PhD Thesis Project Proposals – Cycle 42

RSN1: Galassie e Cosmologia

VST-MAGNET: Mechanisms Affecting Galaxies Nearby and Environmental Trends with VST
Supervisor: Gullieuszik Marco
Co-Supervisor(s): Alessia Moretti; Benedetta Vulcani

Galaxy evolution is fundamentally regulated by the flow of gas, which is heavily influenced by the environment. While recently we made many fundamental steps forward in understanding what drives gas flows in galaxies hosted in clusters, for galaxies in the more common, less extreme environments the core question is still open: what is the importance of each of these processes in regulating the whole galaxy population, as a function of galaxy mass and position within the large-scale cosmic structure?
VST-MAGNET is an ongoing OmegaCAM Large Programme providing narrow-band imaging to study Hα emission at redshift between 0 and 0.04 on a 65 deg2 sky area including galaxy groups and associations in filaments of the cosmic web. The deep, spatially resolved data on ionized gas and star-forming regions will shed unprecedented light on the efficiency of the different environmental mechanisms and of star-formation quenching for galaxies in a wide range of stellar masses
Vera Rubin Observatory's LSST survey will observe the southern sky with unprecedented depth . Its deep photometry will provide galaxy properties and morphology, serving as a powerful complement to VST-MAGNET data.
The PhD project involves working with both surveys, focusing on data reduction, analysis, and scientific exploitation, including the optimization and development of existing pipelines and software.

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https://arxiv.org/abs/2602.15142
https://sites.google.com/inaf.it/magnet/home

A multi-wavelength study of gas circulation in nearby late-type galaxies
Supervisor: Marasco Antonino
Co-Supervisor(s): Alessandro Pizzella (University of Padova)

This PhD project investigates gas flows in and around the discs of nearby late-type galaxies, traced by both the HI 21-cm line and optical emission lines. The candidate will analyze a sample of galaxies observed with the MeerKAT radio telescope and the MUSE spectrograph at the Very Large Telescope. The project aims to constrain: (a) the physical properties of neutral and ionised gas at the disc–halo interface, where galactic fountains and accretion processes regulate baryon cycling; (b) radial gas flows in the outer regions of galaxy discs, which connect galaxies to their circumgalactic medium. In parallel, the candidate will analyze synthetic observations derived from hydrodynamical simulations of galaxy formation and evolution, enabling a direct and quantitative comparison between observational results and theoretical predictions. The project offers strong opportunities for international collaboration between INAF, the Macquarie University (AU), and the University of Groningen (NL).

The environment and the morphology of Active Galactic Nuclei Hosts along the Eigenvector 1 sequence

Supervisor: Marziani Paola
Co-Supervisor(s): M. D'Onofrio

This thesis will explore the host galaxy morphology and environment of a spectroscopically selected sample of type-1 AGN organized along the Eigenvector 1 (E1) sequence. The project focuses on the physical connection between the nuclear properties of quasars—such as Eddington ratio, the occurrence and power of relativistic ejections, and chemical enrichment—and the large-scale properties of their host galaxies and surrounding environments.
The thesis work will follow two main lines of investigation.
First, it will examine the interaction between radio jets and the ambient interstellar medium (ISM). The student will investigate how radio morphology, jet orientation, and feedback signatures manifest in specific classes of type-1 AGN, using archival radio maps (e.g., VLA FIRST) together with optical spectra available from dedicated SOAR observations.
Second, the project will focus on optical imaging analysis to classify the morphology and environment of AGN along the E1 sequence. The host galaxy morphology of type-1 AGN, their colors, and their environments will be studied using multi-band imaging data (e.g., Pan-STARRS). Color maps will be used to trace dust lanes, star-forming regions, and structural asymmetries, helping to identify merger signatures, tidal features, and gradients in stellar populations.
Ultimately, this project aims to link nuclear and galactic-scale processes in a unified evolutionary framework.

Super-Eddington Accretion onto Supermassive Black Holes

Supervisor: Marziani Paola
Co-Supervisor(s): M. D'Onofrio

In recent years, a growing body of observational evidence suggests that supermassive black holes may undergo phases of super-Eddington accretion which appear necessary to explain their rapid growth at early cosmic times. A primary goal of this thesis is therefore to define multi-frequency selection criteria (involving spectral energy distributions, emission line properties, and variability patterns) to make it possible the reliable identification of super-Eddington candidates in large surveys such as SDSS and DESI. The project will afterwards focus on three key aspects: (1) the accurate estimation of black hole mass and Eddington ratio, with particular attention at viewing angle effects; (2) the dynamics of the wind associated with the accretion process — using velocity shifts and profiles of optical and UV emission lines; (3) the chemical composition of the line-emitting gas, in connection with recent scenarios proposing nuclear star formation in the outskirts of an advection dominated accretion flow. Depending on the student background and interest, the analysis might be purely observational or more oriented toward dynamical and photoionization modeling, as well as modeling of accretion-modified stars. The student will benefit from a steady collaboration with astronomers at Gemini/NoirLab, Belgrade Observatory, the Instituto de Astrofísica de Andalucía, and the Instituto de Astronomía of UNAM, among others.

