PhD project in ASTROPHYSICS

Title of the Project - LISCA: Lively Infancy of Star Clusters and Associations

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Scientific Context | Clustered star formation is an important, if not the dominant, mode of star formation since the early Universe. In fact, it is widely accepted that most (70-90%) stars are born in groups, clusters or hierarchies and spend some time gravitationally bound with their siblings when still embedded in their progenitor molecular cloud. The possible end-products of clustered star formation, i.e. star clusters, are potentially powerful tracers of the assembly process of galaxies and their main properties are strictly connected with those of their hosts, making them valuable probes for theoretical and observational astronomy across a wide range of disciplines from cosmology to stellar evolution.

To efficiently exploit stellar clusters as tracers of galaxy and large-scale structure formation, we must understand the physical processes setting their initial masses, structure and chemical composition and how they possibly evolve across the cosmic time.

Outline of the Project | The proposed project aims at characterizing cluster formation and early evolution in two local environments: *the Perseus and the Scutum complexes* in the outer and inner Galactic disc, respectively, and the discs of the *Magellanic Clouds*. These systems are characterized by recent star-formation episodes and by the presence of multiple young clusters and associations that show strong signatures of mutual interactions and of ongoing assembling process.
Young clusters and associations in local disc/spiral arms are the only recently formed stellar systems close enough to be resolved in individual stars, therefore they represent *the ideal laboratory* for constraining the physical mechanisms at the basis of cluster formation and studying their early evolution with a level of detail that cannot be achieved for distant systems.

We will perform the first comprehensive spectro-photometric and kinematical study of the young stars and clusters in the selected star-forming complexes to *i)* characterize the 6D velocity and position phase-space and study their velocity dispersion, rotation and anisotropy profiles and assess the cluster dynamical state, *ii)* compute cluster density profiles and derive their structural parameters (core and tidal radii, ellipticity) and look for evidence of intra-clusters over-densities possibly resulting from mutual interactions, *iii)* measure chemical abundances and abundance patterns and *iv)* derive accurate cluster ages from the turn-off luminosity and constrain the possible presence of age spreads.
To this aim, the project will take full advantage of a synergic use of the available and near-future Gaia astrometric catalogs and of a formidable dataset of state-of-the art proprietary photometric and spectroscopic data obtained with HST and ground-based facilities at the ESO-VLT and TNG telescopes. Eventually, the project will also have access to ESO-VLT/MOONS spectra secured within the GTO Galactic Survey.
We will then use proprietary state-of-the-art hydro-dynamical and *N*-body simulations to interpret the observed stellar cluster properties and to constrain the initial physical conditions for cluster formation and evolution.

The characterization of the stellar content of these systems will allow us to test *i)* the role of the environment on cluster formation, *ii)* the relative importance of individual clusters becoming unbound due to gas expulsion as opposed to the hypothesis of hierarchical structure formation and *iii)* the contribution of cluster formation on large scale structures in their host galaxies.
Interestingly, the properties of the interstellar medium in the Galactic disc are similar to those in the discs of other nearby galaxies. As a consequence, the results obtained within the project on star formation and feedback in local young clusters and associations can probe star formation across much of the local Universe.

Our team is one of the worldwide leading group in the observational study of stellar populations and star clusters, by using the most updated generation of instruments and telescopes from the ground and space. It also includes major experts of dynamical simulations and modeling and has granted access to the major international computational facilities. Hence, the proposed project will offer a great opportunity 1) to be trained on various aspects of stellar evolution, dynamics and chemical evolution from both the observational and theoretical points of view, 2) to get in contact with national and international experts of the field through meetings, workshops and visit exchanges, 3) and to publish original results and present them to international conferences.