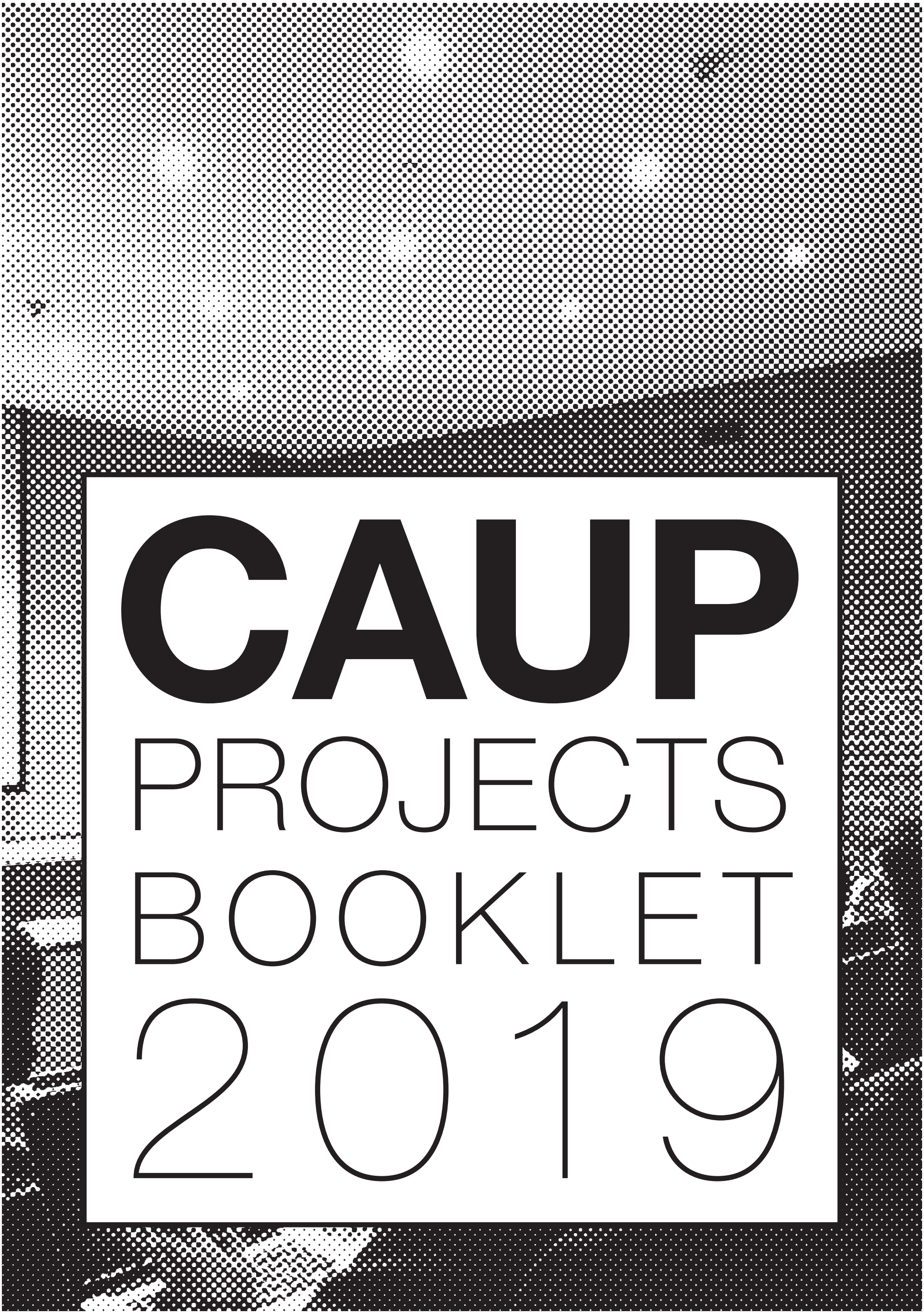

CAUP PROJECTS BOOKLET 2019

CAUP PROJECTS BOOKLET 2019

INDEX

Education/outreach and undergraduate projects

Introduction

CAUP has a strong commitment to providing training opportunities for the next generation of astrophysicists, and we are the only research center in the country with a training activities portfolio that spans all levels from Secondary School to Doctoral Programmes - and entails significant amounts of funding and human resources. As part of our commitment to leadership and excellence, we hereby release a list of research projects offered by CAUP members, for various training levels, in the academic year 2019-20.

We start by listing PhD/MSc projects within our participation in ESA and ESO consortia, as leading the national participation in such consortia is one of our key strategic priorities. These are followed by other astrophysics PhD/MSc projects. These tend to represent more specific interests of individual members, although in some cases they also involve non-CAUP collaborations and external co-supervision. At the PhD level, many of these projects are eligible for funding through our PhD::SPACE in the context of IA as well as through regular FCT PhD grants.

Finally we list education/outreach projects and projects for undergraduate students. In the latter case these are mainly listed in Portuguese, since they are almost always offered through the Faculty of Sciences' PEEC internship program. As an appendix we also list the current CAUP team, including both the researchers and the PhD and younger students.

In the cases where the project has several co-supervisors, the contact person for the project is the one whose e-mail is listed, and you should approach him/her for any enquiries on the project. Although the list is representative of current interests and priorities, it is by no means exhaustive. Many CAUP members have sufficiently broad interests and expertise to be able to supervise other projects. Potentially interested students are encouraged to contact us to explore further possibilities.

Carlos Martins

(Head of the CAUP Training Unit)

March 2019

ESA and ESO related projects

Emission and transmission spectra of exoplanet atmospheres

Type: PhD
Supoervisor: olivier.demangeon@astro.up.pt
Co-supervisor: Nuno Santos
Available at PhD::SPACE: Yes

With more than 3800 extra-solar planets discovered so far, one of the main focus of exoplanet research is the detailed characterization of exoplanets, and specifically their atmospheres. This represents a first effort that should ultimately lead the the detection of life signatures in other worlds.

ESPRESSO, NIRPS and SPIROU are a new generation of high-resolution spectrographs dedicated to exoplanet research. Installed at ESO's VLT, ESPRESSO (Pepe+2014) started its observations in September 2018 and for the next 4/5 years will dedicate 1/3 of its guaranteed observation time (or about 70 nights) to exoplanetary atmosphere studies. NIRPS (Bouchy+2017) and SPIROU (Simon+2012) will start observation within the next year and will also reserve a significant fraction of their time to exoplanetary atmosphere sciences. ESPRESSO observes at visible wavelengths, while NIRPS and SPIROU observe in near infra-red. The observations from these different facilities will thus be complementary, and allow to approach the study of exoplanet atmospheres from a unique perspective. Different observational strategies can be used for this objective depending on the exoplanet studied. When the exoplanet transits in front of its parents star, we are able to observe the minute color dependent changes in the spectra produced by the different fractions of the stellar light passing through the exoplanet's atmosphere (Wyttenbach+2017). From such observation a low resolution transmission spectra of the atmosphere can be extracted. In some cases, the detection of strong absorption lines of molecules like CO is also possible (Désert+2009). For hot exoplanets orbiting close to their parent stars, the spectra of the light emitted by the atmosphere can also be detected (Stevenson+2010).

The main objective of this PhD project is to extract robust observational constraints on the atmospheres of exoplanets as observed with ESPRESSO, NIRPS, and SPIROU. For this, the candidate is expected to perform and optimize the data analysis processes to extract the minute planetary signal and derive the properties of exoplanet atmospheres. The supervisor and co-supervisor of this project are deeply involved in ESPRESSO, NIRPS, and SPIROU. They will offer to the laureate both access to the data and science teams, as well as expertise on the instrument and the observational techniques required for this project.

ESPRESSO's look at fine structures of stellar surfaces using exoplanet transits

Level: PhD
Supervisor: Vardan Adibekyan (vadibekyan@astro.up.pt)
Co-supervisor: Nuno Santos
Available at PhD::SPACE: No

Stellar surfaces are full of inhomogeneities (due to the presence of stellar granulation, magnetic spots, etc.) which cause different types of difficulties for exoplanet related studies (e.g. exoplanet detection, bulk and atmospheric characterization etc.). Ironically, exoplanet transits can provide enormous information about the nature of these inhomogeneities, and stellar surfaces, in general.