Study of high-redshift quiescent galaxies with machine learning
Supervisor: Merlin Emiliano
Co-Supervisor(s): Giulia Rodighiero (UniPD), Andrea Grazian, Paolo Cassata (UniPD)

Recent observations have confirmed the presence of massive quiescent galaxies out to $z \sim 5$ and beyond. These findings challenge standard galaxy-formation theories, and call for statistically robust analyses based on multiwavelength data: combining optical/near-IR observations with FIR/sub-mm and X-ray constraints is essential to accurately characterize stellar populations, dust content, and possible AGN activity. This PhD project aims at exploiting state-of-the-art datasets and established data analysis techniques combined with new machine-learning approaches to robustly identify, validate, and characterize high-redshift quiescent galaxies.
The student will exploit existing photometric and spectrosopic JWST datasets, assemble new multiwavelength photometric catalogs adding data from other facilities, and develop a pipeline for parameter inference (redshift, stellar masses, ages, star-formation histories) possibly exploring hybrid approaches to integrate physically motivated SED modelling and machine learning methods. The goal is to deliver statistically robust measurements of number densities, mass functions, and quenching timescales (providing hints about the mechanisms driving the quenching episodes) of quiescent galaxies at $z>3$. The student will work within a multidisciplinary team that provides expertise in photometric and spectroscopic techniques, forward modelling, and galaxy evolution; data and high-performance computing resources are already available.

Galaxy formation in Modified Newtonian Dynamics
Supervisor: Merlin Emiliano
Co-Supervisor(s): Federico Lelli (INAF-OAA), Flaminia Fortuni (INAF-OAR), Mauro D'Onofrio (UniPD)

ΛCDM is our most successful cosmological model, but exploration of possible alternatives is motivated by emerging tensions with observations (e.g. the H_0 tension, the abundance of massive galaxies at unexpectedly early epochs discovered by JWST, and long-standing issues in the properties of low-mass stellar systems such as dwarf galaxies and tidal streams). Modified Newtonian Dynamics (MOND) provides accurate predictions on many scales, but must be rigorously tested with full hydrodynamical simulations of structure formation. This PhD project will focus on the creation and analysis of galaxy formation simulations in MOND: building on an existing implementation (the Phantom of Ramses code), the student will 1) implement a MOND gravitational solver in a state-of-the-art hydrodynamical simulation code; 2) produce simulations of galaxy formation in cosmological context; 3) process the output using the forward modeling software FORECAST (developed by our team), to produce synthetic imaging and spectroscopic products matched to recent observational programs; and 4) quantitatively compare the results against real data, with particular focus on the properties of satellites and tidal stellar streams, providing robust insights on the accuracy of the MOND hypothesis. The student will work within a multidisciplinary team that provides expertise in numerical methods, forward modelling, and galaxy evolution; data and high-performance computing resources are already available.

Galaxy evolution in dense environments from low to intermediate redshift using resolved and unresolved spectroscopy

Supervisor: Moretti Alessia

Co-Supervisor(s): Benedetta Vulcani, Marco Gullieuszik

The transition of galaxies from active, star-forming systems to passive, quiescent members of the "red sequence" is most dramatic within the context of massive galaxy clusters. However, the dominant physical mechanisms—ranging from slow starvation in the cosmic web to violent ram-pressure stripping in the cluster core—remain poorly constrained across cosmic time. This PhD project proposes a comprehensive, multi-scale study of galaxy evolution by bridging the gap between large-scale environmental statistics and small-scale internal physics.

Using the high-multiplex 4MOST CHANCES survey, the student will analyze the unresolved spectra of ~100,000 galaxies to map the "pre-processing" phase in cluster outskirts (up to 5xR200) at low redshift. These data will be complemented by spatially resolved MUSE IFU observations from the GASP survey and archival data of z~0.3 clusters.

The main goals of the project are to 1) characterize the environment on large scales 2) understand to which extent the galaxy star formation histories are connected to the environment 3) disentangle the effect of intrinsic galaxy properties 4) use the resolved mapping of the different gas phases and stellar populations to infer the presence and the temporal evolution of the physical processes affecting them.

The student will be immediately inserted in a broad international context and will have the possibility to collaborate with other team members both in Italy and abroad.

RSN2: Stelle e Pianeti

Unveiling the Faintest and Coolest Stellar Populations in the Nearest Globular Clusters: A Multi-Mission Investigation with JWST, HST, and Euclid
Supervisor: BEDIN Luigi "ROLLY"
Co-Supervisor(s): M. Libralato, D. Nardiello, G. Carraro

The candidate will develop comprehensive expertise in globular clusters (GCs), their internal kinematics, and their faintest stellar populations, which are among the hottest topics in the stellar-population field. GCs are among the oldest stellar systems in the Universe and serve as powerful laboratories for stellar evolution and dynamical processes in dense environments.
This PhD project will push observations to the extreme faint and cool limits of stellar populations in the nearest Galactic GCs through a coordinated multi-mission analysis combining JWST, HST, & Euclid. We have secured high-priority JWST time to obtain ultra-deep near-infrared photometry & astrometry in clusters. These data will be combined with archival HST imaging for long-baseline proper motions and with wide-field Euclid observations extending the study from crowded cores to cluster outskirts. As members of the Euclid Consortium, we have full access to proprietary data and advanced pipelines, ensuring a homogeneous and optimized analysis.
The project will probe the H-burning limit in metal-poor environments, trace complete white dwarf cooling sequences, and derive state-of-the-art internal kinematics, constraining sub-stellar physics, cluster ages, mass segregation, and energy equipartition. The candidate will acquire advanced expertise in high-precision astrometry & photometry across multiple space missions, building a strong foundation for a career in modern astrophysics.

