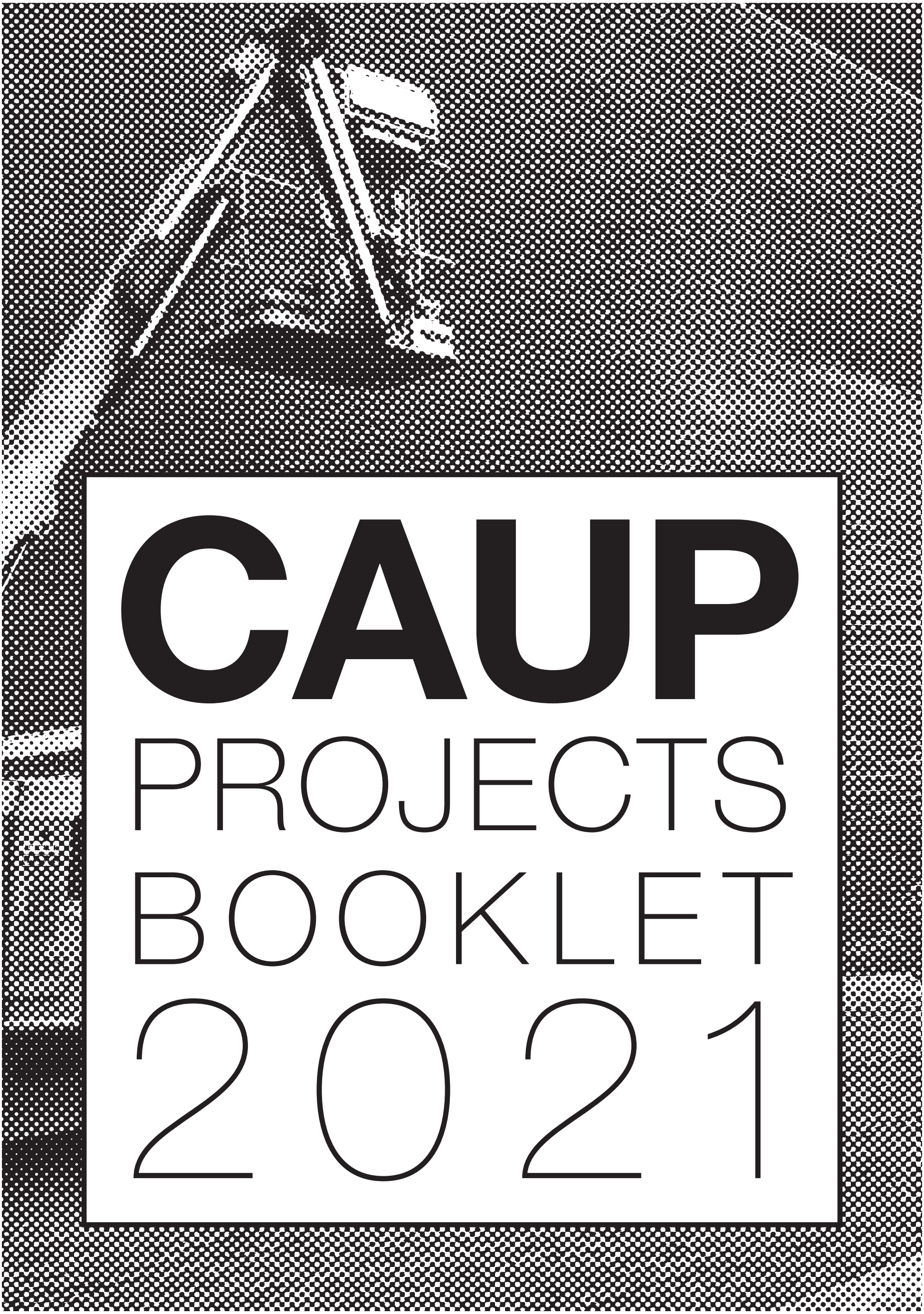

CAUP
PROJECTS BOOKLET
2021

CAUP PROJECTS BOOKLET 2021

INDEX

The CAUP Team, March 2021

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 2021-22.
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 doctoral programs such as IDPASC 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. In each section the projects are listed alphabetically by title. 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 2021

