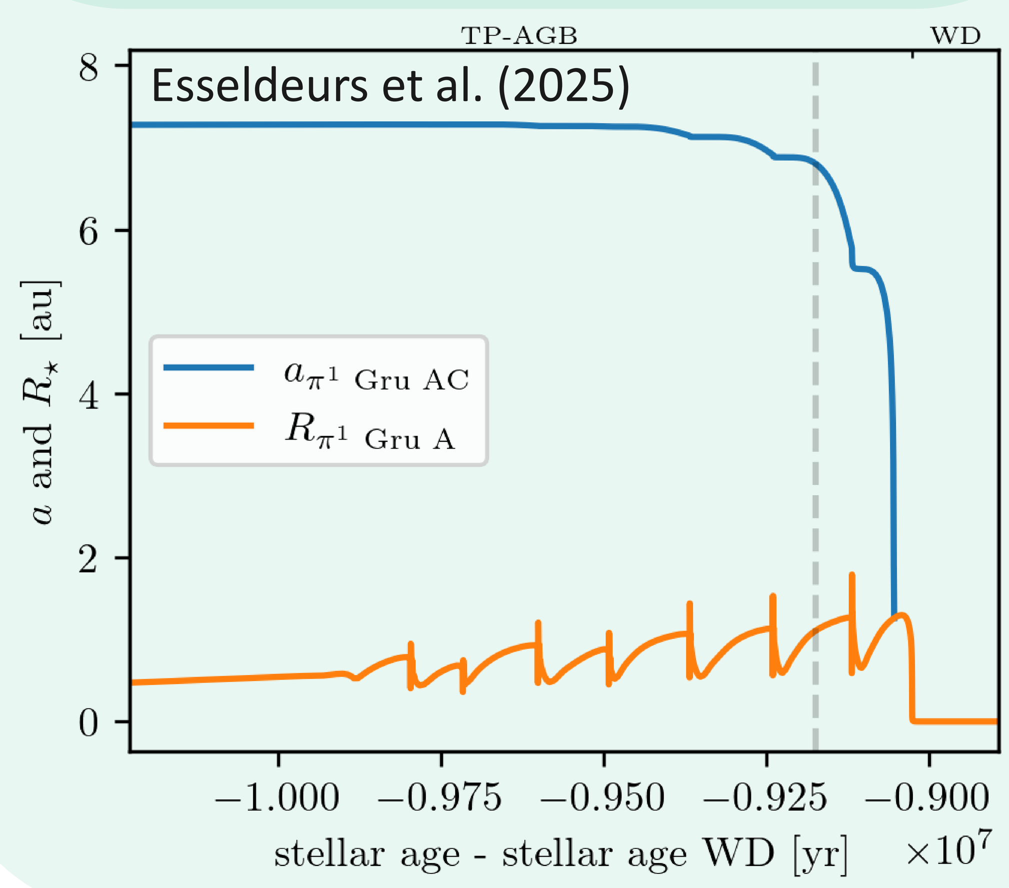
- Complex 3D hydro simulations to calibrate mass-accretion efficiency (β) and angular momentum loss (η)
- Current best values calibrated by Saladino et al. (2019), *A&A*, 626, A68
- Upgrade to more complex 3D radiation-hydro-chemical simulations:
  - radiation: Esseldeurs et al. (2023)
  - pulsations: O. Vermeulen in progress
  - chemistry: talk C. Landri