Mining the Kepler Superstamps: A High-Resolution HST Search for Cluster Exoplanets
Supervisor: BEDIN Luigi "ROLLY"
Co-Supervisor(s): D. Nardiello , M. Libralato, G. Carraro

The Kepler mission revolutionized exoplanet science, yet a massive dataset remains locked within the "superstamp" fields of open clusters NGC 6791 (metal-rich) and NGC 6819 (solar-metallicity). While these fields contain thousands of stars monitored for four years, severe crowding has historically prevented reliable analysis. This PhD project aims to unlock this potential by combining Kepler photometry with HST's high resolution for these two clusters, and in other star clusters and field stars employing Euclid's wide-field astrometry.
Participating in the "25,000-Lightcurve HST–Kepler Treasury Survey," the candidate will use HST imaging to de-blend crowded sources and extract precise light curves. Crucially, the team's Euclid Consortium membership guarantees access to proprietary data, enabling robust cluster membership determination via proper motions to filter out field interlopers.
By applying machine-learning techniques to ~25,000 light curves, we anticipate detecting >70 new transiting exoplanets. This sample will allow a direct test of the planet–metallicity relation in chemically homogeneous environments and provide a legacy catalog for atmospheric characterization with JWST and ARIEL. The candidate will develop competitive skills in "big data" mining, precision photometry, and exoplanet demographics.

Benchmarking Supernovae Progenitors in the Era of Large Surveys
Supervisor: Elias-Rosa Nancy

Massive stars do not all die in the same way, yet we still lack a predictive framework linking their pre-explosion properties to the type of supernova they produce. Direct progenitor detections remain scarce, and mass estimates are often uncertain and model-dependent.
This PhD project aims to build a homogeneous and statistically robust benchmark for supernova progenitors. The student will construct a large photometric database of several hundred spectroscopically confirmed evolved massive stars in the Milky Way and the Magellanic Clouds, mapping their luminosities, temperatures, extinction, metallicities, variability, and mass estimates. Statistical and machine-learning tools will be used to explore correlations and systematic effects.
The resulting framework will be directly compared with observed supernova progenitors, including low-luminosity events and candidates for failed explosions. Fully embedded in the era of large surveys, the project will exploit data from Euclid, Vera C. Rubin Observatory, and Nancy Grace Roman Space Telescope to connect massive stars before explosion with their outcomes.

Exploring the Explosive Deaths of Massive Stars: Linking Optical and Radio Transients
Supervisor: Elias-Rosa Nancy

Understanding how massive stars end their lives requires a multi-wavelength approach. Optical surveys detect large numbers of supernovae, but dust obscuration and circumstellar interaction can hide or alter their signatures. Radio observations provide a direct probe of the pre-supernova mass-loss history and circumstellar environment.
This PhD project will correlate optical and radio properties of core-collapse supernovae to address two key questions: what fraction of stellar explosions is missed due to dust, and what can radio emission reveal about progenitor mass loss and wind structure? By cross-matching optical samples with radio detections and modelling synchrotron light curves, the student will derive mass-loss rates, shock properties, and magnetic field strengths.
The project is fully aligned with INAF's time-domain strategy and will synergise with upcoming facilities such as Vera C. Rubin Observatory and SKA, contributing to a more complete census of massive star deaths.

Asteroseismology in the PLATO era
Supervisor: Girardi Leo
Co-Supervisor(s): Diego Bossini (DFA-UniPD), Andrea Miglio (Uni.Bologna)

Asteroseismology has become a fundamental tool to obtain direct information about the main stellar parameters (mass, radius) and their internal structure. A mine of asteroseismic data of unprecedented precision and richness is now available due space missions like CoRoT, Kepler, and TESS, and it will be further enhanced with ESA's mission PLATO. This PhD project focuses mainly on the asteroseismic modelling of low-mass, metal-poor red giant stars in these databases, which serve as valuable probes of Milky Way halo and thick disk populations. The student will use the PARSEC code to compute stellar evolution models, and the optimisation tool PARAM to derive the most likely stellar parameters. Particular attention will be given on the introduction of alpha-enhancement in the models, a signature of their rapid chemical enrichment. The student will then apply those tools to the high-quality asteroseismic data for thousands of stars from space missions such as Kepler and TESS. The aim is to calibrate stellar models of red-giant stars and set the stage for the upcoming PLATO mission.

