Formazione ed evoluzione di sistemi stellari e planetari
Stellar and planetary systems formation and evolution

These theses are devoted to the observational study of structure formation over all physical scales: from planets to stellar clusters in our Galaxy to extragalactic structures (galaxies). In all the proposed projects the core observational dataset is taken with the best available instrumentation.

Alessia Moretti	**Mapping the molecular gas phase of peculiar galaxies in nearby clusters with ALMA** In the context of galaxy evolution clusters of galaxies play a special role, as they are the places where star formation gets quenched more efficiently, even if it is still largely unclear what is the main mechanism that induces the quenching. Among the various physical processes proposed so far, the ram pressure stripping (i.e. the stripping of gas from the galaxy disk due to the interaction with the hot intra-cluster medium, producing “jellyfish” galaxies) has been extensively studied recently here in Padova thanks to the GASP survey that makes use of the excellent spatial resolution of MUSE@VLT data. This has allowed to map the distribution of ionized gas out to large distances from the galaxies on a scale of ~ 1 kpc. The size and spatial resolution of this dataset is unique in the world. To understand where and how new star formation is happening or is quenched, one needs to be able to map the molecular gas content on the same spatial scale. This spatial resolution at sub-mm wavelengths is nowadays available thanks to the ALMA interferometer, but was impossible to achieve with single dish telescopes at the median redshift of GASP (z~0.05). The PhD student will work on the analysis of the (already acquired) ALMA data of 4 cluster stripped galaxies to a) map the extent of the molecular gas, b) analyze the relation, if any, with the ionized gas phase, c) derive the resolved Star Formation Efficiency to ultimately understand both how the gas stripping acts on the different gas phases, and how the physics of the star formation process proceeds in the peculiar environment of a stripped tail. This work will be one of the first attempting to resolve extragalactic star formation on scales comparables with the ones of our Galaxy. The student will be involved in an international team of young researchers both within INAF and abroad (Chile, Mexico, Netherlands, US).
Benedetta	**The role of the group environment in galaxy evolution**

Vulcani	The majority of typically sized galaxies in the local Universe reside in a common dark matter halo with other similar galaxies known as a galaxy group. However, this was not always the case. Nine billion years ago, when the universe was one third its current age, these galaxies were almost exclusively the only massive galaxy in their dark matter haloes. I propose a thesis to understand the effect galaxy groups have on the evolution of galaxy properties, using mainly observational methods. The project will trace the evolution of the star formation rate, dust content, morphology and total stellar mass of group galaxies from z=1.5 to 0 and compare such evolution to that of galaxies in more and less massive environments, with the intent of understanding the preprocessing in groups. The core of program is based on data coming from the Gemini Observations of Galaxies in Rich Early Environments (GOGREEN, PI Balogh), an ongoing Large program aimed at collecting imaging and deep spectroscopic data of 21 galaxy systems at $1 < z < 1.5$. To trace the evolution with cosmic time, data from the Grism-Lensed Amplified Survey from Space (GLASS, PI Treu) will be exploited in the redshift range $0.5<z<1$ and data from the Wide-Field Nearby Galaxy Cluster Survey (WINGS, PI Fasano) and its follow ups will be exploited as local benchmark. Follow ups for group galaxies in the local universe at various wavelengths are also envisioned (optical with MUSE, HI with Meerkat, CO with ALMA) to characterise the role of the group environments also on the spatially resolved properties of the galaxies. The supervisors of this thesis is highly involved in all the aforementioned collaborations so that the student will be immediately inserted in an international context, participating to the collaboration meeting and visiting collaborators across the world, most likely in Canada and US.
Benedetta Vulcani	**Hunting for jellyfish galaxies in the early universe** Clusters of galaxies are important laboratories for the study of the physical processes that drive galaxy evolution. In clusters galaxy formation proceeded at an accelerated pace compared to the rest of the universe. The physical mechanisms responsible for these effects are, however, still very much debated. A variety of processes have been proposed in the literature, ranging form slow-acting gravitational interactions such as galaxy–galaxy harassment to potentially extremely rapid interactions of galaxies with the gaseous intracluster medium (ICM). The latter process is called ram-pressure stripping (RPS) and is expected to be especially efficient in massive galaxy clusters. In the recent years, the physics and observational signature of RPS have been the subject of extensive numerical simulations and observational campaigns, in the local universe. In contrast, very little

