ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

DIPARTIMENTO DI FISICA E ASTRONOMIA
Department of Physics and Astronomy - DIFA

PhD project in ASTROPHYSICS

Title of the Project: High-precision stellar astrophysics: testing models of stellar structure using asteroseismic, astrometric, and spectroscopic constraints

Supervisor : Andrea Miglio (andrea.miglio@unibo.it),

This PhD project will be developed in collaboration with the team working on the ERC-funded project *asterochronometry* (https://www.asterochronometry.eu).

Scientific Case:
The availability of precise and accurate asteroseismic (*Kepler*, K2, TESS), astrometric (Gaia), and spectroscopic data allows novel and stringent (~% level) tests of stellar physics. These long-sought constraints will significantly improve our ability to determine stellar radii, masses, ages, and chemical yields, with wide-ranging impact e.g. on the characterisation of exoplanets, on our understanding of the assembly history and evolution of the Milky Way, and of galaxies.

Outline of the Project:
Detailed constraints on the internal structure of stars can be inferred by looking at specific signatures in the global oscillation frequencies. In particular, deviations from the expected, approximated, frequency patterns of pressure and gravity pulsation modes can be used to detect and infer detailed properties of *localized gradients* in the deep stellar interior, e.g., in the chemical composition / thermal stratification / sound speed profile. Examples of such localised features include convective boundaries (regions of strong thermal and chemical gradients) and He-ionisation regions where the adiabatic index, hence the sound speed, has a local minimum, and whose signature can be used to infer the envelope He abundance.

The project is comprised of several components, to be discussed and defined in detail also taking into account the student's interests and skills:

- aided by simple models, carry out a semi-analytical study of the effect of sharp-structure variations on the frequencies of pulsation modes;
- compute models of evolved stars and their pulsation spectra exploring several uncertainties related to the micro- and macro-physics used in stellar modelling;
- design tests to differentiate and characterise the physical processes that determine the location and properties of the sharp structure variations (rotationally-induced vs convective mixing, various prescriptions for the transport of chemical elements, also following 3D hydrodynamical simulations);
- analyse and interpret data from the *Kepler*/K2 and TESS missions, as part of large international collaborations.

The nature of the project is such that the student should be happy analysing and manipulating data, developing simple analytical approximations, computing and interpreting results from numerical simulations of stellar evolution. Familiarity with stellar evolution would be beneficial.

Contacts: andrea.miglio@unibo.it