The role of stellar rotation on stellar population models
Supervisor: Girardi Leo
Co-Supervisor(s): Guglielmo Costa (DFA-UniPD)

Hubble Space Telescope data for star clusters in the Magellanic Clouds made crystal clear that rapidly rotating stars are much more common than previously thought. However, most interpretative tools of stellar populations (e.g. age estimates based on the HR diagram or on the integrated spectra of galaxies) completely ignore the presence of rotating stars. To fix this situation, our team has started a deep revision of the PARSEC database of stellar models, with the consideration of rotation on the stellar evolution, on the stellar spectra, and in the surface chemical abundances. During this PhD project, we will complete the transition to stellar population models that fully include the impact of rotation, hence providing an extremely useful database to the astrophysical community. There is plenty of public and proprietary data on which our models can be calibrated, including HST imaging and spectra of Magellanic Cloud star clusters, Keck spectroscopy of giants in nearby galaxies, and the broadening of spectral lines from Gaia. Moreover, new data from JWST and Euclid will be available soon as well as asteroseismic inferences on the internal rotation from the Kepler and TESS satellites.

Mapping the Galactic Disk with Big Data:
Supervisor: Lucatello Sara
Co-Supervisor(s): Lorenzo Spina, Giovanni Carraro

The 4MOST Stellar Clusters Survey will provide an unprecedented dataset of chemical and kinematic measurements for tens of thousands of stars in over 1500 open clusters, by far the largest collected to date.
Aim of the project is to harness the full potential of this big data set to study the evolution of the Galactic disk. By applying machine learning techniques to classify clusters, identify outliers, and model trends in age, metallicity, and motion, the project will map chemo-dynamical gradients and uncover signatures of radial migration and disk heating. Combining 4MOST data with Gaia astrometry, and LSST photometry, this work will offer a novel, data-driven view of disk structure and history.

Kinematics of Multiple Populations in Globular Clusters in 4MOST
Supervisor: Lucatello Sara
Co-Supervisor(s): Lorenzo Spina, Giovanni Carraro

Aim of the project is to explore the internal kinematics of ~80 Galactic Globular Clusters using the data from the 4MOST Stellar Cluster Survey—the largest spectroscopic dataset of GC stars ever assembled. Combining chemical abundances and radial velocities from 4MOST with Gaia astrometry and LSST photometry, and applying data-driven methods, the project will investigate rotation, dispersion, and anisotropy within and between stellar populations to constrain the formation and dynamical evolution of globular clusters.

Stellar populations in star clusters
Supervisor: Marino Anna Fabiola
Co-Supervisor(s): Emanuele Dondoglio

Globular clusters have always been among the most intensively studied stellar systems. Yet, we have never really understood why it was so easy to produce such massive and extremely dense stellar aggregates, and in such a widespread fashion. With the presence of more than one stellar population in these ancient stellar systems, answering these questions became harder than ever.
This is a PhD project to investigate the multiple stellar populations in globular clusters to address the formation mechanisms of this phenomenon in the early Universe.
In recent years, we have developed new tools for characterising multiple populations in star clusters, which are based on the synergy between the knowledge of chemical abundances and multi-band photometry, including data obtained at the James Webb Space Telescope. The project will exploit a plain synergy between different observing
techniques, including spectroscopy, photometry, astrometry and push up to their maximum limits the present telescope facilities to solve the enigma of multiple stellar populations in globular clusters.

Boosting our capability to detect and characterize substellar object exploiting current and future high-contrast instrumentation.
Supervisor: Mesa Dino
Co-Supervisor(s): Cecilia Lazzoni

Direct detection is becoming increasingly important in the field of exoplanetary science. This has been made possible thanks to current state-of-the art instruments (e.g., SPHERE, GPI, SHARKs) that allowed the detection of tens of new objects at separations of few tenths of arcsec from their host stars. Moreover, the spectral capabilities of such instruments allowed to characterize the atmospheres of such object making possible to understand their main physical characteristics. The new instrumentation of the future ELT telescope promises to further improve both our capabilities to detect new low mass companions (allowing to explore the inner part of the planetary systems where we expect that the bulk of their distribution reside) and our capabilities to characterize their physical properties (thanks to the possibility to obtain higher resolution spectra). The PhD student participating to this program will exploit current instrumentation trying to push forward the limits of such instrument with new high-contrast imaging methods. On the other hand, this work will also be a preparatory work to define the sample for observations with ELT instruments. IT tools developed to simulate the performance of such instruments will be coupled with observations to further improve the quality of work.