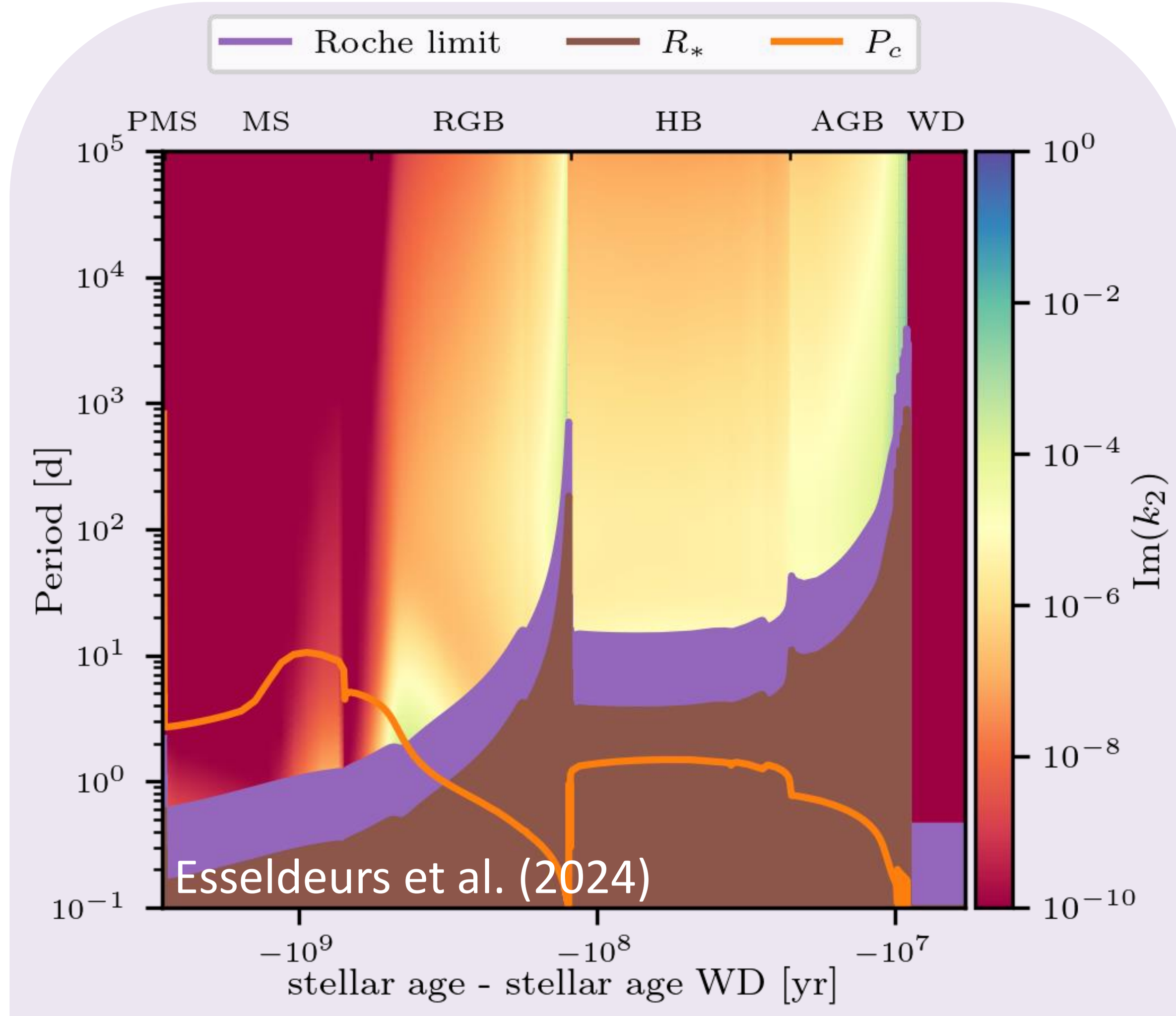


Goal: Orbital Evolution

$$\left(\frac{\dot{a}}{a}\right) = \left(\frac{\dot{a}}{a}\right)_{tide} + \left(\frac{\dot{a}}{a}\right)_{wind}$$