Transiting planets consecutively block the light coming from different segments of the stellar disk. High-resolution differential spectroscopy will provide the spectra of these small surface segments temporarily covered by the transiting planet. Studying center-to-limb variations of asymmetric profiles and wavelength shifts of spectral lines with different properties (different strengths, excitation potential, ionization level), and comparing them with the predictions of the 3D models of stellar atmospheres will unable to characterize the fine structures of these atmospheres. Understanding and characterizing the 3-dimensional and time-dependent properties of stellar atmospheres is crucial for accurate determinations of stellar properties and for the properties of planets orbiting them.

The detection of very subtle changes in line profiles and wavelength shifts requires ultra high signal-to-noise (S/N) ratio. This will be only possible by averaging many spectral lines of similar properties and taken from very high-resolution and high-S/N spectra. The new ESPRESSO spectrograph, installed at the VLT, perfectly fits the aforementioned requirements and provides a unique possibility to perform such an unprecedented study. It is important to note that both supervisors are science team members of the ESPRESSO consortia (N. Santos is the Co-PI of the instrument) and have access to 270 nights of GTO observations. All the observations needed to conduct this project are or will soon be available.

Fundamental cosmology from precision spectroscopy: from ESPRESSO to the E-ELT

Level: PhD or MSc
Supervisor: Carlos.Martins@astro.up.pt
Available at PhD::SPACE: Yes

ESPRESSO is the next generation spectrograph, combining the efficiency of a modern Echelle spectrograph with extreme radial velocity and spectroscopic precision, and including improved stability thanks to a vacuum vessel and wavelength calibration done with a Laser Frequency Comb. ESPRESSO has been installed in the Combined CoudÈ Laboratory of the VLT and linked to the four Unit Telescopes (UT) through optical CoudÈ trains, allowing operations either with a single UT or with up to four UTs for about a 1.5 magnitude gain. One of the key science drivers of ESPRESSO is to perform improved tests of the stability of nature's fundamental couplings, and in particular to confirm or rule out the recent indications of dipole-like variations of the fine-structure constant, alpha.

In this thesis the student will be directly involved in the analysis and scientific exploration of the ESPRESSO fundamental physics GTO, and in the preparation of any follow-up observations. Apart from its obvious direct ñ and very significant ñ impact on cosmology and fundamental physics, the ESPRESSO data will also be important as the first reliable precursor of analogous high-resolution spectrographs for the next generation of Extremely Large Telescopes, and in particular of ELT-HIRES (in whose Phase B we are directly involved). A second goal of the thesis is to use the ESPRESSO data for detailed realistic simulations to assess the cosmology and fundamental physics impact of ELT-HIRES, also including tests beyond the sensitivity of ESPRESSO, such as redshift drift measurements and molecular tests of composition-dependent forces.

Key relevant references are: Alves et al. PRD97 (2018) 023522 & PRD97 (2018) 023522, Avgoustidis et al. PRD 93 (2016) 043521, Evans et al. MNRAS 445 (2014) 128, Leite et al. PRD 94 (2016) 123512 & arXiv:1812.06796, Martins Rep.Prog.Phys. 80 (2017) 126902, Martins et al. JCAP 1508 (2015) 047, PRD 93 (2016) 023506 & PRD 94 (2016) 043001, Martins & Pinho PRD 95 (2017) 023008, and Pinho et al. PLB769 (2017) 491.

Impact of the transport of chemical elements on stellar parameter determination

Level: MSc or PhD
Supervisor: morgan.deal@astro.up.pt
Co-supervisor: Margarida Cunha
Available at PhD::SPACE: No

PLATO is an ESA space mission (launch 2026) that aims at detecting Earth-like planets around Sun-like stars. In order to characterize the detected exo-planets, it is crucial to determine the parameters of the host-star (namely the stellar mass and radius) with high accuracy. In that context, the adequate modelling of the transport of chemical elements inside stars and during the evolution is a key problem to solve. With this in mind, the project will include two tasks aimed at assessing the impact on stellar models and stellar global properties of using different implementations of the physical processes responsible for the transport of chemical elements.

The first task will consist in testing different options for atomic diffusion implemented in one of the most commonly used, publicly available stellar evolution code, MESA (Paxton et al. 2018), against the results from a second stellar evolution code, CESTAM (Marques et al. 2013, Deal et al. 2018), where these processes have been tested in detail. The final objective will be to provide to the many users of the MESA code a comprehensive assessment of the implications of using the different atomic diffusion options offered by the code. The second task will be aimed at testing non-standard transport processes in stellar models to quantify their impact on the stellar parameter determinations. The complete treatment of the transport of chemical elements cannot be included in grids of models due to very large computational times involved. The idea is to test an empirical transport formulation (Richer et al. 2000) that mimics the real physic and estimate the accuracy of such models against the more physical one. The final objective is to establish the options that will lead to the best compromise between accuracy and computational time, aiming at the definition of the model grids which later will be built for the PLATO space mission.

The results of this work are expected to be presented in a PLATO-related conference and lead to a publication.

New Maps of the Dark Side: Euclid and beyond

Level: PhD or MSc
Supervisor: Carlos.Martins@astro.up.pt
Available at PhD::SPACE: Yes

The growing amount of observational evidence for the recent acceleration of the universe unambiguously demonstrates that canonical theories of cosmology and particle physics are incomplete - if not incorrect - and that new physics is out there, waiting to be discovered. The most fundamental task for the next generation of astrophysical facilities is therefore to search for, identify and ultimately characterise this new physics. The acceleration is seemingly due to a dark component whose low-redshift gravitational behaviour is very similar to that of a cosmological constant. However, currently available data provides very little information about the high-redshift behaviour of this dark sector or its interactions with the rest of the degrees of freedom in the model.

It is becoming increasing clear that tackling the dark energy enigma will entail significantly extending the redshift range where its behaviour can be accurately mapped. A new generation of ESA and ESO facilities, such as Euclid, the ELT, and the SKA have dark energy characterization as a key science driver, and in addition to significantly increasing the range and sensitivity of current observational probes will allow for entirely new tests. The goal of this thesis will be to carry out a systematic exploration of the landscape of physically viable dark energy paradigms and provide optimal discriminating observational tests. The work will initially focus on Euclid (whose launch is fast approaching) and will gradually broaden to explore synergies and probe combination with the SKA and relevant ELT-HIRES instruments.

Key relevant references are: Amendola et al. LRR21 (2018) 2, Calabrese et al. PRD 89 (2014) 083509, Di Valentino et al. JCAP 1804 (2018) 017, Martins et al. PRD 93 (2016) 023506, PRD93 (2016) 123524 & PRD 94 (2016) 043001, Martins & Prat Colomer A&A 616 (2018) A32.

Unveiling the composition of exoplanets atmospheres with CHEOPS and ESPRESSO

Type: PhD
Supoervisor: olivier.demangeon@astro.up.pt
Co-supervisor: Nuno Santos, Gabriella Gilli (U.Lisbon)
Available at PhD::SPACE: Yes

Although several thousands of exoplanets have already been detected (see exoplanet.eu), our understanding of their atmospheres is still very limited. In most of the cases, our knowledge of an exoplanet can be reduced to its mass and radius (see Demangeon+2018). The last years have, however, seen considerable developments in terms of instrumentation. New missions like the ESA-CHEOPS satellite (Fortier+2014), the ESA-ARIEL project (Tinetti+2016) and the high resolution spectrograph ESPRESSO@ESO-VLT (Pepe+2014) will shed new lights on exoplanets and their atmospheres.
CHEOPS, ARIEL and ESPRESSO will provide complementary information. On one side, CHEOPS will probe the atmosphere of hot jupiters providing broad spectral measurement of the light reflected by these planets. ARIEL will complement that with low resolution spectra in the infra-red. On the other side, ESPRESSO will provide high resolution observation of these planets and their host stars, from which transmission spectra and specific spectral signatures can be extracted.
For this PhD project, the laureate will be involved in CHEOPS, ARIEL and ESPRESSO science team activities. The first objective will be to focus on the interpretation of CHEOPS and ESPRESSO data. A second step will be to participate to the scientific definition of the ARIEL mission whose launch is planned for 2028. Using state-of-the art models, inspired from those used to simulate the atmosphere of Solar System planets, the laureate will infer several properties of the observed atmospheres: their reflective properties (albedo, presence/characteristics of clouds, e.g. Demory+2013, Martins+2018), their temperature, the molecules and atoms which compose them (e.g. Birkby+2017). Due to the unprecedented precision and flexibility offered by CHEOPS and ESPRESSO on one side and the importance of the ESA-ARIEL mission for the future of exoplanet sciences. The results from this thesis will constitute landmarks in the field of exoplanetary atmospheres and help to shape the future of the field.

