Description of Masters projects 2025

Amy Stutz: Cloud kinematics and cluster formation. Sub-mm, mm-wave radio (ALMA, APEX, IRAM) and catalogue data (e.g. Gaia, SDSS) data. Observational characterization of cloud kinematics in star forming regions in the Milky Way, with a focus on more massive regions than generally accessible in the Gould Belt. The data are already available (mostly), and the project will consist of detailed line fitting and analysis of the molecular line emission, mass profiles of structures like filaments, and velocity features inside these. Ultimately the project aims to place the radial velocities in the context of the gravitational potential of regions, to understand and develop viable theoretical models for the physical state of clouds (evaluating boundedness, rotation, inflow, infall, outflows, etc.). One project will be offered, and possibly up to 2 could be offered.

Sandro Villanova: We have ground-based adaptive optic data and HST data for a large sample of Bulge globular clusters. For the same clusters we also have IR VVV photometric data. Most of the data must be reduced from scratch. The student will have to learn data reduction of photometric data with the aim to obtain the CMD of the clusters. Also field star cleaning is required. The final aim is to use the CMDs to estimate distance, reddening and age of the clusters. This Master project is part of a much bigger project, called CAPOS, that has the goal to trace the primordial formation and evolution of the Galactic Bulge using globular clusters and metal poor field stars. One project is offered and a second application can be evaluated.

Neil Nagar: three options between which the single master's student can choose. All require python programming and data analysis. Projects (b) and (c) require data processing of ALMA and hard X-ray data: (a) black hole mass measurements for galaxies observed with the Event Horizon Telescope, using adaptive optics (AO) integral field unit observations (e.g., Waters et al. 2024 and Osorno et al. 2023); (b) a variability-based investigation of the "Fundamental Plane" (relationship between X-ray luminosity, radio luminosity, and black hole mass) of black hole activity in supermassive black holes; (c) short-term (minutes to days) sub-millimeter variability in supermassive black holes, and implications for the structure of accretion inflows and jets.

Leonardo Krapp: Las propuestas de investigacion estan orientadas el estudio de dinamica de gas y polvo en discos protoplanetarios. Los proyectos permiten desarrollar conocimiento y habilidades en los campo de formacion de planetas, computo de alto rendimiento, dinamica de fluidos y analisis de datos. (1) Estudios del criterio de inestabilidad de ondas de Rossby (Rossby wave instability) e implicaciones para observaciones de subestructura de discos protoplanetarios. (2) Estudios sobre la condición de estabilidad gravitacional para discos formados por gas y polvo. (3) Desarrollos de metodos para resolver el equilibrio termico entre gas y polvo en discos protoplanetarios y sus efectos en la distribucion espectral de energia. (4) Implementacion de un modulo de accrecion inteligente en el codigo FARGO3D para estudios de interaccion de planeta discos y formacion de discos circumplanetarios (5) Estudios de migracion de planetas en discos de gas y polvo (6) Procesamiento de datos de simulaciones 3D de discos circumplanetarios para producir imagenes sinteticas para ALMA y JWST. (7) Estudios multifluidos para la accrecion de pebbles y sus efectos en la formacion de nucleos planetarios. (8) Desarrollo y derivación de las ecuaciones promediadas verticalmente para estudios de discos finos. Posterior implementación del modelo en el codigo FARGO3D.

RHC: The project leverages ALMA observations of star-forming galaxies at z=4-6 (when the Universe was approximately 1 billion years old) alongside new JWST/NIRSpec observations of their optical spectra, as part of the ALMA Large Program CRISTAL(www.alma-cristal.info). The primary objective is to constrain the physical conditions of these early galaxies and gain insights into their formation and evolution.

Nathan Leigh
The project involves using numerical simulations of chaotic three-body interactions to answer the question: Is Chaos Observer-Dependent? The short answer is yes (but to what extent…?), and the way this will be illustrated and quantified is by using phase space diagrams (PSDs). PSDs are plots of the initial binary phase versus the initial inclination angle between the incoming singles velocity vector and the binary orbital place, colour-coded by which of the three-particles is ejected. The simulations will involve using a very accurate and precise gravity integrator called BRUTUS. The student will run suites of simulations, where each suite corresponds to a particular resolution and precision for the integrator. With each successive increase in resolution, the phase space plot will reveal more and more structure corresponding to more and more deterministic interactions that appear as uniform swaths in colour in the PSDs.

Mary Loli Martínez-Aldama

1. The spectral and physical properties of broad-line region clouds of Quasars (QSOs) are well organized in the Quasar Main Sequence (MS), where the Eddington ratio seems to drive such a change. The MS has been widely explored in the optical range in large datasets at intermediate redshift (z < 2.5). Recently, a new MS was found in the UV, supporting the existence of this evolutionary sequence along the electromagnetic spectrum and at higher redshift (z < 4). The master thesis project aims to investigate the UV MS in high-redshift AGNs QSO and exploit the available ground-based observations of 209 UV rest-frame spectra at 3.4<z<7.8, with 87 sources at z>6, whose raw data are publicly available. The student will perform the data reduction using the pipeline PyPeitl, perform spectral fitting using a Fortran MCMC spectral fitting code, and photoionization modeling with the code CLOUDY to determine the physical properties of the broad line region (BLR). Exploring the Quasar Main Sequence in high-redshift QSOs will bridge the gap in our understanding of AGN evolution and help us better comprehend the role of AGNs in the early Universe and their impact on galaxy formation and evolution address discussions such as the Hubble Tension.
2. The broad-line region (BLR) holds the key to measuring black hole mass and the physics of active galactic nuclei (AGNs). The traditional reverberation mapping (RM) technique serves as the most effective way to diagnose BLR geometry and kinematics but still bears its own limitations in the probed BLR dimensions (time delay and velocity). Recent observational breakthrough revolutionized the situation, namely, GRAVITY NIR interferometry on the ESO VLTI resolves the BLR in bright AGNs with the aid of spectro-astrometry (SA). A combination of both methods delivers unique information on BLR properties and allows us to achieve higher-precision black hole mass determination, as well as to measure the absolute

geometric distance to the AGN. Realizing the high necessity of pre-selecting an optimal AGN sample for future RM and SA observations, the selected student will participate in the construction of a systematic NIR spectroscopic survey of nearby bright AGNs (K<13 mag) by compiling high-quality spectra and photometric data from archival data and conducting new NIR observations for other AGNs in the South Hemisphere. This analysis will provide information about optical and NIR geometry/kinematics and quantify statistical relations of NIR emission lines with AGN properties (such as SMBH mass, accretion rate, and luminosity).

Ronald Mennickent: Se propone investigar discos de acreción en sistemas binarios en interacción, especialmente en aquellos que muestran súper ciclos revelados en series de tiempo fotométricas como es el caso del prototipo beta Lyrae. La idea es determinar la influencia del disco y sus propiedades en los cambios de brillo observados, además de relacionar el estado evolutivo de los sistemas estudiados con la transferencia de masa y posterior evolución. Se aplican códigos como MESA, PHOEBE y otros que permiten modelar las curvas de luz y también la evolución de sistemas binarios. Se complementa con estudios espectroscópicos. Esto permite determinar parámetros orbitales y estelares fundamentales. La investigación tiene importancia en el estudio y comprensión. del magnetismo estelar en sistemas binarios y también en poblaciones estelares que incluyen sistemas binarios. Los objetos a estudiar en su mayoría forman parte de la base de datos de OGLE.