Detection and characterization of transiting exoplanets with PLATO
Supervisor: Nascimbeni Valerio
Co-Supervisor(s): S. Desidera, G. Piotto, L. Malavolta

PLATO (Rauer+ 2025) is an ESA satellite designed to discover thousands of transiting exoplanets, with a particular focus on habitable Earths hosted by bright and nearby Solar-type stars. Equipped with 26 wide-field optical cameras optimized for ultra-high-precision photometry, PLATO will be launched in early 2027 and, after a commissioning phase, it will stare at its first field for at least two years continuously (Nascimbeni+ 2025). PLATO will deliver a huge amount of data (400 GB/day), and most of its >200,000 light curves will be released to the public as soon as the technical validation is performed. In other words, starting in early 2028, the community will be involved in a large effort of detection, vetting, and follow-up of candidate planets. We will build on the expertise of the OAPD exoplanet group and its deep involvement in the mission consortium to actively contribute to scientific exploitation. The first months of this PhD will be spent optimizing advanced transit-detection techniques to mock data. In 2028, these tools will be applied to real data to identify planetary candidates to be first validated through photometric techniques, and later followed up with dedicated radial velocity and/or direct imaging observations. A strong focus will be given to dynamical methods such as TTV analysis (Nascimbeni+ 2023, 2024) as a way to get accurate planetary masses and densities, and to constrain the inner structure and evolutionary pathways of the studied systems.

Systematic characterization of the interacting gap transients in the era of large surveys
Supervisor: Pastorello Andrea

Gap Transients (GTs) are stellar transients sitting in the under-populated absolute magnitude interval ("gap") from -10 to -14 mag. While the spectra ot GTs are similar at early phases, with typical narrow Balmer emission lines indicating the presence of a dense H-rich circumstellar medium, the later spectral evolution and the light curves show a large heterogeneity. In 2018, our group began a project of monitoring GTs discovered by the panoramic surveys, and new opportunities will be offered by the forthcoming Legacy Survey of Space and Time at the Vera Rubin Observatory. Comparing spectro-photometric data with theoretical models revealed that GTs can be produced by diverse physical processes (eruptions, mergers, terminal SN explosions), and their progenitors span a wide range of evolutionary phases and masses.
The PhD project consists of studying new GTs, and the activities include:

1. Leading observational campaigns at major facilities (VLT, NTT, GTC, NOT).
2. Analyzing public archival data (HST, JWST, Euclid) to identify the quiescent progenitors and study their historical variability.
3. Comparing observational data with theoretical models to infer key physical parameters.
4. Carrying out statistical studies and rates estimates. The PhD student will trigger observations, reduce and analyse photometric and spectroscopic data in multiple domains and will be an active part of international collaborations (ePESSTO, NUTS, SOXS).

Observational evidence of the formation phase of extrasolar giant planets
Supervisor: Rigliaco Elisabetta
Co-Supervisor(s): Raffaele Gratton

Over the past three decades, thousands of extrasolar planets have been discovered, making the study of planet formation a key topic in astronomy. The analysis of protoplanetary disks - the birthplace of planets - has gained new momentum.
Multi-wavelength and multi-technique approaches have revealed their importance in this field. By combining observations at different wavelengths, using different instruments and methods, we can reach a comprehensive view of the process of planet formation. To this observational approach, it must be mentioned the theoretical models, which are key to the interpretation of disk evolution and planet formation, such as the time-evolution, the migration of planets around the host star, and the impact of the surrounding environment on planet formation and disk evolution.
The student will work in this field, performing multi-wavelength (UV to millimetric) and multi-technique (employing direct imaging, spectroscopy, IFU) approach on a sample of objects to gain a comprehensive view of the planet formation and disk evolution process. The student will be asked to put the knowledge acquired from the past techniques in perspective with the new-generation instrumentation that will soon be available on the ELTs, such as METIS and MORFEO. Moreover, the student will perform a comparison of the planet formation analysis with our own Solar System planetary architecture, allowing us to bridge the formation of extrasolar planets to our own star.

Deciphering the Milky Way with Machine Learning
Supervisor: Spina Lorenzo
Co-Supervisor(s): Sara Lucatello

Modern astrophysics faces a data revolution, with millions of stellar spectra observed by next-generation surveys shifting the challenge from simply gathering data to finding innovative methods to extract knowledge from it. This PhD project leverages advanced Machine Learning techniques to solve fundamental puzzles of our Galaxy, offering a unique opportunity to work at the frontier of astrophysics and data science. You will develop data-driven algorithms to reconstruct the Galaxy's assembly history, mapping how stars migrate across the disk to understand the dynamical evolution of the Milky Way. Furthermore, you will work to identify stars with ultra-rare or theoretically anomalous chemical signatures —objects so peculiar that they challenge our current understanding of stellar physics and nucleosynthesis. Beyond the scientific impact, this project will allow you to master Python and deep learning frameworks. These skills are highly transferable and sought-after in the private sector, ensuring you a competitive edge in the job market whether you pursue an academic career or move into industry.