ESA and ESO related projects

Fundamental cosmology from precision spectroscopy: from ESPRESSO to the ELT

Level: PhD or MSc

Supervisor: Carlos.Martins@astro.up.pt

ESPRESSO is a latest-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. It is installed in the Combined Coudé 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. A key science driver of ESPRESSO is to perform improved tests of the stability of natureís 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 (and very significant) 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. The student, who should have a genuine interest and previous experience in experimental spectroscopy and astrophysical data analysis, will be working within the general framework of the ESPRESSO and ELT-HIRES science teams, and will also join the FCT-funded CosmoESPRESSO project.

Key relevant references are: Alves et al. PRD 97 (2018) 023522 & MNRAS 488 (2019) 3607, Martins Rep.Prog.Phys. 80 (2017) 126902 & A&A 646 (2021) A47, Martins et al. PRD 94 (2016) 043001, Martins & Vacher PRD100 (2019) 123514, Martins & Vila Minana Phys. Dark Univ. 25 (2019) 100301, Schmidt et al. A&A 646 (2021) A144, Vilas Boas et al. A&A 635 (2020) A80 , an dWilczynska et al. Sci.Adv. 6 (2020) eaay9672.

New Maps of the Dark Side: Euclid and beyond

Level: PhD or MSc

Supervisor: Carlos.Martins@astro.up.pt

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 increasingly 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 ELT-HIRES. More specifically, the work will be done in the framework of the Euclid TWG (who have already endorsed the project, and will provide a co-supervisor in due course). Thus the student will be a member of Euclid, as well as joining the FCT-funded CosmoESPRESSO project.

Key relevant references are: Alves et al. MNRAS 488 (2019) 3607, Amendola et al. LRR21 (2018) 2, Faria et al. A&A 625 (2019) A127, Fernandes et al. Phys.Dark Univ. 31 (2021) 100761, Marques & Martins, Phys. Dark Univ. 27 (2020) 100416, Martinelli et al. A&A 644 (2020) A80, Martins et al. PRD 94 (2016) 043001, Martins & Vacher, PRD 100 (2019) 123514, Tavares & Martins PRD103 (2021) 023525.

Other astrophysics projects

Activity-free radial velocities

Level: MSc
Supervisor: Joao.Faria@astro.up.pt

Finding an exoplanet like the Earth is complicated by the magnetic activity of the stars: spots and plages on the stellar surface can produce similar effects to those of planets, making it harder to disentangle the two signals. With the radial-velocity technique, we measure the stellar spectrum and how it changes due to the presence of the planet. The only clear difference between signals coming from stellar activity and planet is that stellar activity deforms the spectral lines while a planet only shifts them in wavelength.

This project will explore new methods to separate activity from planets in high-resolution spectra from the HARPS and ESPRESSO spectrographs. The student will study two complementary approaches: measuring RVs on individual spectral lines in order to discard those more affected by stellar activity, and mathematically decomposing the spectral line changes into radial velocity shifts and shape deformations.

Relevant references are Holzer et al. 2020, https://arxiv.org/abs/2005.14083 and Cretignier et al. 2020, https://arxiv.org/abs/1912.05192 We are looking for a candidate who is enthusiastic about learning and has good communication and organization skills. The project does not require prior knowledge of astronomy and/or exoplanets. The candidate is expected to have completed a numerical analysis course and have basic knowledge of a scientific programming language such as Python or C/C++.

Analytic Methods for Astrophysical Defect Fingerprinting

Level: PhD or MSc

Supervisor: Carlos.Martins@astro.up.pt

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 and gravitational wave observations shows how some of these scenarios can in principle be constrained by high-resolution data, but also highlight several bottlenecks which make current constraints unreliable. To fully exploit the potential of ESA facilities such as CORE and LISA, or of the SKA, 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, especially additional degrees of freedom on the defect worldsheets.