The supervisors of this project, along with the team which will host the laureate, has a deep involvement and expertise in both CHEOPS, ARIEL and ESPRESSO. They will guarantee the laureate access to the data, to sophisticated 3D atmospheric models and involvement in the science team's activities.

Other astrophysics projects

Analytic Methods for Astrophysical Defect Fingerprinting

Level: PhD or MSc
Supervisor: Carlos.Martins@astro.up.pt
Available at PhD::SPACE: Yes

Cosmic strings arise naturally in many proposed theories of new physics beyond the standard model unifying the electroweak and strong interactions, as well as in many superstring inspired inflation models. In the latter case, fundamental superstrings produced in the very early universe may have stretched to macroscopic scales, in which case they are known as cosmic superstrings. If observed, these objects thus provide a unique window into the early universe and possibly string theory.

Recent progress in CMB polarization and gravitational wave detection shows how some of these scenarios can be constrained by high-resolution data. However, to fully exploit the potential of ESA facilities such as CORE and LISA, one needs matching progress both in high-resolution HPC numerical simulations of defect networks and in the analytic modelling of key physical mechanisms underlying their evolution. This thesis will address the latter, using a series of novel mathematical and statistical techniques to develop more accurate analytic models for general defect evolution (building upon the successes of the current canonical VOS model) as well as for their astrophysical fingerprints, which is able to match the sensitivity of ongoing and future observational searches.

A recent introduction to the field can be found in Martins, Defect Evolution in Cosmology and Condensed Matter: Quantitative Analysis with the Velocity-Dependent One-Scale Model (Springer, 2016).
Other relevant references are: Correia & Martins PRE96 (2017) 043310, Lazanu et al. PLB B747 (2015) 426, Martins & Cabral PRD 93 (2016) 043542, Martins et al. PRD 93 (2016) 043534 & PRD 94 (2016) 116017, Rybak et al. PRD96 (2017) 103535, PRD98 (2018) 063519 & PRD99 (2019) 063516, and Vieira et al. PRD 94 (2016) 096005.

Astrophysical and Local Tests of the Einstein Equivalence Principle

Level: PhD or MSc
Supervisor: Carlos.Martins@astro.up.pt
Available at PhD::SPACE: Yes

The Einstein Equivalence Principle (EEP, which Einstein formulated in 1907) is the cornerstone of General Relativity (only formulated in 1915) but also of a broader class known as metric theories of gravity. Although they are often confused, the two are conceptually distinct, and different experiments optimally constrain one or the other. Recent developments, including quantum interferometric tests and dedicated space missions, promise to revolutionize the field of local tests of the EEP and dramatically improve their current sensitivity.

This thesis will explore new synergies between these imminent new local tests of the EEP and ongoing or planned astrophysical and cosmological tests: some of these directly test the EEP, while others only test GR on various scales. We will explore relevant paradigms (including scenarios with and without screening mechanisms), develop a taxonomy for various model classes, and study how they are further constrained by experiments such as MicroSCOPE and ACES, in combination with astrophysical data from ESPRESSO, ALMA and other facilities. The work will also be directly relevant for the science case of several ELT instruments, as well as Euclid and the SKA.

Key relevant references are: Alves et al. PRD97 (2018) 023522, Dimopoulos et al. PRL 98 (2007) 111102, Leite et al. PRD 94 (2016) 123512 & arXiv:1812.06796, Magano et al. PRD96 (2017) 083012, Martins Rep.Prog.Phys. 80 (2017) 126902, Martins & Pinho PRD95 (2017) 023008, Martins et al. JCAP 1508 (2015) 047 & Martins et al. PRD 93 (2016) 023506, Pinho et al. PLB769 (2017) 491, and Will LRR 17 (2014) 4.

Composition of Earth-size planets

Level: PhD or MSc
Supervisor: susana.barros@astro.up.pt
Co-supervisor: Olivier Demangeon
Available at PhD::SPACE: Yes

Many transiting small exoplanets where found and are waiting to be found by the K2 mission (Barentsen+2018). Our group has developed tools to reduce K2 data, compute high precision light curves and search for planetary transits. Using these tools, we already discovered multiplanetary systems (Barros+2017) and a planet smaller than the Earth (Santerne+2018).

This project consists in optimizing and using these tools to create a complete list of transiting planetary candidates from K2 data; prioritize them for follow-up observations and confirm them using state-of-the-art spectrographs: HARPS, ESPRESSO, NIRPS.
The recently launched TESS satellite is also providing transiting candidates, which can also be included in the priority list for follow-up. The student will thus have the unique opportunity to discover and characterize new exoplanets. One important part of the project is the development of tools to prioritize the planetary candidates using all the available information.

The second part of the project involves combining the transit observations from K2 and TESS with the radial velocity observations taken with HARPS, ESPRESSO and NIRPS. This will allow deriving the mass and radii of the planets and hence constrain their composition. Our group already has its own code to derive the planetary parameters but the student is expected to optimize it.

The tools developed here will also be important for future surveys like PLATO. Our group is responsible for their development for the ESA mission PLATO giving the opportunity for the student to be involved in this extra-ordinary mission which gather most of the European exoplanet community.

Detection of phase-curves in the K2 data

Type: MSc

Supervisor: olivier.demangeon@astro.up.pt

The NASA-Kepler satellite has revolutionized the field of exoplanetology in many aspects. One of them is the detection of tens of exoplanet phase-curve, see Esteves et al 2015. Phase-curves are particularly interesting since, when they are produced by a planet, they constitute a manifestation of the exoplanet atmosphere. After the loss of two reaction wheels, the Kepler satellite pointing accuracy was severely damaged but cleaver engineering allowed the continuation of the mission in a new configuration named K2. Our team developed a software called POLAR (see Barros, Demangeon et al. 2016) to reduce the data coming from K2 and retrieve a photometric precision close to the original Kepler mission.

Thanks to the retrieved photometric precision, a phase-curve has been recently observed in the light-curve of the exoplanet WASP-157 b observed with K2 (see Mocnik et al. 2016). The objective of this project is to look for phase-curves in the light-curve provided by the POLAR software. The student will first go through the list of planets detected in the K2 data and announced for example in Barros, Demangeon et al. 2016. From this list, he will select the planets which have the best chances of displaying a phase-curve in there light-curve (shorter periods and bigger radius). Finally, he will analyze the selected light-curves to extract the phase-curve variations. Depending on the result of the analysis this work could lead to a publication.

Galactic archaeology of solar-type stars with the NASA TESS mission

Level: PhD
Supervisor: tiago.campante@astro.up.pt
Co-supervisors: Vardan Adibekyan, Aldo Serenelli (ICE-CSIC & IEEC, Spain)
Available at PhD::SPACE: Yes

The Transiting Exoplanet Survey Satellite (TESS) is a NASA space mission, launched in April 2018, that will perform an all-sky survey for planets transiting bright nearby stars. Furthermore, TESS's excellent photometric precision will enable asteroseismology, the study of stars by the observation of their natural, resonant oscillations. Asteroseismology is proving to be particularly relevant for the study of solar-type stars (i.e., low-mass, main-sequence stars and cool subgiants), in great part due to the exquisite photometric data previously made available by NASA's Kepler space telescope and, more recently, by the repurposed K2 mission. In extending the legacy of Kepler/K2, one will perform an ensemble asteroseismic study of bright solar-type stars that reside in the solar neighborhood, making use of data collected by TESS.

The proposed research will provide a well-characterized sample of benchmark solar-type stars to be used in studies of the chemical evolution of the solar neighborhood, which in turn will impact on Galactic archaeology studies. Specifically, one will aim at constraining the relation between age and elemental abundances for nearby field stars. Calibration of this relation with the accuracy and precision offered by asteroseismology is crucial for a better understanding of the chemical history of the Galaxy, and offers clues to the degree to which different stellar populations in the disk have mixed. This relation can then be used to estimate the ages of stars with no asteroseismic measurements but with precise abundance determinations (e.g., using the high-resolution ESPRESSO spectrograph at the VLT), thus allowing to significantly expand the above sample beyond the solar neighborhood.

