ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA
DEPARTMENT OF PHYSICS AND ASTRONOMY
"AUGUSTO RIGHI"

# PhD project in ASTROPHYSICS – MUR FARE GRANT *DUETS*

**Title of the Project:** *Duets* - Identifying and characterising populations of binary stars using asteroseismology

**Supervisor :** Andrea Miglio
**Co-Supervisors** : Enrico Corsaro (INAF OACt)

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 project *Duets* will leverage the combination of astrometric, spectroscopic, and, crucially, asteroseismic data to open a new window on the population of (products of) binary systems among red giant stars. We will identify unresolved stellar binary systems comprised of red giants by detecting the presence of two solar-like oscillation spectra in the frequency spectrum of a single light curve (in so-called asteroseismic binaries). Determining the occurrence rate of such objects will yield invaluable results to probe the initial mass ratio distribution function of binaries and provide well-constrained systems that can be used to stress-test models of stellar structure.
Moreover, we will identify and study products of coalescence and mass exchange, with the aim of quantifying the occurrence of these objects in the composite galactic disk population. By comparison with synthetic binary populations and with parameterised post-merger / post-mass-transfer evolution models, we will constrain some of the key assumptions in models of binary evolution, such as the initial binary fraction and the initial period distribution, with the potential of reducing some of the uncertainties affecting the description of mass-transfer events.

**Outline of the Project:**
The student will focus initially (year 1) on identifying candidate unresolved binaries via:

- Comparison between astrometric and "asteroseismic" parallaxes. The detection of binaries through this method requires highly precise parallax measurements, which Gaia has now delivered in its DR3.

- Power spectra analysis. We will devise metrics based on the power excess associated with solar-like oscillations that are sensitive to the presence of a companion. This task will be aided by generating artificial unresolved (seismic) binaries by combining appropriately rescaled light curves of stars in the Kepler field. This is similar to the procedure adopted in Miglio et al 2014, where one can see e.g. the reduced oscillation amplitudes and granulation background (due to the dilution of the perturbations in the combined flux of the two components) and an extended / asymmetric power excess associated with oscillations.

- Including astrometric information on any wide binary systems among the sample of giants showing solar-like oscillations (see e.g. Gaia DR3, El-Badry et al. 2021), and stars that show evidence for companions in their light spectra (e.g. Traven et al. 2021).

The student will then concentrate on studying in more detail the properties of the stars in the catalogue, both from the data-analysis (year 2) and modelling (year 3) standpoint. The student will perform a detailed analysis of their oscillations spectra, and measure individual-mode frequencies for the most promising targets in the catalogue. This will require extending data-analysis techniques (see https://github.com/EnricoCorsaro/FAMED) to account for the effect of contamination and, possibly, of a second pulsating component.

The nature of the project is such that the student should be happy coding, analysing and manipulating data, and interpreting results from numerical simulations of stellar evolution.

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