Master thesis projects

The following is a list of possible projects that are possibly available for a Master thesis. The list is not exclusive and students are encouraged to talk to astronomy professors in the department following their research interests.

1. The molecular gas content of local low metallicity and high-z galaxies (Prof. Rodrigo Herrera-Camus)
The aim of this project is to use multiple tracers of the molecular gas (e.g., CO, [CI], [CII] transitions, dust continuum) to determine the "real" content of molecular gas in systems where the typical tracer used in the literature, the CO transition, might heavily underestimate the real content of molecular gas available.

2. The formation of triple star systems via chaotic four-body interactions (Prof. Nathan Leigh)
Four-body interactions dominate over all other types of interactions in most star cluster environments, making them of critical importance to understanding the origins of binary and multiple star systems throughout the Universe. There are three possible outcomes when four particles are involved in chaotic gravitational interactions : eject two singles, keep a binary; eject two binaries; or eject one single and keep a stable triple system. This project will focus on the latter outcome, namely the formation of stable hierarchical triple systems, with a focus on those systems that form near the stability boundary. Working together with Dr. Andrei Tokovinin at Gemini South, the student will perform numerical integrations of chaotically interacting four-body systems. The goal is to study the properties of dynamically formed triples as a function of initial conditions motivated by the star formation environment, where the parameters of all four-body interactions are ultimately decided. By comparing to observed triple star systems thought to be on the border of dynamical stability, this project will not only uncover the origins of binary and triple star systems, but also constrain the stability boundary for hierarchical triples, one of the outstanding fundamental questions needed to completely solve the gravitational three-body problem.

3. Analyzing the NIR spectrum of 14 Active Galactic Nuclei (Prof. Mary Loli Martinez)
The main continuum source in the near-infrared region (NIR, 0.8-2.5 microns) of Active Galactic Nuclei (AGN) is the accretion disk plus the emission from the hottest part of the dusty torus. The emission lines with the lowest ionization potentials (IP<10 eV) are also emitted in the NIR region, such as the FeII and the NIR CaII triplet. Despite the relevance of this zone, it has been scarcely analyzed. This project aims to get the NIR region of 14 AGN at $0.005<z<0.142$ and compare the behavior of the NIR and optical emission lines. The sample was observed with the Magellan Telescope in April 2023. In seven sources, the size of the BLR was estimated through the reverberation mapping technique, which allows us to determine the black hole mass by different methods and corroborate the influence of the Eddington ratio in the Radius-Luminosity relation. This data will help to corroborate previous correlations such as FeII and CaII triplet with the Eddington ratio and then reduce the scatter in the Radius-Luminosity relation. Moreover, we will corroborate the enhancement of the metal enrichment of the BLR in intermediate-z with respect to low-z AGN, and thus its use as a metal indicator and star formation tracer.

4. Candidate binary supermassive black holes for EHT observations (Prof. Neil Nagar)
With a resolution better than 0.2 pc across the universe, the Event Horizon Telescope (EHT) has the unique ability to resolve and image the two components of a binary supermassive black hole, and potentially track their orbits during their gravitation-wave emitting inspiral. However, many open questions remain on the selection of candidates and the observing cadence required. Within this thesis we will work on comparing observed spectral energy densities of candidate binary supermassive black holes with model predictions of their emission (thus also helping in improving

the models) in order to identify the best candidates for EHT observations, and to determine the best observational cadence for observing these candidates in order to constrain orbital proper motions.

5. Mass loss during mergers of main-sequence stars (Prof. Dominik Schleicher)
Runaway collisions in dense stellar clusters are an important possible pathway for the formation of supermassive black holes. The efficiency of this process could however be limited if a significant fraction of mass is lost during the mergers of stars due to ejection of stellar material. In this project, the goal is to model multiple stellar mergers using the StarSmasher code (https://jalombar.github.io/starsmasher/), with the aim to explore the mass loss in case of multiple subsequent mergers and as a function of the merger frequency. The project is available only for students with already advanced experience in computation, who need to demonstrate the ability to compile and run the code and to produce some simple results.

6. CAPOS (Prof. Sandro Villanova)
CAPOS is a project devoted to the study Bulge Globular Clusters using GAIA database and APOGEE dedicated spectroscopic observations. From GAIA data we obtained membership and mean proprer motion, while from spectroscopic data we measured radial velocities andabundances for the following elements: C,N,O,Na,Mg,Al,Si,Ca,Ti,Cr,Fe,Ni and Ce. The variation of light element abundance were used to study the formation of these clusters in the context of the multiple populations phenomenon. We focus our attention also on the distance determination, a key information to know the origin of the object. We have to solve several problem like the very large differential reddening and the fact that, due to the huge interstellar absorption, for most of the cluster only the giant branch is avaliable from photometry. Using these distances, we are calculating Bulge Globular Cluster orbits adopting state of the art Galactic potential, which includes rotating bar, in order to establish the origin of the objects.

7. Laboratory projects (some also for pregrado, please check with Prof. Rodrigo Reeves):

LCT con potencial para magister
-Estudio del sistema de apuntamiento del radio-telescopio LCT
-Holografía para el radio-telescopio LCT
-Estudio y puesta en marcha del sistema de control de la superficie del telescopio LCT (DSOS)
-Concepto para una cámara de 3mm para el LCT
-Estudio de sistemas MKIDs para el LCT

Proyectos con potencial de transferencia tecnológica:
-Viabilidad de caracterización de humedad en madera usando microondas
-Viabilidad de caracterización de materia orgánica y humedad en suelos usando microondas
-Viabilidad de la caracterización de velocidad de masas de agua atmosférica
-Empaquetamiento de MMICs y activos de ondas mm para aplicaciones científicas y espaciales
-Puesta en marcha del sistema de multi-espectral de imágenes HF para ionósfera:ISI

3m-Pregrado
3m Mecánico: Análisis FEA del radio telescopio de 3m de CePIA-UdeC
3m Astro: Generación de mapas desde observaciones continuas y autónomas de hidrógeno neutro en nuestra galaxia
3m Rx: Desarrollo de receptor de microondas integrado para sistema de hidrogeno neutro

LCT general
-Uso de Tango-controls para software distribuido de control de instrumentos y telescopios
-Puesta en marcha del sistema de control del CSO en CePIA

-Puesta en marcha de un receptor de 230 GHz del observatorio CSO en CePIA
-Estudio de diferentes sistemas de domos para radiotelescopios