Supernovae without the hydrogen envelope: Observations and Modelling
Supervisor: Tomasella Lina
Co-Supervisor(s): Andrea Pastorello

Supernovae (SNe) lacking hydrogen envelopes encompass both peculiar thermonuclear (Iax and Ca-rich events) explosions, and stripped-envelope core-collapse (SE-CC) SNe Ib/c, offering key insights into diverse progenitor systems and explosion mechanisms. SNe Iax events exhibit on average low luminosities, fast rises, low ejecta velocities, and spectra dominated by Fe-group elements with weaker IMEs. Ca-rich events are characterised by unusual spectra dominated by

Ca lines at late phases; SNe Ib/c arise from massive stars that have lost the H envelope. SNe Iax progenitors involve He-donor/C-O white dwarf (WD) systems, while a plausible explanation for a fraction of Ca-rich events invokes a He shell detonation in a WD surface. Ib/c originate from ~8-30 Msun stars (binary interaction or winds explain the loss of the H envelope).
The proposed PhD project aims to collect and analysing extensive datasets for H-free SNe, which will be modelled with radiative-transfer and hydrodynamic codes to constrain progenitors and explosion mechanisms. The student will: coordinate multi-wavelength observational campaign; reduce/analyse data for light curves, velocities, and spectral evolution; search public archives for pre-explosion images to identify progenitors; make use of non-LTE radiative transfer and hydro codes to be compared with observational data; 4. perform statistical analyses on the collected datasets.

The Milky Way galaxy revealed by Rubin/LSST first data
Supervisor: Zaggia Simone
Co-Supervisor(s): Leo Girardi, Giada Pastorelli

The Rubin/LSST survey will soon start creating the deepest-and-widest photometric catalogue ever, containing about 19 billion stars over half of the sky, in six different wavelengths, and with rich variability information. This will be a treasure trove for studies of stellar evolution and of the Milky Way structure and evolution. Our team is deeply involved in the preparation of the survey and in developing the tools to interpret the stellar data. In this PhD project, we will develop the tools needed to exploit the star counts in the Rubin/LSST data. They include: 1) to compare the star counts revealed by these images to our predictive models that generate synthetic LSST data starting from grids of stellar evolutionary tracks, spectral models, spatial densities and star formation histories; 2) to improve the latter prescriptions so that we gain a better description of the Milky Way components, and their stars. Particularly interesting will be the application of these methods to the star clusters and nearby dwarf galaxies to be imaged during the Science Verification phase. The PhD student will be inserted into Rubin/LSST – the most ambitious astrophysical project of the next decade – with full data rights, and will be expected to interact with our main collaborators in the USA (Seattle and Tucson) and in Croatia (Zagreb and Rijeka).

Preparing for the Roman imaging of nearby galaxies
Supervisor: Zaggia Simone
Co-Supervisor(s): Leo Girardi, Giada Pastorelli

The Nancy Grace Roman Space Telescope (Roman for short) will be launched next year, adding a fantastic facility for the study of nearby galaxies in the near-infrared. It will be able to image an area 100 times larger than the Hubble SpaceTelescope, in just one shot and with similar spatial resolution. Together with Leo Girardi we are deeply involved in the preparation for the "nearby galaxies" part of the Roman surveys, together with colleagues at University of Washington, Seattle. Present work is concentrated on making detailed simulations of the Roman data, but soon it will change to the exploration of real Roman data. Particularly interesting will be the improvements in the determination of space-resolved star formation histories, and dust mapping in galaxies, provided by the combination of Roman and already-available Hubble Space Telescope data. Another important possibility will be the simultaneous measurement of thousands of light curves for long period variables in galaxies, hence improving their calibration as standard candles. The PhD student will develop the tools needed to model and interpret such new data, starting from our libraries of stellar evolutionary tracks, isochrones, and pulsation models.

RSN3: Sole e Sistema Solare

Surface investigation of icy satellites in the Outer Solar System

Supervisor: Lucchetti Alice

Co-Supervisor(s): Luca Penasa, Maurizio Pajola

The exploration of the icy satellites in the outer Solar System reveals an extraordinary diversity of surface geology. These bodies are also of great astrobiological interest because they are "ocean worlds", hosting or potentially hosting a subsurface salty ocean beneath their cold icy crust. Understanding both the geological processes that shape their surfaces and the connection between the subsurface ocean and the exterior is crucial to gaining new insights into their present state and long-term evolution.

The aim of the PhD project is to carry out a comparative analysis of the main icy satellites of the outer Solar System in order to identify common and distinct geological processes. This study will be based on data acquired by past space missions, including Voyager at Uranus, Galileo at Jupiter, Cassini-Huygens at Saturn, and New Horizons at Pluto-Charon. The project includes geomorphological mapping, structural analysis of surface features, and spectral and compositional investigations using visible imaging data from these missions. The goal is to understand how surface observations can constrain the internal structure and evolutionary history of each body.

Particular attention will be devoted to the Europa, Ganymede, and Callisto in view of the upcoming JUpiter Icy Moons Explorer (JUICE) mission, in which the PhD candidate will be involved fostering strong international collaborations. Enceladus will also play a key role in light of future ESA L4-class missions.

Investigating the link between stony asteroids and meteorites

Supervisor: Migliorini Alessandra

Co-Supervisor(s): Dr. Cristian Carli (INAF-IAPS); Prof. Fiorangela La Forgia (UniPd); Dr. Stefano Rubino (INAF-IAPS)

Stony asteroids, such as V-, S-, A-, O-, Q-, R-, and K-types, have similar compositions, which consist primarily of pyroxenes (both calcium-poor and calcium-rich) and olivine, albeit in different amounts.