Galaxy interactions at Infrared wavelengths

Level: MSc
Supervisor: Tom.Scott@astro.up.pt
Co-supervisor: Catarina Lobo

Galaxies, especially in galaxy clusters and galaxy groups, can tidally interact with one another and these interactions produce characteristic distortions in the galaxy?s shape, e.g. tidal tails. During their orbits in galaxy clusters, spiral disk galaxies like the Milky Way can also interact with a hot X-ray emitting gas, which pervades galaxy clusters and is known as the intra-cluster medium (ICM). This interaction, known as ram pressure stripping, can remove the galaxy?s gaseous interstellar medium. During ram pressure stripping it is only the galaxy's gaseous interstellar medium which interacts with the ICM leaving the galaxy's old stellar population unaffected. However, ram pressure stripping can affect the location of young stars, by displacing the gas from which they form. So to distinguish between tidal and ram pressure-stripping interactions we need to understand which wavelength best traces a spiral galaxy?s old stellar population. We can then see whether the old stellar population has been disturbed or not by the interaction, thus allowing us to distinguish between tidal and ram pressure interactions. In turn this will help understand how the cluster environment drives the evolution of its galaxies.

In general, infrared wavelengths are better tracers of old stellar populations than optical wavelengths. But, it remains unclear which of these wavelength band(s) optimally reflects a galaxy's old stellar population. The project will begin by reviewing the literature to gain an understanding of the sources of the emission detected for nearby galaxies in each broadband filter, e.g. J, H K and Spitzer 3.6 and 4.5 micron bands. The study will then use astronomical software to compare the emission from a sample of spiral galaxies from a few nearby clusters imaged in different infrared wavelength bands and with different telescopes, including the Spitzer space telescope (all data is available and in archives). Part of the study will test the feasibly of using the independent component analysis (ICA) technique to isolate differences between images from different IR bands. Investigating these differences and the reasons for them, based on theories of the emission detectable in each band, will help determine which band best reflects the emission from the old stellar population. Resolving this question is an important step to understanding more fundamental issues of galaxy evolution.

How rare is the Earth and the Solar System architecture?

Level: PhD
Supervisor: Pedro Viana (viana@astro.up.pt)
Co-supervisor: Olivier Demangeon
Available at PhD::SPACE: No

The estimation of how rare Earth-like planets are, as well as planetary systems similar to our own, requires the joint statistical characterization of the full population of exoplanets and their systems. This can also be used to indirectly infer exoplanet or exoplanetary system properties, given direct knowledge about others. It leads to a better understanding of the physical processes that were most important during planetary formation and evolution. However, if these aims are to be achieved, the selection effects associated with the sampling of the exoplanet population, have to be taken properly into account.

The PhD student will use advanced statistical and machine learning techniques, namely Hierarchical Bayesian Modelling, Approximate Bayesian Computation, Importance Sampling and Gaussian Processes, to characterize the population of exoplanets considering the full impact of sample selection effects. The objective is to obtain robust and unbiased estimates of: planetary occurrence rates as a joint function of exoplanet mass, radius, insolation and orbital parameters, as well as stellar characteristics; the population of exoplanetary systems, through the occurrence rate of distances in the space of exoplanet properties, as a function of stellar characteristics. This work will be based on exoplanet catalogues assembled by searching for planetary transits in front of the stars observed with the NASA missions Kepler and TESS, for which the selection effects are well understood. And take into account spectroscopic data obtained with ground-based telescopes, namely at the European Southern Observatory (ESO), which holds essential information about exoplanet mass and stellar characteristics. For this data to be properly considered, it will be jointly analyzed with the transit data using always the same methodology, based on Bayesian joint modelling of planetary and stellar activity. Its accuracy and precision will be characterized through simulations.

Mitigate stellar activity to characterise Earth-size planets

Level: PhD
Supervisor: susana.barros@astro.up.pt
Available at PhD::SPACE: Yes

The detection of terrestrial mass planets is a major goal in astrophysics. This has recently become possible due to two space-based transit surveys, namely CoRoT and Kepler and improvements in the precision of radial velocity measurements. Future space based missions (e.g. CHEOPS, PLATO) and new high-resolution spectrographs such as ESPRESSO (Pepe+2010) and NIRPS (Wildi+2017) are being planned to detect and characterise Earth-like planets around bright nearby stars. This research project aims to improve the accuracy and precision of planetary parameters derived from transits and radial velocities obtained with these future facilities, which our institute has privileged access.

One of the project goals is to develop tools and methods that are essential to explore the data from these missions. A second more general goal of this project is to study the effect of stellar activity in observations of small sized planets. The student will investigate how the stellar activity biases planetary parameter measurements and develop methods to correct for it. The corrections will be implemented in an already existing tool to derive mass and radii of exoplanets. Then he/she will apply the new tool to new observations of exoplanets obtained with CHEOPS, EXPRESSO and NIRPS. This is crucial to improve the accuracy of the measurements of mass and radii of planets in the range from Earth-Neptune size. Accurate masses and radii are essential to derive the composition of very low mass planets and gain insight into planetary structure. This will provide constrains on planetary formation and evolution theories. Moreover, bright systems allow further characterisation of the planets. Optionally the student can also be involved in developing stellar activity corrections for observations of Rossiter‚ÄìMcLaughlin effect to measure the relative angle between the planet orbit and the stellar spin or observations of planetary atmospheres. The tools developed here will also be important for future surveys like PLATO.

Novel software for state-of-the-art spectrographs: stellar radial velocity extraction

Level: PhD
Supervisor: sergio.sousa@astro.up.pt
Co-supervisors: Pedro Viana, Nuno Santos
Available at PhD::SPACE: Yes

The detection of an increasing variety of exoplanets, planets orbiting other stars, and in particular the derivation of their masses, has been possible thanks to the continuous development of high-resolution, stable spectrographs, and making use of the Doppler radial-velocity method. Over the past two decades, technological progress together with significant advances in data reduction and analysis techniques already allowed this method to detect and characterize a thousand or so exoplanets. Now, the dawn of a novel generation of ground and space-based instruments and missions promises to bring us close to the discovery and characterization of temperate Earth-like worlds, similar to Earth in both mass and composition and thus potential islands of life in the Universe.

Several interesting challenges remain, however. In particular, a new data analysis paradigm is needed to significantly improve the extraction of radial velocity information from stellar spectra. Therefore, we propose as the main objective of this project the development and implementation of a novel data processing and analysis software for the precise estimation of stellar radial velocities from state-of-the-art spectra. This software should be developed using high-performance programming and computing techniques, in order to optimize its speed. It will be used to analyze data taken with instruments such as ESPRESSO (ESO-VLT), NIRPS (ESO-3.6m) and SPIROU (CFHT), where our team has a leading participation.

The candidate will have the opportunity to apply the algorithm to existing data in collaboration with the team, namely in the search for temperate Earth-like exoplanets.
By the end of the project, the candidate will have acquired expertise on the reduction and analysis of high-resolution stellar spectra, pipelines for astronomical instrumentation, as well on general-purpose advanced programming, computational, statistical and machine-learning techniques.

On the extinction laws and dust re-emission of extragalactic objects

Level: MSc
Supervisor: Jean Michel Gomes (jean@astro.up.pt)
Co-supervisor: Catarina Lobo

The presence of dust in galaxies is ubiquitous and has changed completely our understanding of galaxy formation and evolution. It is estimated that more than one-third of the total luminosity in local galaxies is dimmed due to the reprocessing of ultraviolet (UV) light by dust into the infrared (IR) emission. Additionally, dust limits our ability to interpret the electromagnetic emission of local and distant galaxies because it selectively dims the galaxy light from UV to IR bands, which leads to the reddening effect. A fundamental task in modern extragalactic research is to recover the star formation- and chemical enrichment history (SFH & CEH, respectively) of galaxies from spectra, the main objective of spectral synthesis codes. However, dust opacity makes the proper interpretation of the spectral energy distribution of galaxies in terms of the stellar populations' properties, such as age and metallicity distributions, difficult. FADO (Fitting Analysis using Differential evolution Optimization) is a conceptually novel, publicly available population spectral synthesis code developed at IA with the distinctive capability of permitting identification of the SFH and CEH that best reproduces the observed gas characteristics of a galaxy taking into account the effects of dust absorption and emission in the optically thin limit.