$$(\dot{e^2}) = (\dot{e^2})_{tide} + (\dot{e^2})_{wind}$$





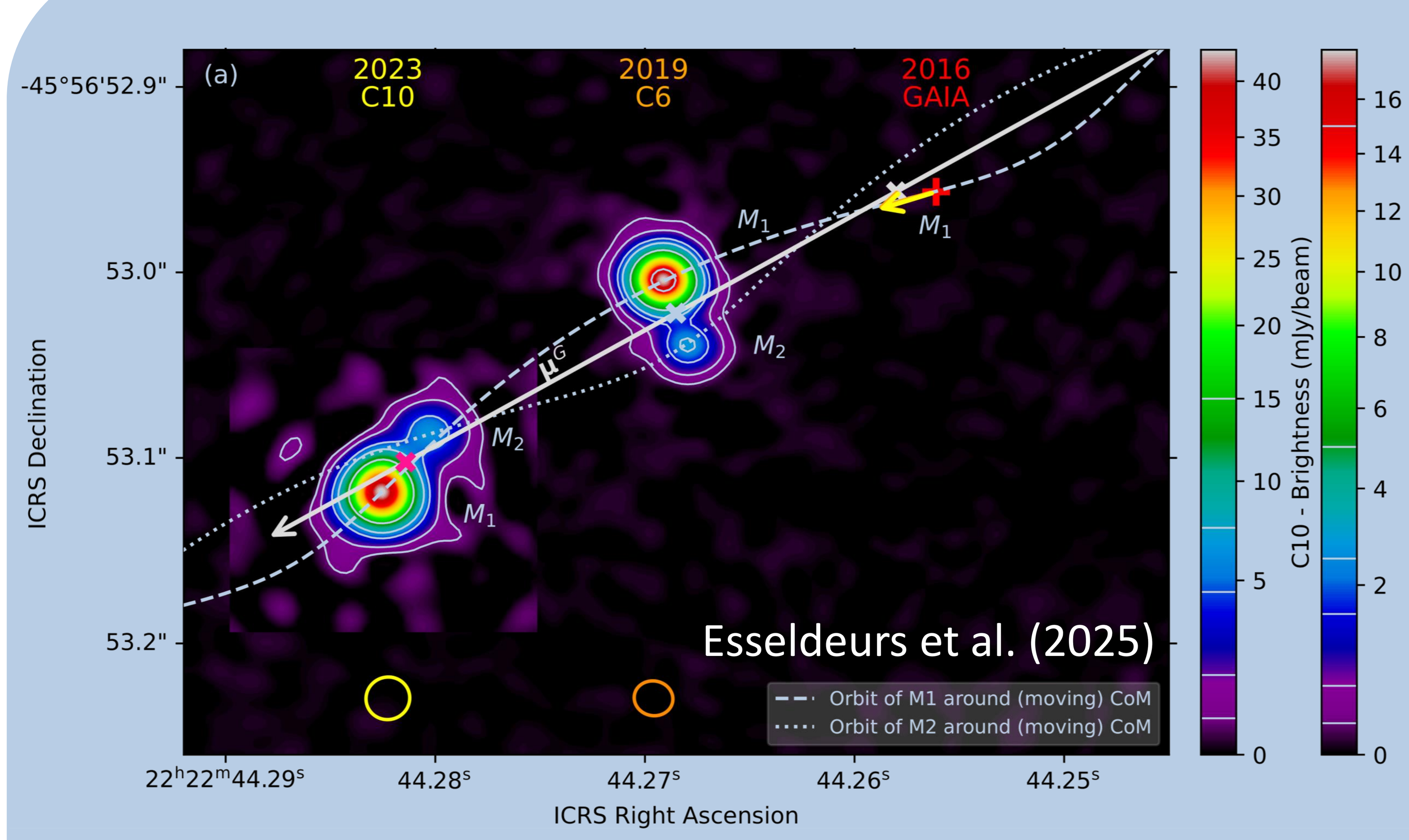
Tidal Dissipation

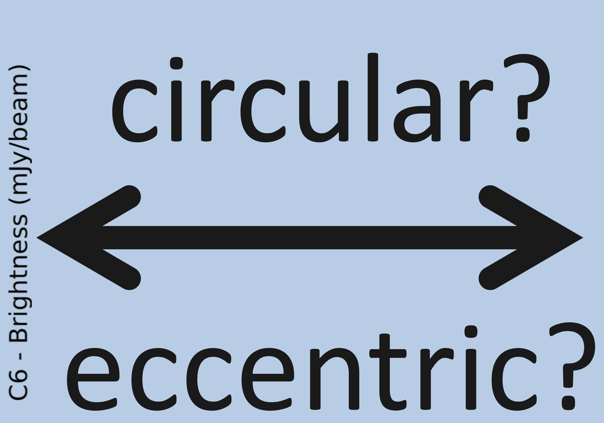
Equilibrium Tide:

