Available projects

2022

IMPORTANT: The available projects do not reflect the number of "cupos".

Prof. Stefano Bovino

Project # 1: CR's propagation and its effect on deuterated species: In this project the student will study the effect of proper CRs propagation on the chemistry of deuterated species under different conditions. Good computational skills in python and fortran are required.

Project # 2: Protostellar feedback in star-forming clumps: In this project the student would have to implement a protostellar feedback prescription in simulations of high-mass stars and study its effect on key tracers, possibly comparing with observations. This includes the use of different codes and post-processing techniques.

Prof. Rodrigo Herrera-Camus

Project # 1: ALMA Large Program The project is based on the ongoing ALMA Large Program CRISTAL (www.alma-cristal.info, Principal Investigator Herrera-Camus), which has the goal of building a census of the gas, dust, stars (from HST), and ionized gas (from JWST) of star-forming galaxies when the universe was only 1 billion years old. The project can be associated with one or more of the main scientific goals of CRISTAL, which are: 1) the study of the interstellar medium, 2) the search and characterization of outflows, and 3) the analysis of the kinematics of disks and mergers

Prof. Nathan Leigh:

Project #1: Evolving the Stellar, Galaxy Cluster, Galaxy Group (etc.) Particle Mass Function: Using the Boltzmann equation presented in Leigh & Fragione (2020), a system of self- gravitating finite-sized particles is analytically evolved due to collisions/mergers and two- body relaxation in a tidal field. The system will lose preferentially low-mass particles quickly as they evaporate across the tidal boundary, meanwhile it will build up more massive particles in the core due to collisions. In this project, we will study the evolution forward through time of the particle mass function, given these competing physical effects. The analytic calculations will be confronted with N-body simulations to test its robustness. A good case study for this project would be ultra-diffuse galaxies (UDGs).

Project #2: BH mergers in galactic nuclei: Using data from GW mergers, develop constraints on the environments in which the mergers must have occurred. For example, for a given galaxy, you roughly know the SMBH mass from the observed M-σ relation. Thus, to first order, you know the SMBH mass in a given galaxy just by measuring the galaxy's mass. Together with the minimum allowed BH mass, this constrains how low of a mass ratio merger you can get (if the lowest mass stellar-mass BH merges with the SMBH). So, above some critically low mass ratio, couldn't the merger ONLY have occurred in a galactic nucleus? What is this critical mass ratio and it is observable?

Project #3: Mass transfer in triple star systems: Using the AMUSE simulation code, simulate and study the transfer of mass from an outer tertiary star onto an inner binary within a stable hierarchical triple star system. When does a circumbinary disk form around the inner binary? In this limit, when is the accretion stable, and when it is chaotic? How do the properties of the disk depend on the masses of the components of the inner binary (E.g., do more massive inner binaries form more massive disks?). This project will explore compact object mergers in triple star systems, driven by mass transfer from the outer tertiary companion. Under what conditions does the inner binary merge? When does it survive and grow in mass by accreting from the circumbinary disk? The student will quantify when the circumbinary disk is massive enough to be able to generate an electromagnetic counterpart to the GW merger signal of the inner binary? This project will be done in collaboration with Prof. Simon Portegies Zwart from Leiden University, Prof. Robert Mathieu from University of Wisconsin-Madison and Prof Silvia Toonen from the University of Amsterdam.

Project #4: Comparing analytic theories for star cluster formation and evolution to suites of numerical N-body simulations: This project will be done in collaboration with Prof. Aaron Geller at Adler Planetarium and Northwestern University, Prof. Robert Mathieu from University of Wisconsin-Madison and Prof. Simon Portegies Zwart from Leiden University. Can we constrain the initial conditions at the time of formation for particular star clusters observed in our Galaxy? We will use the present-day observed properties of the clusters to compare to, and explore realistic sets of initial conditions that evolve to reproduce what we see today. This project will involve performing N-body simulations of star cluster evolution, in order to constrain the initial conditions that must have evolved to produce what we observe today.

Project #5: Chaos in the general three-body problem: The student will study observational data of observed triple star systems, and perform three-body simulations to determine if they should be dynamically stable in their current configurations. The over-arching goal is to develop a robust criterion for the stability of hierarchical triple star systems, and to confront this new theory with real observational data of triples.

Prof. Neil Nagar:

Project # 1: Sample and science with the next-generation Event Horizon Telescope: Our group leads the effort to define and characterize all targets for the Event Horizon Telescope (EHT; https://eventhorizontelescope.org/) and next-generation EHT (https://www.ngeht.org/). Thesis projects here include large database programming, modelling of AGN spectral energy densities (SEDs), assembling samples of suspected gravitational-wave (GW) emitting supermassive black hole (SMBH) binaries, simulating their orbits, their EHT-detectability, and their GW emission.

Project # 2: Black hole mass measurements in nearby galaxies: the mass of a supermassive black hole (SMBH) can be directly measured via high resolution spectroscopic observations. These observations can reveal either the Keplerian rotation of ionized (eg. Halpha) or molecular gas (eg. CO, H2O) around the SMBH or the increased stellar dispersion (width of the stellar absorption lines) close to the black hole. We use high resolution ALMA and VLT-MUSE (AO) data to measure the SMBH masses in individual galaxies via multiple means in order to investigate the systematic errors of different methods. These systematics are important to understand as a lot of our understanding of black hole masses in the universe come from ~200 SMBH mass measurements and this small sample clearly suffers from many systematic effects.

Prof. Dominik Schleicher

Project #1: The chemistry of the early Universe: The goal of this project is to study the chemistry of the first molecules in the Universe and their possible

signatures in the cosmic microwave background. A particular emphasys will be on the HeH+ molecule where new reaction rates were recently obtained, but possible extensions also include lithium chemistry. We will extend previous studies by including radiative backgrounds from the first stars into the calculation, which can photodissociate the molecules and reduce their abundances. We will subsequently study the signatures of these molecules in the cosmic microwave background.
The project is strongly based on numerical modeling and the development of chemical networks. Any student working on the project needs to have programming experience, ideally from "Metodos Numericos de Astrofísica Teorica" or equivalent. We will also work with the publicly available codes RECFAST and KROME during the project.

Prof. Sandro Villanova

One or more projects, to be decided: Our group is studying kinematics, ages and chemical abundances of a sample of Bulge Globular Clusters using public databases and dedicated spectroscopic and photometric observations. For each cluster we obtain membership, proper motions, radial velocities, magnitudes in several bands and abundances for key elements. The variation of light element abundance are used to study the formation of these clusters in the context of the multiple populations phenomenon, while velocities and photometric data are used to obtain the position of each object in the phase space and finally its orbit. Deep photometric data are used to obtain ages and are treated in order to solve the differential reddening problem, which is one of the main challenges as far as Bulge objects are concerned. The thesis project will be devoted to the study of one of these Bulge Globular Clusters and can be focused in one of the aspect mentioned before: kinematics, ages or chemical abundances.