This thesis will address the latter, using a series of novel mathematical and statistical techniques, informed by the world's most accurate defect simulations (being done by the supervisor's team) to build upon the successes of the canonical VOS model of Martins & Shellard to develop a new generation of accurately calibrated analytic models for general defect evolution as well as for their astrophysical fingerprints, which is able to match the sensitivity of ongoing and future observational searches and yield reliable constraints. The student will join the FCT-funded CosmoESPRESSO project and will also be a member of a recently approved Paris-Porto-Cambridge exchange grant.

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 PRD 100 (2019) 103517, Martins & Cabral PRD 93 (2016) 043542, Martins et al. PRD103 (2021) 043538, Rybak et al. PRD96 (2017) 103535 & PRD99 (2019) 063516, and Vieira et al. PRD 94 (2016) 096005.

Coding the Cosmos: Simulating Superstrings in the GPU Era

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

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 provide a unique window into the early universe and possibly string theory. Recent progress in CMB polarization and gravitational wave detection highlights how some of these scenarios could be constrained by high-resolution data. However, they also show that the current bottleneck is the lack of accurate high-resolution simulations of defect networks that can be used as templates for robust statistical analysis, implying that none of the current constraints is reliable. This will be an even bigger problem for next-generation facilities such as CORE and LISA. Moreover, most numerical simulations so far have been performed for the simplest Abelian-Higgs (or Nambu-Goto) model, while realistic cosmic strings will have non-trivial internal structure, including charges and currents.

The scientific goal of the thesis is to fill this gap, continuing the deployment of a new generation of high-scalability defect evolution codes that will match the sensitivity of ongoing and forthcoming observational searches, and using them to develop and calibrate suitable analytic models. It will use both CAUP computational resources (including a GPU donated by NVIDIA) and world-leading HPC facilites accessed through PRACE. The student should have an interest and relevant previous experience in computational physics, data analysis and visualisation. Experience of parallel and/or GPU programming would also be highly beneficial. The student will join the FCT-funded CosmoESPRESSO project and will also be a member of a recently approved Paris-Porto-Cambridge exchange grant.

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 Ach˙carro et al. Phil. Trans. Roy. Soc. Lond. A 377 (2019) 2161.0004, Correia & Martins PRD100 (2019) 103517, PRD102 (2020) 043503 & Astron.Comput. 34 (2021) 100438, Lazanu et al. PLB B747 (2015) 426, Martins et al. PRD103 (2021) 043538, Rybak et al. PRD 96 (2017) 103535 and Vieira et al. PRD 94 (2016) 096005.

Do binary stars form as frequently in dark matter dominated galaxies as in normal ones?

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

The MUSE-Faint survey is a large survey using the MUSE instrument on the VLT to study the most dark-matter dominated galaxies in the Universe: ultra-faint dwarfs. These systems are nearly completely dominated by dark matter but they do contain stars. We know relatively little about their stellar populations and next to nothing about the frequency of binary stars in them: are they as common as we see in the Milky Way or was the high density of dark matter an impediment to their formation? This project aims to answer this question.

The binary stars are also crucial for determinations of dark matter content in these galaxies – they act as noise sources in these estimates. A second goal of this project will be to assess the importance of the binary stars identified for constraints on dark matter properties using MUSE-Faint data.

Helio/Asteroseimic tests of the new solar abundances

Level: MSc
Supervisor: Morgan.Deal@astro.up.pt
Co-supervisor: Diego Bossini

Beside influencing our planet and the solar system, the Sun is our only true point of reference to look at for studying the other stars. Nevertheless, many of its aspects still nowadays remain uncertain. In this project we will focus in one of the hot-topic issue in solar and stellar physics, i.e. the solar composition. Its correct determination is crucial for modelling not only the Sun, but also all the other stars.

