Subject 1 Title: Contributions to research in astronomy education and communication
Supervisiors: Ilídio André Costa & Joana Marques– IA and Planetário do Porto-CCV/UPorto
Pre-requirements: None
Participants will have the opportunity to carry out exploratory investigative projects in the field of astronomy education or communication. The project will involve the processing, analysis and communication of data already collected during IA activities. The work plan involves 1) the selection of the IA data to work with, 2) data processing/analysis, 3) discussion of the results and conclusions and 4) presentation of the project.

Subject 2 Title: ADCs design of the ANDES seeing limited arms
Supervisor: Bachar Wehbe - Instituto de Astrofísica e Ciências do Espaço, Universidade de Lisboa, Portugal. Departamento de Física, Faculdade de Ciências, Universidade de Lisboa, Portugal
Pre-requirements:
- Good understanding of optics
- Familiar with programming languages (preferably Python
Language: English
The main requirements for an atmospheric dispersion corrector (ADC) are to perform variable counter dispersion to compensate for that of the atmosphere at a given zenithal angle, and to produce zero deviation at a reference wavelength, within the range of interest for all zenithal angles. When a high level of compensation is needed, typical ADC configurations to achieve these requirements are the rotating ADCs. Wehbe, B. et al. (2019) developed an ADC optical design tool in order to select the best set of glasses in terms of residuals, transmission, and Fresnel losses, taking into account the required spectral range and typical atmospheric conditions where the ADC will be working. In its current shape, the tool assumes that the ADC is a rotating two-glass prisms ADC in the configuration of AB-BA in terms of glass orientation.ANDES is a group of three high-resolution spectrographs (from 350 nm to 1800 nm) to be installed at the new ELT. One of the observing modes of ANDES is by using two identical seeing-limited arms where 3 sets of ADCs will be used in each arm. The main objective of the proposed project is to use the tool to select the best glasses combination for each of the 3 ADCs, by comparing the residuals, transmission, and pupil wobbling for all the possible combinations.

Subject 3 Title : Deciphering Planetary Atmospheres Through Transit Spectroscopy
Supervisors: Eduardo Cristo and William Dethier - CAUP/UPorto
Pre-requirements:
- Familiar with programming languages
Language: English
With over 5000 exoplanets detected today, we have recently started characterization studies to learn more about their atmospheres and interiors. The goal of this project is to probe the atmosphere of an exoplanet using high-resolution spectroscopy. It involves the analysis of exoplanet transit data (transmission spectra) to potentially detect atmospheric signatures.

The project we propose can be divided into four phases. In the first, the student familiarizes themselves with transit observations and derives transmission/absorption spectra from data. The second phase focuses on selecting suitable synthetic stellar spectra by comparing it to observations using a chi-squared minimization code. The third phase involves simulating in-transit spectra based on the chosen stellar spectrum and comparing them to the results of the first phase. Finally, the student will interpret the results of the planetary absorption signal.

Subject 4 Title: Hands-on Galactic Archaeology and Machine Learning using Synthetic Data
Supervisors: Andreas Neitzel and Tiago Campante - CAUP/Uporto
Pre-requirements: At least 2nd year BSc in Physics or Astronomy competence, experience with Python programming.
How the Milky Way evolved into its presence state is still a matter of much debate. Understanding the processes that led to the Galaxy's present state has implications for our understanding of galactic evolution in general, ranging from early universe conditions to feedback processes. Galactic archaeology is the field of astrophysics that aims to uncover the evolutionary and formation history of the Milky Way. Cosmological zoom-in simulations provide us with synthetic galaxies whose evolutionary history is known. These serve as testing grounds for the application of big data analysis techniques which can help differentiate different phases in the galaxy's evolution. The student will be given a theoretical introduction to the field of Galactic archaeology and apply machine learning methodologies for data analysis.

Subject 5 Title: Why is the Universe accelerating?
Supervisor: Nelson Nunes - ULisboa
Pre-requisites: none
It has been fairly established that our Universe is currently undergoing an accelerated expansion. However, several inconsistencies between several cosmological observations indicate that the simplest model consisting of cold dark matter and a cosmological constant might not be the correct description.

In this work, the students will make a fresh look at alternative models of dark energy and use statistical methods to compare them against current observations and evaluate which ones can be competitive with the standard LCDM model.
Image:
https://physics.aps.org/assets/d0fb6d64-13d6-47da-a6c2-4a6ed83671c8/e111_1.png
Image description: Schematic representation of the history of the universe. Credits: Harvard & Smithsonian Center for Astrophysics

Subject 6 Title: Beyond Four Dimensions: Exploring the Fabric of Spacetime
Supervisors: David Pereira, Miguel Pinto, Tiago Gonçalves - Lisbon – Faculdade de Ciências da Universidade de Lisboa
Pre-requirements:
- Be in 3rd year of a Bachelor's program or 1st year of a Master's program
- some prior knowledge of Special and General Relativity is recommended.

The concept of spacetime is fundamental to describe gravity. In particular, it is common to assume that our universe is a 4-dimensional spacetime continuum: three spatial dimensions and one time dimension (3+1). But, is this the full story? Could there be additional dimensions beyond our perception of the world?

In this project, students will investigate the theoretical foundations and implications of extra-dimensional models. What happens when we introduce additional spatial and/or temporal dimensions? How do gravitational theories adapt to the higher-dimensional frameworks? Can these extra dimensions help us towards the unification of all fundamental interactions?

