



# Hunting for binary stars and exotic stellar populations in star clusters and beyond

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**Abstract.** The first edition of a three-day workshop dedicated entirely to binary systems in star clusters and beyond was held at the Department of Physics and Astronomy of the University of Florence. The goal of the workshop, organized as part of the ERC-funded StarDance project, led by Dr. Pancino, was to bring together experts in simulations of detailed binary evolution and population synthesis codes, asteroseismologists and observers of binary stars in different environments (e.g., open vs globular clusters) to share ideas, discuss current results and build new collaborations that can help us take the field a step further.

**Keywords:** binaries, star clusters, stellar rotation, exotic stellar populations (blue stragglers stars, blue lurkers).

Binary stars have long served as fundamental astrophysical laboratories, providing some of the few direct means to measure stellar masses and distances. These systems are fundamental for calibrating models of stellar evolution and have become key to understanding the diverse and exotic stellar populations observed in clusters. Their relevance extends to the final stages of stellar evolution and to unveiling hidden populations of compact objects – black holes, neutron stars, pulsars and white dwarfs. In the age of gravitational-wave astrophysics, binary stars have taken center stage, as mergers of compact remnants such as black holes and neutron stars are now being observed directly. Moreover, understanding binary evolution remains crucial for studying Type Ia supernovae, which continue to serve as standard candles for probing the distant universe.

In recent years, advances in large-scale spectroscopic, photometric, astrometric and asteroseismic surveys – such as *Gaia*, *Kepler*, *APOGEE* and *LAMOST* – have dramatically expanded the number of known and well-characterized binary systems. Yet our understanding of binaries remains far from complete. Despite their remarkable precision, even space-based missions like *Gaia* face limitations when it comes to identifying and characterizing binaries in dense stellar environments, such as globular and massive young clusters. In this context, instruments like MUSE at the ESO Very Large Telescope have demonstrated the potential of integral field spectroscopy to overcome these challenges, delivering unprecedented datasets that are reshaping our understanding of binary populations in crowded regions.

At the same time, innovative and underexplored strategies are emerging. These include the application of machine learning techniques to large survey catalogs and archival spectra, as well as the use of indirect diagnostics like signatures of stellar interaction and chromospheric activity to uncover new binary candidates.

On the theoretical side, a new generation of public codes for modeling the evolution of binary systems – ranging from population synthesis tools like *SEVN* to detailed stellar evolution frameworks such as *MESA* – is transforming the field. However, despite their sophistication, these models still rely on significant approximations, the effects of which are not yet fully understood. Progress in this area depends critically on assembling large, homogeneous samples of well-characterized binaries against which theoretical predictions can be rigorously tested.

The conference gathered 45 participants from around the world, with a strong representation from Europe (33 participants) and a significant presence from other continents, including North America (5), South America (4), Australia (2) and Asia (1). The meeting featured ten invited speakers and its format was designed to promote collaboration and discussion: each invited participant was encouraged to bring one or two collaborators, with whom they shared a 45-minute slot. The slot was divided into 20 minutes of scientific presentation and 25 minutes of guided discussion, allowing a dynamic exchange of ideas and perspectives. This interactive format proved extremely successful, fostering open dialogue and active participation from all attendees.

Every day ended with a focused discussion session, dedicated alternately to observations, theoretical modeling, and the potential synergies between the two. These sessions encouraged cross-disciplinary engagement, identified key challenges in connecting data and models, and laid the foundations for future collaborations and coordinated efforts.

The workshop website is available at the following link: <https://sites.google.com/inaf.it/binariesworkshop2025/home-page?authuser=0> while presentations and posters can be found in the “StarDance - Binaries Workshop 2025” community created in Zenodo: [https://zenodo.org/communities/stardance\\_binaries25/about](https://zenodo.org/communities/stardance_binaries25/about). A group picture is shown in Figure 1.

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Figure 1. Group picture with all the participants at the Workshop.