	is known on RPS events at z>0. At high redshift clusters are not only intrinsically more massive, but they are also dynamically less evolved and more likely to be undergoing mergers than systems in the local Universe, a critical requirement as extreme RPS events are most likely triggered by merger-driven shocks. To date, only sparse RPS candidates have been identified beyond the local universe, based on morphological asymmetries detected on multi band imaging. Only one statistically significant sample of RPS candidates at z= 0.3-0.7 has been published, and only the basic information on the position of these galaxies within the clusters has been discussed. The proposed project will detect and investigate RPS candidates using the data of the Reionization Lensing Cluster Survey (RELICS) of the Hubble Treasury Program, which observed 41 massive galaxy clusters at 0.2<z<1. Ancillary data will be used to obtain a first characterisation of the galaxies, including spectroscopic redshift, stellar mass and colors. Dedicated campaigns will follow up the most striking RPS cases to characterise the spatially resolved properties of the objects, with the intent of understanding how, where and why gas is removed from galaxies, and at measuring the timescale and efficiency of gas stripping as a function of galaxy mass and environment. The detailed comparison of the observed morphological, kinematic and age information with simulations will also provide constraints for the physical recipes adopted in simulations. Comparisons with RPS candidates in the local universe (e.g. form the survey GASP, PI Poggianti) will allow to characterise the evolution of the strengths of the RPS across cosmic time. The student will be inserted in an international context and spend at least few months in foreigners institutes, where the collaborators to this project are based.
Silvano Desidera w. R. Gratton V. D'Orazi, R. Claudi, D. Mesa, R. Claudi	**Search and characterization of young planets with SHARK-NIR at LBT** We propose a PhD program focused on the search and characterization of young planets with SHARK-NIR, a new instrument coupled with the LBT extreme adaptive optics system at LBT and optimized for these science goals. In particular, the candidate will work on the main scientific aim of SHARK, the study of planets caught in formation phase. The thesis will include the acquisition, reduction, and analysis of data taken with SHARK-NIR (possibly complemented by those from the other instruments that could be used simultaneously, SHARK-VIS and LMIRCAM), their interpretation, with possible synergies with theoretical models of planet formation and dynamics. The schedule foreseen for SHARK-NIR (first light during the winter 2019/2020) is optimal for a PhD program starting in late 2019, allowing to the student to take part to the scientific exploitation of the