In this MSc project, the student will study, implement and test distinct model predictions for the extinction and emission of dust grains given their size distribution, their optical and thermal properties using, for instance, models available in the literature, such as DÈsert et al. (1990), Draine & Li (2001,2007), CompiËgne et al. (2011), Jones et al. (2013) and Koehler et al. (2014). These predictions will be intercompared using the FADO dust module. Then, FADO will be applied to real star-forming galaxies from the SDSS and CALIFA in order to test possible biases on the recovered SFH & CEH of galaxies. Preferable computing languages are Fortran & Python.

Probing the architecture of multi-planetary systems

Level: PhD or MSc
Supervisor: susana.barros@astro.up.pt
Co-supervisor: Olivier Demangeon
Available at PhD::SPACE: No

The Kepler satellite has revealed that a large percentage of the known transiting exoplanets are in multi-planetary systems (‚àº40%). Multi-planetary systems are great laboratories to test theories of formation and migration of planetary systems. Many interesting systems found by Kepler and others recently found by the K2 mission are still awaiting detailed modelling due to the extra-complexity that the gravitational interaction between the different planets of the system introduce. This project aims at the study of the architecture of multi-planetary systems using detailed state of the art n-body simulations coupled with a Bayesian modelling.

The project is built on a photodynamic transit and radial velocity (RV) fitting tool developed by our group to study interesting known Kepler multi-planetary systems and/or new multi-planetary systems discovered by the K2 and TESS new surveys. A photodynamical analysis, accounting for the dynamical interactions between the planets of the system at the earliest stage of the data analysis, achieves a better precision and accuracy on the determination of the system parameters than usual methods. It is also more sensitive to the low masse planets. The goal of this project is to focus on the lowest mass planets (super-Earths and mini-Neptunes), for which it is not possible to determine masses with current RV instruments alone and will probe this fascinating population of planets.

Our group has developed a pipeline to reduce K2 data and compute high precision light curves combined with a transit search algorithm to search for planetary transits. Hence we have a competitive advantage to discover knew interesting systems from K2 or even TESS data. We are also involved in a collaboration to obtain precise radial velocities with the HARPS spectrograph to confirm and characterise these candidates. The student will study the most promising know systems and is also expected to be involved in the search and characterisation of these new multi-planetary systems.

Rossiter Mac-Laughlin: A new generation of models for a new generation of instruments

Type: MSc

Supervisor: olivier.demangeon@astro.up.pt

ESPRESSO is the new generation of radial velocity instruments (Pepe+2014) which entered in operation in September 2018. Its extreme precision (up to 10 cm.s-1 compared to the 1 m/s of the last generation) open the door to extraordinary discoveries like the discovery of an Earth like planet in the habitable zone of another star, but not only.

The Rossiter Mac-Laughlin (RM) effect is a well known effect which occurs when a planet transit in front of its parent star (Rossiter 1924, MacLaughlin 1924). As all stars rotate, part of their surface moves away from us, while the other part moves towards us. Due to the Doppler effect, the spectra emitted by these different parts are slightly red-shifted (for the part moving away from us) or blue-shifted (for the part moving towards us). When a planet transits in front of a rotation star it successively occults blue-shifted and then red-shifted region. As consequence, the overall radial velocity of the star first increases and decreases drawing a curve call the RM effect (e.g. Queloz+2000). The exact shape of this curves can provide a wealth of information. Due to the limited precision of the previous generation of RV instruments, these observations mostly told us about the projected inclination between the planet orbital plan and the axis of rotation of the star. With ESPRESSO, we can now access new details. In particular, we can detect the effect of stellar differential-rotation. Indeed we know that the Sun does not rotate like a solid ball. Next to the equator the Sun rotates faster than at the pole. This difference can be seen in RM observation, since the planet will occult region have higher radial velocities when it passes at the stellar equator than at the pole. This new physical process require a new generation of model to be able to interpret the data and extract the relevant information.

This objective of this project is to test a new concept of model based on spherical harmonic decomposition. Spherical harmonics are frequently used in astrophysics, astero-seismology for example and have recently been applied to exoplanet sciences. Luger+2019 developed a open source code called starry for the modeling of high precision photometry data (Kepler, K2, TESS). For this project, the student will apply the starry, but instead of using the spherical harmonics to simulated the flux variation over the stellar surface, he will use them to simulate the different radial velocities at the stellar surface. The advantage of this method is the flexibility of the spherical harmonics that can reproduce any radial velocity field and thus be used to model differential rotation, contrary to other model like AROME (Boue+2013). Furthermore, as spherical harmonics are purely analytical such model will be computationally much faster than other numerical models like SAOP (Oshagh+2013).

Shedding a new light on outstanding problems in stellar physics with the NASA Kepler mission

Level: MSc
Supervisor: diego.bossini@astro.up.pt
Co-supervisor: Tiago Campante

Major advances in stellar interiors physics and evolution have recently been made possible by asteroseismology, the study of stars by means of their natural, resonant oscillations. This paradigm shift was largely due to the exquisite space-based data made available by CNES/ESA's CoRoT and NASA's Kepler/K2 missions. In particular, asteroseismology has vastly benefited the study of red-giant stars, which exhibit convection-driven, solar-like oscillations.

The main goal of this project will be to perform an ensemble asteroseismic study of bright red giants, both in the field and belonging to stellar clusters, making use of data collected by Kepler during its nominal, 4-year operation period. To that end, we propose an all-embracing project that will provide the student with skills in asteroseismic data analysis and stellar modeling techniques. The implications of this project are far-reaching. The proposed research will provide a well characterized sample of benchmark red-giant stars to be used in studies of stellar interiors physics along the red giant branch (RGB) and horizontal branch (HB) phases of stellar evolution.

The build-up of metals within galaxies with cosmic time

Level: PhD

Supervisor: Jarle Brinchmann (jarle@astro.up.pt)

Available at PhD::SPACE: Yes

The project will devise a method to combine MUSE integral field spectroscopic data with space-based grism spectroscopy from HST to study metallicity gradients in the galaxies. This project will make use of a large amount of state-of-the-art deep observations of the sky from 250 nights of VLT time.

The M20 star forming region as seen by MUSE

Level: MSc

Supervisor: Jarle Brinchmann (jarle@astro.up.pt)

The MUSE instrument has made a massive mosaic of the M20 star forming region (the Trifid nebula). This is 11×11 arcmin and contains a wealth of information and therefore a number of possible projects. One example is to study the metal content of the ionised gas in the nebula using different indicators - strong forbidden lines and fainter recombination lines, another possibility is to classify the stars in the field and study the overall energy balance of the HII region.

The nature of ultra-faint dwarfs

Level: PhD or MSc
Supervisor: Jarle Brinchmann (jarle@astro.up.pt)
Available at PhD::SPACE: Yes

This project focuses on a 100hr large program with the MUSE Integral Field Spectrograph to study ultra-faint dwarfs around the Milky Way. These are the faintest galaxies we know and are extremely dark matter dominated. Various projects are possible here, developing methods for determining the dark matter density distribution using stellar velocities; exploring the stellar metallicity distribution functions of the dwarfs and what they tell us about their history; searching for binary stars in the dwarfs to make a first census of binaries in ultra-faint dwarfs.

The potential of galaxy evolution studies with future space survey telescopes

Level: MSc
Supervisor: Jarle Brinchmann (jarle@astro.up.pt)

The coming decade will see at least three survey telescopes with potential for galaxy evolution: Euclid, WFIRST and SphereX and there are plans to construct a spectroscopic survey telescope in space as well, ATLAS. The aim of this project is to combine large galaxy formation simulations with models for galaxy spectra and use this to simulate what the spectra from (some of) these facilities will look like and explore how well we can use these facilities to study the evolution of scaling relations like the mass-metallicity relation with redshift.

What are HI profiles of cluster galaxies telling us?