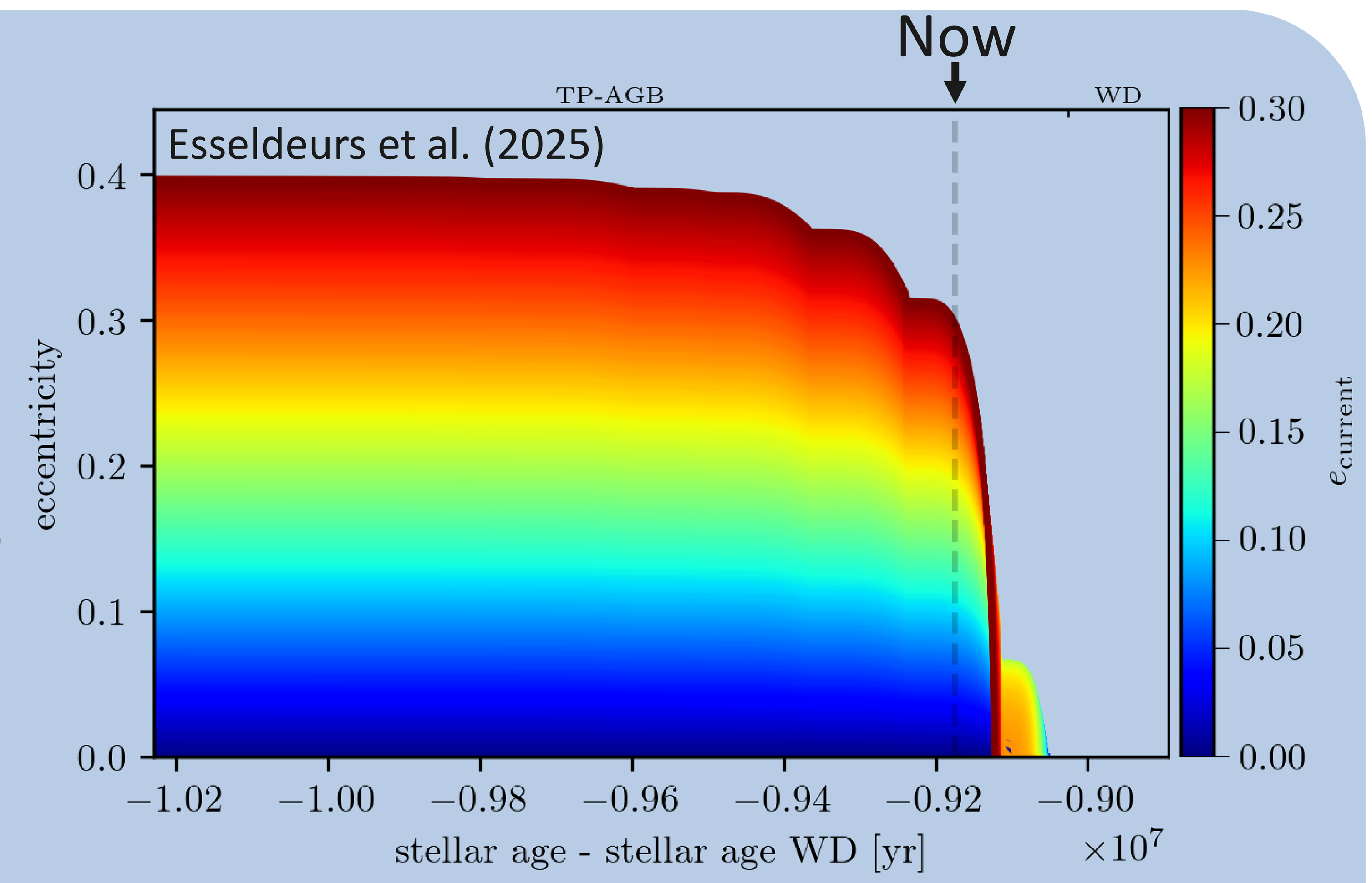
- Hydrostatic displacement due to deformation from companion's gravity
- Its energy is dissipated because of turbulent friction in convective layers

Dynamical Tide:

- Inertial modes in convective envelope (not efficient in giant stars)
- Low-frequency gravity waves in radiative core (less efficient in giant stars)







Multi-epoch (sub)millimetre interferometry of π^1 Gru reveals clear Keplerian motion of a close companion orbiting the central AGB star. ***Surprisingly, the orbit appears nearly circular***, whereas our orbital evolution simulations predict that any initially eccentric orbit should have retained a measurable eccentricity at present. This implies that either the system was circular from the start, an unlikely outcome given typical binary formation statistics, or that current ***tidal dissipation theories underestimate the efficiency of circularisation*** in such evolved systems.

Get in Touch!

Mats Esseldeurs
PhD student at KU Leuven
mats.esseldeurs@kuleuven.be

Esseldeurs et al. 2023, *A&A*, 674, A122
Esseldeurs et al. 2024, *A&A*, 690, A266
Esseldeurs et al. 2025, *Nature Astronomy*

This poster presents part of the work published in Esseldeurs, Decin, De Ridder, Mori, Karakas, Malfait, Danilovich Mathis, Richards, Sahai, Yates, Van de Sande, Baes, Baudry, Bolte, Ceulemans, De Ceuste, El Mellah, Etoka, Gottlieb, Herpin, Kervella, Landri, Martinho, McDonald, Menten, Millar, Osborn, Pimpanuwat, Plane, Price, Siess, Vermeulen, Wong (2025), **Evidence for a Keplerian orbit of a close companion around a giant star**, *Nature Astronomy*