	instrument from the early stages. In case of delays of the availability of the instrument, we have large availability of additional datasets taken with SPHERE at VLT (in the framework of SPHERE GTO and other approved programs, including a large program) for works on the same research area.
w. R. Claudi, V. Nascimbeni	**Short-period planet at young ages** We propose a PhD thesis in the framework of the GAPS program (approved with long term status at TNG). We are working on the search and confirmation of young planets with the radial velocity technique and in the characterization of the atmospheres of transiting planets using HARPS-N + GIANO-B (GIARPS) at TNG. Candidate transiting planets around young stars identified with the TESS space mission are very promising for both areas. We propose a PhD program aimed at the confirmation of young planets identified with TESS with the radial velocity technique and their atmospheric characterization. Both aspects are crucial for the understanding of the origin of short-period planets and their migration histories, the main scientific driver of the GAPS2 long-term program. The PhD student will become a member of the GAPS team, a wide collaboration of more than 80 researchers working on exoplanets in Italy with several foreign collaborators.
Antonella Vallenari w. M. Pasquato	Gaia is an ambitious mission to map more than one billion stars in the Milky Way to unprecedented levels of accuracy, and is revolutionizing our views on the Galaxy formation and evolution. As more data pours in, several unsolved puzzles in the formation and evolution of our Galaxy can finally be addressed. Gaia gave us clear-cut memberships, astrometry, and proper motions for 1200+ Open Clusters (OC; Cantat, Vallenari et al 2018; Soubiran,...Vallenari et al. 2018). Meanwhile Gaia-ESO, APOGEE, WEAVE (first light 2020), the SPA and OSTTA projects at TNG and NOT telescopes complement GAIA with spectroscopy. The scale of these datasets is well into the big-data regime, and proper tools are needed to dissect them. The Ph.D. student will mine OC data with unsupervised machine learning -from simple clustering approaches to cutting-edge representation learning via deep neural nets- to unearth the answer to the following questions: 1) are all stars born in clusters, and what is the relation between clusters and the field? (Bouy et al. 2018) 2) why is the Galactic disk out-of-equilibrium (Gaia Collabration, Katz et al 2018) and what is perturbing it: spiral arms and bar, or satellites? (Antoja et al 2018) 3) how is stellar migration shaping the disk (e.g. see Freeman & Bland-Hawthorn 2002) and how are mergers affecting its evolution? The end goal is the statistical characterization of OC global properties

	in terms of chemical abundances, kinematics, and structural parameters. In particular: - are there distinctive groups of OCs corresponding to competing modes of formation and/or stage of dynamical evolution? How many groups and how strongly divided? (see e.g. Pasquato & Chung 2019) - are there OCs that are clear outliers with respect to this pattern, possibly corresponding to accreted OCs as opposed to OCs formed in-situ? - what is the intrinsic dimensionality of the OC dataset, i.e. the minimal number of independent parameters that define OC properties? A further goal is the characterization of individual stars in terms of chemistry, using abundance patterns to reveal OC stars lost to the field (chemical tagging). In the first year the Ph.D. student will gain the relevant skillset (Python with Astropy, Scikit-Learn, Keras+Tensorflow running on GPUs) and theoretical knowledge in cluster analysis (Kaufman & Rousseeuw 2009) and nonlinear dimensionality reduction (Lee & Verleysen 2007). The second year will be spent training autoencoders (see e.g. Goodfellow et al. 2016) on raw spectral data of stars from e.g. APOGEE, WEAVE, GES public data complemented with photometry and kinematics. Cluster analysis in the autoencoder latent variable space will improve on the state-of-the-art of chemical tagging, currently based on linear techniques (see e.g. Leung & Bovy 2019). The third year will see the application of similar techniques to OC global properties, astrophysical interpretation in terms of origin (e.g. in situ VS accreted) and determination of the number of subgroups in the OC dataset in latent space. Expected scientific products: papers, sharing of trained models/codebase in the spirit of reproducible research, and thesis. The student will be involved in the WEAVE, GAIA, and LSST international collaborations and spend part of the time working abroad. In addition to the supervisors (expert in open clusters/disk kinematics and machine learning techniques, respectively) the student will interact with other team members based at INAF/OaPD (Ricardo Jimenez Carrera, Rosanna Sordo) and with collaborators in Barcelona (Carme Jordi, Tristan Cantat) and Bordeaux (Caroline Soubiran). This is a young, dynamic and international team, with members involved in GAIA, WEAVE, and LSST.
Luigi Bedin	For the three theses described below the main training would be on high level astrometric and photometric techniques. During the PhD short periods (3-12 months) could be spent abroad (STScI,UCSD,UCLA,Univ.AZ).
	Stellar population in globular clusters Using three proprietary HST Large Program data, work on white dwarfs, multiple stellar populations

	Brown dwarfs Using three proprietary HST data, work on characterization and astrometric parameters of brown dwarfs, search for extrasolar planets.
	Extrasolar planets Search for extrasolar planets using archive data from KEPLER/K2/TESS. Synergy with HST and ground-based observations with the Schmidt telescope in Asiago