Level: MSc
Supervisor: Tom.Scott@astro.up.pt
Co-supervisor: Catarina Lobo

Isolated late-type galaxies (LTGs) typically contain disks of rotating HI gas with diameters approximately twice the diameter of their stellar disks. Integrated HI spectra of these HI disks show the distribution of mass at different velocities. Large scale surveys of these HI spectra for isolated LTGs show their HI velocity profiles display a high degree of symmetry as measured by their A_flux parameter.

LTG HI disks are much more easily perturbed than their stellar counterparts. In galaxy clusters the higher density of galaxies makes it more likely that tidal interactions with other galaxies will disturb/and or remove their gaseous inter-stellar medium (including HI). Additionally, during their orbits in galaxy clusters, LTGs can also interact with a hot X-ray emitting gas, which pervades galaxy clusters and is known as the intra-cluster medium. This interaction, known as ram pressure stripping, can also disturb/remove an LTG's HI. It is well established that these processes are responsible for the higher fraction of HI deficient LTGs observed in clusters compared to the field, although the relative importance of each mechanism is still debated. However, a recent study of Abell 1367 and Virgo in comparison to an isolated sample, indicated the mean A_flux of LTGs in a cluster maybe related to the cluster's dynamical state. Abell 1367 is a merging cluster and has the highest mean A_flux, which denotes more asymmetric HI profiles. In this project we aim to extend this study of A_flux to other nearby galaxy clusters with different dynamical states using archive HI spectra and python code developed in house.

Abell 262 is a cluster with significantly lower X-ray luminosity and velocity dispersion than Abell 1367 and Virgo thus providing a cluster with contrasting properties. For Abell 262 there is sample of about 30 HI spectra available. The project is to use the python code to measure various properties of these spectra, including A_flux, and then determine from the sample's statistics how likely it is that the mean A_flux is different to those for Abell 1367, Virgo and isolated samples. Also there were indications from Abell 1367 that higher A_flux values are measured for galaxies belonging to groups and pairs within the cluster; statistical tests will also be carried to determine if this is also seen in Abell 262. After studying Abell 262, the project can be expanded by identifying and applying the same methods to other nearby clusters.

Weather forecast on exoplanet through the modeling of phase-curves

Type: MSc

Supervisor: olivier.demangeon@astro.up.pt

Accessing the conditions in exoplanet atmospheres is the new focus of the exoplanet community. During the past ten years, the space missions CoRoT, Kepler and K2, based on the high-precision photometry technique, have provided us with exquisite light-curves allowing the detection of thousands of exoplanets. In favorable cases where the detected planet orbits very close to its parent star, those light-curves can provide additional information regarding the planet's atmospheric conditions through the observation of phase-curves (see Esteves et al 2015).

This project propose to implement the model described in Esteves et al 2015. The student will then plug this model into an existing software developed by our team to analyse the light-curve of exoplanets. Finally, the software will be used to interpret the phase-curve of known exoplanets and look for variability in the phase-curve of already know planets as recently done by Armstrong et al 2016 for HAT-P-7b. Such variability constitutes the first observed signs of weather evolution in an exoplanet's atmosphere. In case a new variability is discovered in the phase-curve an exoplanet, the student will be involved in the resulting publication.Education/outreach and undergraduate projects

Education/ outreach and undergraduate projects

Desenvolvimento de conteúdos de astrofísica para o ensino secundário

Orientador: Carlos.Martins@astro.up.pt
Local do Estágio: CAUP (incluindo visitas a várias escolas).

Perfil do Candidato:
É dada preferência a alunos de mestrado de ensino. Experiência prévia de programação, análise e visualização de dados é útil. Espera-se uma dedicação mínima de 6 horas de trabalho por semana, parcialmente presenciais. Poderá ser realizada uma entrevista aos candidatos.

Objectivos e Actividades:
Os estagiários participarão no desenvolvimento de conteúdos apropriados para alunos do ensino secundário (de áreas científicas), no âmbito do projecto CosmoESPRESSO (PTDC/FIS-AST/28987/2017, Investigador Principal: Carlos Martins), um projecto de investigação científica financiado pela FCT que inclui uma componente (com orçamento próprio) de educação e divulgação em escolas secundárias. Actividades específicas incluem:
1) Pesquisa bibliográfica sobre a área relevante;
2) Desenvolvimento de conteúdos relacionados com os objectivos científicos do projecto apropriados para alunos do ensino secundário, em colaboração com os investigadores e alunos de doutoramento da equipa científica do projecto e com professores de escolas secundárias parceiras do projecto;
3) Implementação destes conteúdos em pequenos grupos de alunos do ensino secundário das escolas parceiras;
4) Organização e publicação destes conteúdos, e dos resultados obtidos.

Espera-se que os resultados sejam apresentados, entre outros locais, no Encontro Nacional de Astronomia.

DetRedshift: a new tool for the assessment of the spectroscopic redshifts for the MOONS/VLT spectrograph

Supervisor: Jean Michel Gomes, jean@astro.up.pt

Candidate profile:
Candidates in areas related to astronomy/astrophysics. Not necessary any background in extragalactic courses. Basic knowledge on Fortran & Python computing languages.

Goals and activities:
Automatic assessment of the spectroscopic redshift of galaxies is fundamental for both extragalactic and cosmological studies of large galaxy samples (e.g., 2dF, 6dF, SDSS). For instance, by having the redshift of galaxies and associating it with a given cosmological model we can accurately determine distances in order to study the stellar populations in galaxies.
The IA-CAUP extragalactic team is one of the members of the MOONS (Multi Object Optical and Near-infrared Spectrograph for the VLT) consortium. MOONS is a new ESO instrument that will provide to the astronomical community the necessary observational power to study a wide range of scientific key-questions in astronomy (Galactic, extragalactic and cosmological studies). For instance, MOONS will allow us for the first time to obtain high-quality spectra for a statistically significant number of galaxies (~1 million) at redshift greater than 1.
However, spectroscopic redshifts are subject to several uncertainties that depend on the quality of the observed spectra (e.g., Signal-to-Noise). This project will investigate the reliability of redshift determinations by means of DetRedshift, a new tool for the assessment of spectroscopic redshifts of galaxies. Additionally, we will furnish confidence in levels for the redshift determinations as a function of S/N and redshift for MOONS-like spectra. The work plan for this project is as follows:
i) The student will study scientific articles related to the main techniques for spectroscopic redshift determination;
ii) The student will learn the foundations of DetRedshift tool and how to run it on large galaxy samples;
iii) The student will apply DetRedshift to a mock-galaxy catalog with redshifts up to 4 and determine the redshift confidence levels as a function of Signal-to-Noise;
iv) The student will apply DetRedshift to the SDSS catalog and compare with previous measurements using other techniques (e.g., wavelet transform);
General Goals: Learn from galaxy spectra what are their typical features (e.g., emission and absorption-lines) and estimate the number of false redshift detections with DetRedshift as a function of Signal-to-Noise and redshift. This project will be co-supervised by Catarina Lobo.

Explorando os dados científicos provenientes do satélite TESS da NASA

Orientador: tiago.campante@astro.up.pt

Perfil do candidato:
Os candidatos deverão estar a frequentar pelo menos o terceiro ano de formação superior numa das seguintes áreas: Astronomia/Astrofísica, Física, Engenharia Física ou Ciências da Computação. Algum conhecimento prévio de programação é necessário, preferencialmente em Python.

Objectivos e actividades:
O satélite TESS (Transiting Exoplanet Survey Satellite), lançado em Abril de 2018, é uma missão espacial da NASA que irá efectuar um levantamento detalhado de planetas em trânsito em órbita às estrelas mais brilhantes no céu. Além disso, a excelente precisão fotométrica alcançada pelo TESS permitirá a condução de estudos em astrossismologia, ou seja, a investigação minuciosa das estrelas através da observação das suas oscilações naturais. A astrossismologia tem vindo a desempenhar um papel muito relevante no que se refere ao estudo de estrelas do tipo solar e de gigantes vermelhas, em grande parte devido aos excelentes dados fotométricos previamente disponibilizados pelo telescópio espacial Kepler da NASA. Com o intuito de ampliar o legado do Kepler, o presente projecto tem como principal objectivo a realização de um estudo astrossísmico conjunto de estrelas do tipo solar e/ou gigantes vermelhas fazendo uso dos dados provenientes do TESS. Para esse fim, propomos um projecto ambicioso que dotará o aluno de competências relativamente à análise de dados astrossísmicos e a técnicas de modelação estelar. As implicações deste projecto são de grande alcance. O projecto fornecerá uma amostra bem caracterizada de estrelas do tipo solar e/ou gigantes vermelhas, a ser posteriormente usada em estudos de sistemas exoplanetários e da evolução química da Via Láctea, o último dos quais com impacto em estudos no âmbito da arqueologia Galáctica.