By performing a literature review, hands-on theoretical and computational exploration, and collaborative discussions, the participants will analyse not only existing models but also formulate new alternatives. The final goal is to assess their physical plausibility.

Subject 7 Title: Estimating the projected stellar rotational velocity of slow rotators for planetary mass determination

Supervisors: João Gomes da Silva, Pedro Branco - CAUP/UPorto

Pre-requirements: Familiarity with python is required

Stellar projected rotation velocity, vsini, is an extremely important stellar parameter. When combined with the star's rotation period and radius, it can provide for the stellar inclination, which is crucial to measure planetary true masses.

This stellar parameter is usually obtained by fitting spectral line profiles with a rotational profile. While this is efficient for fast rotators, for slow rotators, like stars generally included in planet search surveys, which have narrower rotational broadening, the extraction of vsini is complicated by the combination of effects from micro- and macro-turbulence broadening, along with spectrograph resolution smearing effects.

Recently, Reiner et al. (2023) developed an empirical method to estimate the vsini of slowly rotating stars using the Full-Width at Half-Maximum (FWHM) of the Cross-Correlation Function (CCF), which represents the average profile of all absorption lines in the spectrum, and is an output of the spectrograph data reduction pipeline.

The aim of this project is to apply the relations of Reiner et al. to a sample of stars observed with the HARPS spectrograph, estimate vsini with uncertainties and validade the results with literature values. The student will then estimate if the obtained precisions in vsini are enough to ensure that true planetary masses can be estimated with a 10% precision, a requirement for the follow-up of the ESA PLATO space telescope, being launched in 2026.

Subject 8 Title: Synergy of Surveys: A Multi-Wavelength view of SMBH demographics with Next-Generation facilities

Supervisors: J. Afonso, I. Matute, H. Miranda, D. Barbosa, E. Worrell (IA/FCUL)

Pre-requirements: None

To deepen our understanding of the complex relationship between Supermassive Black Holes (SMBHs) and their host galaxies requires careful study of their demographics and intrinsic properties (e.g., mass, accretion rate, radio jet power) as a function of cosmic time. Connecting this information to the inherent properties of the host galaxies (such as star formation rate, stellar mass, and gas/dust content) offers crucial insights into galaxy evolution throughout cosmic history.

When SMBHs grow through the accretion of matter, they manifest as Active Galactic Nuclei (AGN). The powerful energetics associated with AGN influence the host galaxy and allow them to be detected and studied across vast stretches of cosmic time. Recent astronomical surveys have generated an unprecedented wealth of multiwavelength data, encompassing both imaging and spectroscopy. This influx of data provides unparalleled opportunities to illuminate the origin and growth mechanisms of SMBHs and their fundamental role in shaping galaxy evolution.

This project will leverage data from the latest generation of large observational facilities, both space- and ground-based, coupling it with advanced methodologies for data analysis. The goal is to further detail the impact of SMBHs within contemporary models of galaxy evolution and formation.

Subject 9 Title: Galaxy Compactness and Environment in Euclid Q1 Deep Fields
Supervisor: Ana Paulino-Afonso (IA-UPorto, CAUP)
Pre-requirements: None
Galaxies across the Universe exhibit significant diversity in their spatial distributions, colours, and morphologies. Using galaxies up to z~1 in the Euclid Quick Data Release Deep Fields, this project offers the opportunity to explore the relationship between galaxy compactness and environmental conditions. By focusing on galaxy concentration, we aim to identify and characterise peculiar objects within various environments. We will specifically investigate why certain galaxies might keep their morphologies despite the known environmental impact in shaping galaxies.

Subject 10 Title: The bright Hα emitters in Euclid Q1 Deep fields
Supervisor: Ana Paulino-Afonso (IA-UPorto, CAUP)
Pre-requirements: None
At intermediate redshifts ($0.9<z<1.5$), Hα-emitting galaxies are crucial for understanding star formation processes and galaxy growth. The Euclid Quick Data Release Deep Fields already provide an excellent dataset for systematically studying these bright Hα emitters. In this project, we aim to characterise their morphologies and spectral features through detailed imaging and spectroscopic analysis, enhancing our knowledge of the star formation activity during a key period in the Universe’s history.

Subject 11 Title: Active Galactic Nuclei in Euclid Q1 Deep Fields
Supervisor: Ana Paulino-Afonso (IA-UPorto, CAUP)

Pre-requirements: None

Active galactic nuclei (AGN) significantly impact galaxy evolution through feedback mechanisms and the growth of supermassive black holes. This project aims to identify AGN candidates in the Euclid Quick Data Release Deep Fields and conduct a detailed study of their host galaxies using high-quality imaging. By performing spectral analysis and refining the methods for estimating their physical properties, we also aim to obtain deeper insights into the role of AGNs across cosmic time.

Subject 12 Title: Ultra-cool objects in nearby star-forming regions

Supervisor: Ana Paulino-Afonso (IA-UPorto, CAUP)

Pre-requirements: None

Distinguishing high-redshift galaxies from brown dwarfs is challenging, as both appear faint and red in photometric surveys. Nearby star-forming regions such as Taurus, Barnard 20, Messier 78, Horsehead, and Lynds Dark nebula offer excellent datasets to investigate this classification problem. By combining multi-wavelength photometry from Euclid, Spitzer/WISE, and Gaia astrometric data, we aim to identify ultra-cool substellar objects. This approach refines classification criteria, which is crucial not only for high-redshift galaxy studies but also for understanding local substellar populations.