Although no direct link has yet been found between asteroids and specific meteorites, a part from few cases like the Howardite-Eucrite-Diogenite (HED) suite and the asteroid (4)Vesta, these classes of asteroids show similarities with olivine-rich meteorites, both chondrites and achondrites. Brachinites are a specific type of achondrite meteorites, recently studied in the laboratory using spectroscopic techniques, that contain between 57% and 94% olivine. They also exhibit variations in mineral composition and abundance, with characteristics that cover properties similar to S- and A-type asteroids, but not typical of common chondrites, particularly the LL type.

The aim of the proposed work is to identify the possible parent bodies of these meteorites by analyzing visible and near-infrared spectral data from both asteroids and meteorites.

New ground-based observations and laboratory experiments may also be planned to expand and complete the available data.

This study will disclose new details about the chemical conditions during the early phases of the Solar System formation, providing information on the origin and evolution of the Solar System and our planet.

Surface properties of Near-Earth Asteroids
Supervisor: Pajola Maurizio
Co-Supervisor(s): Alice Lucchetti

Researching asteroids is pivotal for understanding the Solar System's evolution. As pristine remnants from the pre-planetary era, these bodies offer a window into the early stages of planet formation. However, surface processes like impacts and thermal fatigue can alter their uppermost layers. Analyzing geomorphological features—such as crater and boulder size-frequency distributions (SFD), mass movements, lineaments, and fractures—alongside spectroscopic data provides pivotal clues regarding their geological history.
This PhD thesis aims to analyze extensive imagery, topographical, and spectral datasets of Near-Earth Asteroids (NEAs). The research focuses specifically on the binary system (65803) Didymos-Dimorphos (target of DART, LICIACube, and Hera) and (101955) Bennu (target of OSIRIS-REx). The candidate will investigate:

- Geological Units: Identification of distinct surface regions.
- Statistical Distributions: Mapping crater and boulder SFD.
- Structural Features: Analyzing global lineaments and localized fractures.
- Surface Dynamics: Documenting evidence of mass movements.

By integrating these morphological findings with spectral properties, the candidate will establish a state-of-the-art framework for Didymos-Dimorphos ahead of Hera's 2027 arrival and provide critical context for the Bennu samples returned in 2023. This research offers the unique opportunity to contribute to active international space missions in a collaborative, high-impact environment.

PLANNING OPTIMISATION OF THE REMOTE SENSING ACQUISITIONS APPLYING AI HEURISTICS.
Supervisor: Re Cristina
Co-Supervisor(s): Manuel Iori

The PhD will focus on conceptualizing, developing and implementing AI-based heuristics to optimize remote sensing observation planning. The goal is to tackle the operational complexities of planetary missions in covering the targets on the surface where constraints such as data transmission rates, power consumption, and geometric limitations must be balanced with scientific priorities. The main case study is the BepiColombo mission and its SIMBIO-SYS instrument, particularly the Stereo Imaging Channel (STC) for stereo and multispectral imaging of Mercury's surface. The research, developed through collaboration between INAF-OAPD and UNIMORE, has already produced a flexible, low-cost heuristic solution to optimize target coverage. Future work will enhance these algorithms using MILP, CP, QUBO, and metaheuristics such as Genetic Algorithms and Ant Systems, aiming to integrate predictive optimization and improve the efficiency of planetary mission planning.

RSN4: Astrofisica Relativistica e Particelle

Relativistic MHD modelling of kilonovae and GRB jets from binary neutron star mergers

Supervisor: Ciolfi Riccardo

Co-Supervisor(s): Andrea Pavan

The first multi-messenger observation of a binary neutron star (BNS) merger in 2017 proved that such systems, in addition to their powerful gravitational wave (GW) emission, can launch relativistic jets compatible with gamma-ray bursts (GRBs) and produce strong radioactively-powered kilonova (KN) signals in the optical/IR band. Despite the unprecedented richness of data collected for the specific event, the most revealing aspects of the underlying physical scenario remain however uncertain due to an incomplete theoretical description.

Relativistic magnetohydrodynamic (MHD) simulations represent the necessary approach to properly model the system evolution. The group in Padova led by Ciolfi, among the key competitors in the field, has now the ambition of building the first consistent description of BNS mergers including their GW, GRB, and KN emission, exploiting a direct combination of different types of simulations to cover the whole range of scales of the problem.

The proposed project will engage a motivated PhD student to simulate (with the gPLUTO code) the post-merger phase, when the jet is launched into the surrounding environment and interacts with the ejecta responsible for the KN emission. Moreover, using the outcome of the simulation as direct input, the student will model the KN signal itself and compare the results with the 2017 observations. This represents a critical and novel step for the group, paving the way for further development.

RSN5: Tecnologie Avanzate e Strumentazione

Toward ELT Laser Guide Star Adaptive Optics with the Ingot Wavefront Sensor

Supervisor: Arcidiacono Carmelo

Co-Supervisor(s): Kalyan Kumar Radhakrishnan Santhakumari, Simone Di Filippo

The project addresses one of the challenges limiting the scientific exploitation of 40-m class Extremely Large Telescopes (ELTs): achieving optimal Adaptive Optics (AO) correction with elongated Sodium Laser Guide Stars (Na-LGS). The performance of current wavefront sensors degrades significantly in this diameter regime, directly affecting Strehl ratio, sky coverage, and ultimately the detectability of faint or high-contrast objects.

