ANR-PEPPER PhD - 2022

Title: Magnetic field and convection in evolved stars and their role in the mass-loss processes

Location: Université Côte d'Azur, Nice, France

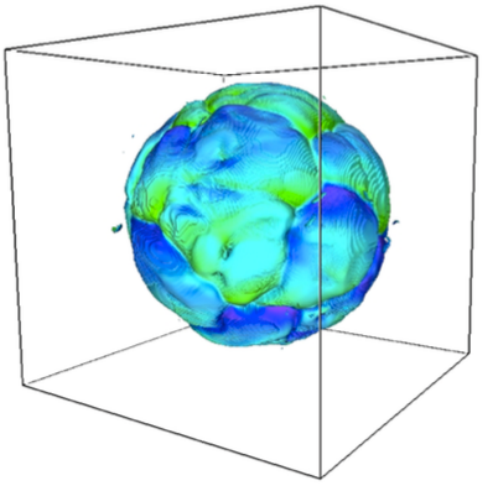
Starting date: October 1st, 2022 **Ending date:** September 30th, 2025

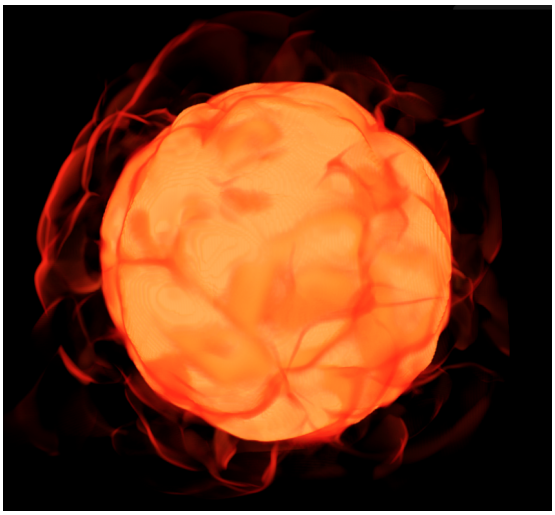
Supervisor: Andrea Chiavassa (CNRS research staff, Laboratoire Lagrange/OCA)

Collaborators: Fabian Menezes (Postdoc PEPPER, Lagrange), Agnès Lebre (LUPM, Montpellier), Philippe Mathias (IRAP, Toulouse), Miguel Montargès (LESIA, Paris), and the ANR-PEPPER consortium team

Context: Evolved cool stars are major cosmic engines, providing strong mechanical, chemical, and radiative feedback on their host environment. Through strong stellar winds (billions times larger than the Sun), still poorly understood, they enrich their environment with chemical elements, which are the building blocks of planets and life. These objects are known to propel strong stellar winds that carry the mass and angular momentum of the stars' surfaces at speeds that vary with stellar brightness, evolution phase and chemical composition. A complete understanding of their evolution in the near and distant Universe can only be achieved with a detailed knowledge of wind physics across the life cycle of these stars as well as in relation to their circumstellar environment.

To provide quantitative constraints to the physics of cool evolved stars, observational techniques have reached such a level of excellence that it is now possible to reconstruct spatially resolved images of stellar surface in the near IR with interferometric techniques, simultaneous intensity and polarization stellar surface images were obtained at unprecedented resolutions with SPHERE@VLT, spectropolarimetric observations (with the instruments Narval@TBL and ESPaDOnS@CFHT) have made it possible, among other things, to detect and characterize the surface magnetism of these objects.





The interpretation of these observations requires realistic modelling that takes into account most of the processes at work in the atmosphere (i.e., convection, shocks, pulsation, radiative transfer, ionization, molecules and dust formation, magnetic field). In this context, the radiative hydrodynamics codes (RHD) have been developed, including the CO5BOLD code (Freytag et al. 2012). These simulations of AGB (Freytag et al. 2017) and RSG (Chiavassa et al. 2011) stars make it possible to follow the flowing matter, in complete 3D geometry, from the stellar interior to the circumstellar envelope, via the stellar atmosphere and the dust formation region.

Proposed work: Two physical ingredients play a predominant role in initiating and maintaining the high mass loss. In the first place the evolution of evolved stars is impacted by the vigours stellar convection, as well as the magnetic field. To provide quantitative steps forward in the comprehension of the physics of mass-loss, it is crucial to produce state-of-the-art 3D magneto-hydrodynamical (MHD).
The Ph.D candidate will work on the calculation of spectropolarimetric and interferometric synthetic data from the newly calculated grid of 3D MHD simulations of evolved stars. These simulations are already ready (or on-going) to be exploited and are the core part of PEPPER project. He/She will use a multidimensional radiative transfer code to provide a set of basic observables that will be directly compared to the actual observation programs of PEPPER (spectropolarimetry and interferometry). Part of these data are already acquired or will be by the begin of the Ph.D.

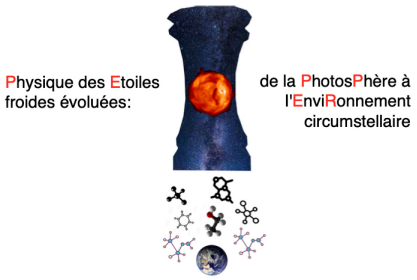
The aim of the Ph.D is to make the 3D simulations directly compared to explore and interpret all the observations made with different techniques in order to obtain a global, coherent vision of the evolved cool stars thanks to the synergy between theory and observation.

Hosting institute:

The LAGRANGE laboratory is a joint research unit of the Observatoire de la Côte d'Azur, CNRS and the University of Côte d'Azur. It is a multidisciplinary laboratory that brings together teams in astrophysics (planetology, stellar and solar physics, galaxies and cosmology), fluid mechanics, signal and image processing, and instrumentation for high spatial resolution and high dynamic range astronomical observation. The laboratory is leading the european consortium who developed MATISSE. Moreover, it is also involved in several space missions (Gaia, EUCLID, Osiris-Rex, and Hayabusa 2. The Stellar and Solar team's main research themes aim at advance the knowledge of the internal structure, atmosphere and environment of stars through heavy numerical simulations (carried out at the computing mesocenter), and research and developments of new and current instrumentation, with a particular accent on interferometry.

ANR-PEPPER

This Ph.D is part of the funded ANR (Agence Nationale de la recherche) project PEPPER (https://lagrange.oca.eu/fr/welcome-to-anr-pepper). *PEPPER* consortium includes five nodes in France (Nice, Montpellier, Toulouse, Bordeaux and Paris) which represent all the poles where stellar physics and, in particular, evolved stars are actively studied simultaneously from an observational, theoretical, or instrumental point of view.



The Ph.D will take part to all the collaborating meetings of PEPPER and a there is a dedicated budget for international conferences and workshops.

For any information/questions, write to Andrea Chiavassa (andrea.chiavassa@oca.eu)