Impacto cosmológico da observação da expansão do universo em tempo real

Orientador: Carlos.Martins@astro.up.pt
Local do Estágio: CAUP; dependendo do desempenho, o estágio incluirá também visitas de trabalho a colaboradores no estrangeiro e/ou deslocações a conferências para apresentação dos resultados.

Perfil do Candidato:
Experiência de programação, análise e visualização de dados é essencial. Experiência anterior com projectos deste tipo é valorizada. Espera-se uma dedicação ao projecto de pelo menos 6 horas de trabalho por semana, parcialmente presenciais. Poderá ser realizada uma entrevista aos candidatos.

Objectivos e Actividades:
O aluno será integrado num projecto internacional (PTDC/FIS-AST/28987/2017, Investigador Principal: Carlos Martins) que desenvolve estratégias observacionais optimizadas para a caracterização das propriedades da energia escura. Em particular, pretende-se utilizar para esse fim medições em tempo real da taxa de expansão do universo (designado redshift drift) que serão pela primeira vez feitas em breve, juntamente com dados do satélite Euclid (ESA) e instrumentos previstos para o ELT (ESO). Actividades específicas incluem:
1) Estudo semi-analítico de modelos com campos escalares para a aceleração do universo e das suas consequências observacionais;
2) Desenvolvimento de ferramentas estatísticas de comparação desses modelos com os dados observacionais actualmente existentes;
3) Desenvolvimento de catálogos simulados de observações do redshift drift e outras observáveis, e optimização das respectivas estratégias observacionais;
4) Organização e apresentação dos resultados obtidos.

Exemplos de bibliografia relevante para este projecto (alguma da qual resultou de estágios anteriores) incluem:
https://arxiv.org/abs/1508.00765 | https://arxiv.org/abs/1606.07261
https://arxiv.org/abs/1704.08728 | https://arxiv.org/abs/1709.02923
https://arxiv.org/abs/1902.01783

Literacia científica e numeracia em Portugal

Orientador: Carlos.Martins@astro.up.pt
Local do Estágio: CAUP (incluindo possíveis visitas a escolas)

Perfil do Candidato:
É dada preferência a alunos de mestrado de ensino, e a alunos com experiência prévia de programação, análise e visualização de dados. Espera-se uma dedicação mínima de 6 horas de trabalho por semana, parcialmente presenciais. Poderá ser realizada uma entrevista aos candidatos.

Objectivos e Actividades:
Os estagiários participarão na implementação de um estudo sobre literacia científica em geral (e a numeracia em particular) no ensino secundário e superior em Portugal.

Actividades específicas incluem:
1) Pesquisa bibliográfica sobre a área relevante;
2) Planeamento e organização da logística do estudo, nas versões digital (para alunos do ensino superior) e em papel (para alunos do ensino secundário);
3) Implementação do estudo e análise dos resultados;
4) Organização e apresentação dos resultados obtidos.

Espera-se que os resultados do estudo sejam apresentados, entre outros locais, no Encontro Nacional de Astronomia.

Scientific literacy and astronomy teaching

Level: PhD or MSc
Supervisor: Carlos.Martins@astro.up.pt

We have recently carried out a survey of high-school students (from 7th to 12th grade) in Portuguese schools, aiming to determine the degree of understanding of some basic astronomy concepts which are supposedly part of the national schools curriculum. The main result of the survey was that most students do not in fact meet the set national standards.

The goal here is to take advantage of our privileged contacts with schools to extend this study, ideally reaching several tens of thousands of students and possibly also extending it to university students. The increased population will enable a more detailed statistical analysis that should allow meaningful comparisons between different sub-samples.

Although the focus will be on astronomy, in the case of a PhD project we will also aim to quantify the degree of scientific literacy of the students, either by implementing in Portugal methodologies previously developed in other countries or by designing and implementing our own, optimized to the specific context of Portuguese schools. Finally we will seek to quantify the degree of scientific literacy of the school teachers themselves, and how that may impact some of the knowledge (and the possible misconceptions) acquired by the students during their school years.

Simulação computacional e visualização de supercordas com GPUs e CUDA

Orientador: Carlos.Martins@astro.up.pt

Local do Estágio: CAUP; dependendo do desempenho, o estágio incluirá também visitas de trabalho a colaboradores no estrangeiro e/ou deslocações a conferências para apresentação dos resultados.

Perfil do Candidato:

O aluno deve ter interesse em programação, física computacional e data science. Experiência de programação, análise e visualização de dados é essencial. Experiência de programação paralela e/ou em GPUs será útil (em particular, o aluno terá acesso a GPUs de última geração, através de um projecto financiado pela NVIDIA). Experiência anterior com projectos deste tipo é valorizada. Espera-se uma dedicação ao projecto de pelo menos 6 horas de trabalho por semana, parcialmente presenciais. Poderá ser realizada uma entrevista aos candidatos.

Objectivos e Actividades:

O aluno será integrado num projecto internacional (PTDC/FIS-AST/28987/2017, Investigador Principal: Carlos Martins) que estuda a evolução de vários tipos de defeitos topológicos, incluindo paredes de domínio, cordas cósmicas e supercordas. Estes objectos formaram-se necessariamente no universo primitivo, e a sua caracterização dá-nos pistas cruciais sobre a física fundamental. O estudo da sua evolução é essencial no contexto dos dados do satélite Planck e de possíveis missões futuras da ESA (CORE e LISA). O objectivo do estágio é a simulação computacional da evolução de alguns destes modelos cujo comportamento não foi ainda estudado em detalhe, recorrendo a programação em CPUs e/ou GPUs, e o pós-processamento e análise destas simulações. Actividades específicas podem incluir:

1) Estudo de modelos analíticos para a evolução de redes de defeitos topológicos;
2) Desenvolvimento, optimização e/ou validação de códigos numéricos de evolução de redes;
3) Processamento, análise e visualização de resultados de simulações numéricas de alta resolução destas redes (incluindo o desenvolvimento de videos destas simulações);
4) Organização e apresentação dos resultados obtidos.

Exemplos de bibliografia relevante para este projecto (alguma da qual resultou de estágios anteriores) incluem:

https://arxiv.org/abs/1602.08083 | https://arxiv.org/abs/1612.08863
https://arxiv.org/abs/1710.10420 | https://arxiv.org/abs/1809.00995
https://arxiv.org/abs/1809.04033

Testes da universalidade das leis da física com o ESPRESSO e o ELT

Orientador: Carlos.Martins@astro.up.pt

Local do Estágio: CAUP; dependendo do desempenho, o estágio incluirá também visitas de trabalho a colaboradores no estrangeiro e/ou deslocações a conferências para apresentação dos resultados.

Perfil do Candidato:

O aluno deve ter interesse em espectroscopia observacional e análise de dados. Experiência de programação, análise e visualização de dados é essencial. Experiência anterior com projectos deste tipo é valorizada. Espera-se uma dedicação ao projecto de pelo menos 6 horas de trabalho por semana, parcialmente presenciais. Poderá ser realizada uma entrevista aos candidatos.

Objectivos e Actividades:

O aluno será integrado num projecto internacional (PTDC/FIS-AST/28987/2017, Investigador Principal: Carlos Martins) que usa o espectrógrafo ESPRESSO para testar o modelo cosmológico padrão e procurar indícios da presença de nova física para além deste. Em particular, pretende-se estudar a possibilidade de as leis da física que conhecemos não serem válidas em regiões ou épocas diferentes do universo. O aluno contribuirá para alguns dos testes em curso e para a definição e prioritização destes testes. Possíveis actividades incluem:

1) Exploração dos testes de física fundamental feitos pelo ESPRESSO como ferramentas para testes mais precisos de modelos de energia escura e do Princípio de Equivalência de Einstein;

2) Simulação de espectros de alta resolução obtidos com o ESPRESSO, e criação de catálogos de dados simulados para optimização de estratégias observacionais;

3) Planeamento e design experimental de futuros testes mais precisos, no contexto do ESPRESSO e dos instrumentos previstos para o ELT;

4) Organização e apresentação dos resultados obtidos.

