PhD Job Announcement within the 4D-STAR ERC-Synergy Project

Host institute:

The host institute is Institut de Recherche en Astrophysique et Planétologie (IRAP[1]) located in Toulouse, France. IRAP is a Joint Research Unit (UMR 5277) which is affiliated with the National Center for Scientific Research (CNRS) and the Paul Sabatier University – Toulouse III (UPS). It is a member of the Midi-Pyrénées Observatory (OMP) and also has close connections with the National Center for Space Studies (CNES). IRAP is one of the largest astrophysics laboratories in France, gathering 300 people, which include about 100 researchers, 50 PhD students, 50 post-docs and a 100 engineers or adminsitrative staff. The research themes span almost every domain of astrophysics, including cosmology, high-energy astrophysics, stellar and solar physics, and planetology.

The PhD thesis will take place within the PS2E team, namely the Physics of the Sun, Stars and Exo-Planets team[2] and will be supervised by Prof. Michel Rieutord.

PhD subject description:

A study of hydrodynamic instabilities in Be stars

Be-stars form a subset of B-type stars, which are main sequence stars of mass in between 3 and 10 solar masses. The special property of Be stars comes from their spectrum where one usually sees emission lines, like hydrogen Balmer lines. These emission lines betray the existence of a hot circumstellar gas, hot enough so that atomic collisions can steadily populate excited levels of the gas atoms which then radiates energy through emission lines. Another characteristics of Be-stars is their fast rotation. Many of them show a rotation rate that is about 80% of the critical angular velocity. We recall that the critical angular velocity is such that matter at the stellar equator has reached the Keplerian velocity. In the interpretation of the Be phenomenon, emission lines and rapid rotation have been quickly related. Presently, the scenario which seems the most likely is that emission lines are produced by an excretion disc that surrounds the star. This disc is fed by the star, by an unsteady process generally, which is signed by the variability of the emission lines. However, this model fails to explain how the star is able to put this matter into orbit. Indeed, while the rotation of the star is very fast, it is always less than critical: equatorial matter neither has the energy nor the angular momentum to be in orbit. Hence, some additional mechanism is needed to make the step from the surface to the orbit. The most promising way seems to be that of hydrodynamic instabilities which would destabilize surface waves and would provide matter with the needed angular momentum and energy to be sent into orbit.

This PhD thesis therefore proposes to study rigorously the hydrodynamic problem. The first step will be to study the stability of inertial waves when there is a sub-surface differential rotation. Such differential rotation is indeed driven by the baroclinic torque that is present in the radiative envelope of the star. It may be computed using the ESTER code. The stability of this flow will be analyzed regarding the various parameters that characterize the surface layers of the star (like thermal stratification, density profile, etc.). The work should start

[1] `https://www.irap.omp.eu/`

[2] see `https://www.irap.omp.eu/research-team/physique-soleil-etoiles-exoplanetes-ps2e/`

with a linear analysis of the problem to identify the most promising unstable modes. Then, in a second step, we will investigate the nonlinear evolution of these instabilities and their capabilities to provide energy and angular momentum to send matter into orbit.

This PhD thesis is meant for students interested by stellar hydrodynamics and the associated questions, which extend from stellar evolution to asteroseismology. Hence, good knowledge in fluid mechanics is useful and as well as some ease at scientific computing. Many numerical tools are already available to perform this analysis, so that the student may concentrate on the physics and that the coding part remains reasonable. The student will benefit from the stimulating environment of the PS2E-team, the collaboration with Prof. L. Valdettaro at Politecnico di Milano, and the broad team of the 4D-STAR ERC project[3].

The contract: The selected PhD student will be offered a 3-year contract, which is the normal duration of a French PhD thesis. The net salary is the standard scale for PhD students in France, namely 2 044.12 euros per month (gross salary since January 2023). It includes social and medical insurance as well as pension rights.

Funding: 4D-STAR ERC Synergy project

Requirements: PhD applicants must hold a M.Sc. degree in physics or astrophysics. The degree must be dated at the latest one month before the position can be taken up. Previous internships in a research laboratory are an asset. Good knowledge of the English language, oral and written is a requirement.

Application: The applicant should prepare a single pdf file that contains: 1/ a curriculum vitae, with a publication list if relevant, 2/ a one page (max.) statement of interest, 3/ a summary of the research experience (one page max.), 4/ a list of University courses taken and transcripts of grades obtained (i.e. original transcripts and also a translated version if not in French, English, Italian, Spanish or German - It does not need to be notarized), 5/ names and contact details of two persons who would be prepared to send a reference letter.

Application (and inquiries) should be sent by e-mail to **Michel.Rieutord@irap.omp.eu**

Deadline: March 24th, 2023

Final selection: The short-listed applicants will be invited for a video-interview in the first week of April.

Starting date: The foreseen starting date is October 1st, 2023. It is however flexible but cannot be earlier than September 1st, 2023.

[3] `https://fys.kuleuven.be/ster/research-projects/4d-star/`