The project focuses on the laboratory development to on-sky validation of the Ingot Wavefront Sensor (I-WFS), a novel concept designed to overcome the limits of traditional sensors when dealing with Na-LGS. The I-WFS advances AO by addressing the 3D geometry of the Na beacon.

The student will contribute to the full development of the sensor, exploring specific topics. It starts with end-to-end simulations in IDL and Python of the I-WFS response under realistic turbulence and Na-LGS elongation, assessing performance limits. The student will join the development of the I-WFS through the exploitation of a dedicated optical bench at INAF-OAPD, evaluating closed-loop performance against numerical simulations. The project will extend to preparatory on-sky verification, including performance analysis and comparison with existing AO systems.

This provides a solid basis for a career in astronomical instrumentation with expertise in AO, wavefront sensing, and real-time control, with skills in optical alignment, numerical simulation, and data analysis.

The hyperspectral stereo camera SHY-4D for a lunar rover

Supervisor: Cremonese Gabriele

Co-Supervisor(s): Emanuele Simioni, Cristina Re

INAF and CNR have initiated a coordinated research program within the Basic Space Research framework (PRORIS), funded by the Italian Ministry of University and Research (MUR). Within the PRORIS framework has been defined the High-resolution Autonomous Resource Lunar Observation & Characterization Kit (HARLOCK). The initiative aims to develop and validate a suite of instruments dedicated to the in-situ exploration and mapping of strategic resources such as water, rare earth elements (REEs), rare metals, and platinum group elements (PGEs).

In this context, the Astronomical Observatory of Padova is tasked with developing the hyperspectral stereo camera (SHT-4D). This camera will provide images and stereo pairs of the surface surrounding the rover and at various distances. The SHY-4D consists of two hyperspectral cameras that generate 3D data, as the 2D images contain spectral information as a third dimension. If the two cameras observe the same target but from different lines of sight, we obtain a stereo pair that can be utilized to create the Digital Terrain Model (3D image). SHY-4D will acquire a stereo pair for each spectral band, enabling the generation of a Hyperspectral Digital Terrain Model (4D). This entails a 3D image where each pixel possesses spectral information. The PhD student will focus on optimizing the optical design, integrating the cameras, and calibrating them on the optical bench of the IFN-CNR Luxor laboratory in Padova.

Photogrammetric Techniques for an Hyperhemispheric Imaging System - Photogrammetric and Image Analysis Techniques for the Hyperhemispheric PANCAM for Lunar Cave Exploration
Supervisor: Simioni Emanuele
Co-Supervisor(s): Emanuele Simioni

In recent years, hyperhemispherical lenses have demonstrated their effectiveness in astronomical applications, thanks to the reduced need for mechanical structures and the immediacy of the results they provide. For this reason, these lenses (in particular the PANCAM designed in OAPD) have been selected by ESA for the exploration of lunar lava tubes, which are considered promising candidates as potential habitats for future human colonization. The geometry of hyperhemispherical lenses is non-classical and requires further research to achieve optimal performance.

PANCAM biphocal lens application to Moon exploration projects
Supervisor: Simioni Emanuele
Co-Supervisor(s): claudio.pernechele

The Pancam lenses (designed at the Padua Observatory) are capable of acquiring both high-resolution images and low-resolution images over a hyperhemispherical field of view. For this reason, they have been selected for several space-exploration projects, including the Daedalus mission for lava tube exploration and the Plumecam project, where they are used as a safety monitoring system for landing sites. Due to the uniqueness of their optical design, further research is required to bring these instruments to concrete operational applications on the lunar surface and beyond.

TRASVERSALE

Safeguarding the Nocturnal Environment: A Transdisciplinary Public Engagement Framework for Light Pollution and the New Space Era

Supervisor: Boccato Caterina
Co-Supervisor(s): Stefania Varano (INAF-IRA Bologna)

The integrity of the night sky is facing a dual threat: the pervasive increase of Artificial Light at Night (ALAN) from terrestrial sources and the rapid expansion of Low Earth Orbit (LEO) satellite constellations. These phenomena not only compromise professional astronomy and radio astronomy but also degrade the nocturnal environment as a cultural, biological, and societal resource. While the IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference (IAU CPS) is addressing technical mitigation for orbital threats, a comprehensive societal understanding that connects ground-based light pollution with the industrialization of space is still lacking.

This PhD project aims to bridge this gap by developing a unified Public Engagement (PE) strategy.

The research will:

- Integrate Impact Analysis: Correlate ground-based sky brightness data with orbital radiometric models to provide a holistic view of the deterioration of the night sky.
- Assess Cultural & Societal Risks: Investigate the combined effects of light pollution and satellite interference on cultural heritage and human connection to the cosmos.
- Develop Advocacy Tools: Design and validate evidence-based communication frameworks to foster "Sky Stewardship" among the public and policymakers, supporting international efforts to protect the Dark and Quiet Sky as a unified environmental commons.