Exemplos de bibliografia relevante para este projecto (alguma da qual resultou de estágios anteriores) incluem:

https://arxiv.org/abs/1704.08728 | https://arxiv.org/abs/1709.02923
https://arxiv.org/abs/1801.08089 | https://arxiv.org/abs/1902.02785
https://arxiv.org/abs/1903.04310 | https://arxiv.org/abs/1904.07896

Testes de modelos de energia escura a baixo e alto redshift

Orientador: Carlos.Martins@astro.up.pt

Local do Estágio: CAUP; dependendo do desempenho, o estágio incluirá também visitas de trabalho a colaboradores no estrangeiro e/ou deslocações a conferências para apresentação dos resultados.

Perfil do Candidato:
Experiência de programação, análise e visualização de dados é essencial. Experiência anterior com projectos deste tipo é valorizada. Espera-se uma dedicação ao projecto de pelo menos 6 horas de trabalho por semana, parcialmente presenciais. Poderá ser realizada uma entrevista aos candidatos.

Objectivos e Actividades:
O aluno será integrado num projecto internacional (PTDC/FIS-AST/28987/2017, Investigador Principal: Carlos Martins) que desenvolve estratégias observacionais optimizadas para a caracterização das propriedades da energia escura. Em particular, pretende-se alargar a gama de redshifts para os quais o comportamento gravitacional da energia escura é bem conhecido, graças a uma nova geração de instrumentos, tais como o Euclid, o E-ELT e o SKA, que possibilitarão também testes completamente novos.
Actividades específicas incluem:
1) Estudo semi-analítico de modelos com campos escalares para a aceleração do universo e das suas consequências observacionais;
2) Desenvolvimento de ferramentas estatísticas de comparação desses modelos com dados observacionais (cosmológicos e astrofísicos) actualmente existentes;
3) Aplicação destas ferramentas a modelos de energia escura e gravitação modificada, e modelação de estratégias observacionais para o estudo estes modelos com instrumentos futuros;
4) Organização e apresentação dos resultados obtidos.

Exemplos de bibliografia relevante para este projecto (alguma da qual resultou de estágios anteriores) incluem:
https://arxiv.org/abs/1601.02950 | https://arxiv.org/abs/1606.08380
https://arxiv.org/abs/1709.02923 | https://arxiv.org/abs/1801.08089
https://arxiv.org/abs/1806.07653

Understanding the planetary system Kepler-210

Level: Undergraduate

Supervisor: susana.barros@astro.up.pt

Candidate profile:

As the project includes the improvement of a codes written in Python, the successful candidate should have experience in programming or should be willing and motivated to learn the Python programming language.

Goals and activities:

The Kepler satellite has revealed that a large percentage of the known transiting exoplanets are in multi-planetary systems (â^¼40%). Multi-planetary systems are great laboratories to test theories of formation and migration of planetary systems.The objective of this project is to use an already existing to to model the transits and radial velocities of an interesting exoplanetary system with two planets to derive the mass and radius and hence the composition of both planets and a possible long period companion. Kepler-210 (KOI-676) hosts two transiting super-Earths with periods of 2.45 days and 7.97 days and radius of 3.75 RâŠ• and 4.78 RâŠ•. Analysis of the TTVs detected in both planets led to the prediction of the existence of a longer period and more massive companion with a period â^¼ 63 days and a mass of â^¼ 0.4 MJup (Ioannisdis et al 2014). The student will learn how to model exoplanet transits and radial velocity data and how to constrain multi-planetary system parameters.

What are HI profiles of cluster galaxies telling us?

Level: Undergraduate

Supervisor: Tom.Scott@astro.up.pt

Isolated late-type galaxies (LTGs) typically contain disks of rotating HI gas with diameters approximately twice the diameter of their stellar disks. Integrated HI spectra of these HI disks show the distribution of mass at different velocities. Large scale surveys of these HI spectra for isolated LTGs show their HI velocity profiles display a high degree of symmetry as measured by their A_flux parameter.

LTG HI disks are much more easily perturbed than their stellar counterparts. In galaxy clusters the higher density of galaxies makes it more likely that tidal interactions with other galaxies will disturb/and or remove their gaseous inter-stellar medium (including HI). Additionally, during their orbits in galaxy clusters, LTGs can also interact with a hot X-ray emitting gas, which pervades galaxy clusters and is known as the intra-cluster medium. This interaction, known as ram pressure stripping, can also disturb/ remove an LTG's HI. It is well established that these processes are responsible for the higher fraction of HI deficient LTGs observed in clusters compared to the field, although the relative importance of each mechanism is still debated. However, a recent study of Abell 1367 and Virgo in comparison to an isolated sample, indicated the mean A_flux of LTGs in a cluster maybe related to the cluster's dynamical state. Abell 1367 is a merging cluster and has the highest mean A_flux, which denotes more asymmetric HI profiles. In this project we aim to extend this study of A_flux to other nearby galaxy clusters with different dynamical states using archive HI spectra and python code developed in house.

Abell 262 is a cluster with significantly lower X-ray luminosity and velocity dispersion than Abell 1367 and Virgo thus providing a cluster with contrasting properties. For Abell 262 there is sample of about 30 HI spectra available. The project is to use the python code to measure various properties of these spectra, including A_flux, and then determine from the sample's statistics how likely it is that the mean A_flux is different to those for Abell 1367, Virgo and isolated samples.

APPENDIX

The CAUP Team, April 2019

Researchers [40]
Vardan Zh. Adibekyan
Doris Arzoumanian
Pedro P. Avelino
Susana C. C. Barros
Diego Bossini
Jarle Brinchmann
Tiago J. L. C. E. Campante
Leandro S. M. Cardoso
Vítor M. M. Costa
Margarida S. Cunha
António C. da Silva
Paulo Maurício de Carvalho
Morgan Deal
Elisa Delgado Mena
Olivier D. S. Demangeon
João P. S. Faria
Pedro Figueira
Daniel F. M. Folha
Jorge Filipe Gameiro
Jean Michel Gomes
João N. T. Gomes da Silva
Andrew J. Humphrey
M. S. Nanda Kumar
Maria Teresa V. T. Lago
Patricio Lagos
João J. G. Lima
Catarina Lobo
Jorge H. C. Martins
Carlos J. A. P. Martins
Mário J. P. F. G. Monteiro
Pedro M. Palmeirim
Polychronis Papaderos
Ivan Rybak
Nuno C. Santos
Tom C. Scott
Lara G. Sousa
Sérgio A. G. Sousa
Maria Tsantaki
Pedro T. P. Viana
Mathieu Vrard

Ph.D. Students [24]
Babatunde Akinsanmi
Raquel M. G. Albuquerque
Alexandros Antoniadis Karnavas
Rui P. L. Azevedo
Lupércio B. Bezerra
Iris P. Breda
João D. R. Camacho
José Ricardo Correia
Vasco M. C. Ferreira
Fábio A. R. Ferreira
Andressa C. S. Ferreira
Saeed Hojjatpanah
Ana C. O. Leite
Sandy G. Morais
Jason J. Neal
Benard Nsamba
L. Filipe Pereira
Pedro I. T. K. Sarmento
Luisa M. Serrano
Marckelson S. Silva
Guilherme D. C. Teixeira
Solène C. Ulmer-Moll
Bachar Wehbe
Paulina M. Zaworska

Junior Students [8]
Asier Anguiano Arteaga
Bianca R. Bomfim de Jesus
Thibault Boulet
Eduardo A. S. Cristo
Bernardo Dias
Stefano R. García Castañeda
Vasco Tavares
Tiago Teixeira

CAUP

Centro de Astrofísica da Universidade do Porto

Centro de Astrofísica da Universidade do Porto

U.PORTO

Rua das Estrelas
4150-762 Porto, Portugal
T. +351 226 089 830
geral@astro.up.pt

www.astro.up.pt
www.facebook.com/astro.up.pt
www.twitter.com/astro_up
www.youtube.com/cauptv