In the 90's the GN93 (Grevesse & Noels 1993) or GS98 (Grevesse & Sauval 1998) solar abundance mixtures made the standard solar models successful, leading to an excellent agreement between helioseismology (study of the oscillation of the Sun, similar to seismology on Earth) and solar models. More recently, new solar abundances came out (Asplund et al. 2009, Caffau et al. 2011), these abundances were determined using 3D atmospheres simulations. With these solar mixtures, the agreement between solar models and helioseismology was not as good as before, leading to the so-called solar abundances problem.

New solar abundances will be soon released and the aim of this project is to determine how they compare to the other ones for solar models, and what is the impact of these new abundances on the characterization of other stars observed by the Kepler/NASA space mission. This work will also be interesting in the context of the scientific preparation of the future PLATO/ESA space mission.

Observational constraints on magnetic properties of solar-type stars

Level: PhD
Sipervisor: Ângela Santos (sangel3@gmail.com)
Co-supervisors: Margarida Cunha, Tiago Campante

In this project, we propose to determine properties of surface rotation and magnetic activity of solar-type stars (spectral types from mid-F to M) observed by the NASA Kepler satellite. We will obtain constraints on surface differential rotation, which has been revealed as a non-trivial measurement to be made from spot modulation of stellar light curves. Differential rotation is, however, key for the generation of magnetic fields and magnetic cycles. Therefore, such constraints will be important to inform magnetic-generation models and better understand stellar magnetism. Attempts have been made to detect and characterize activity cycles in solar-type stars observed by Kepler. However, activity cycles have been unambiguously detected only for a small number of stars. In this project, we will use the long-term brightness variations due to dark magnetic spots to search for activity-cycle candidates and constrain properties related to stellar dynamo processes.

At least three scientific papers are expected from this project:
1) testing and validation of the technique to determine differential rotation;
2) measurements of the amplitude and signal of differential rotation of solar-type stars observed by Kepler and how these properties depend on other stellar properties; and,
3) validation of the technique, detection of activity cycles in solar-type stars, and determination of the dependence of cycle period and strength on other stellar properties.

Probing the invisible: inferring the far UV emission in galaxies from optical and UV emission lines

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

The spectra of galaxies are replete with emission lines that provide essential information on the physical conditions in the (mostly ionized) gas within galaxies. The modeling of these emission lines has a long history and the technique of photoionization modeling has become a cornerstone of astrophysics. These models rely on knowing the far-UV (20-90nm) ionizing spectra of the sources lighting up the gas, but this part of the spectrum of a star has only been observed directly for only 3-4 stars and it is a major uncertainty for the interpretation of the spectra of distant galaxies. In this project you will develop methods to place strong constraints on the shape of the ionizing spectrum of stars from the observation of the emission lines they give rise to, basically see the invisible, and help settle this debate.

The basis for this project is that we now have a wide range of galaxies with spectra covering both the UV (120-300nm) and optical (350-1000nm) regions which originate from transitions that require different energies for the excitation or ionization. In this project you will develop methods, building on previous work in the literature such as e.g. Zastrow, Oey & Pellegrini (2013, APJ, 769), but now combining optical and UV data and aimed to tackle not only HII regions but also galaxies.

The models will be used to constrain the ionizing spectrum in nearby galaxies from the CLASSY survey with HST, as well for the future interpretation of data on higher redshift galaxies, combining MUSE, Euclid, MOONS and 4MOST data. The end result of the thesis will be a systematic study of the ionizing spectra of stars & galaxies as a function of metallicity and redshift.

SOAP+: modelling active region evolution

Level: MSc
Supervisor: Joao.Faria@astro.up.pt

The SOAP code allows us to simulate the effects of stellar activity in radial velocity and transit observations. It was developed to understand the impact of stellar noise in the data we use to search for exoplanets. This project aims to extend SOAP with an important missing feature: the ability to simulate the evolution of active regions during the magnetic cycle of the star. The inclusion of this effect will allow us to create realistic simulations of Sun-like stars and M dwarfs, to study how stellar activity can be corrected in order to allow for the detection of low-mass planets like the Earth.

A relevant reference is Dumusque, Boisse, Santos 2014, https://arxiv.org/abs/1409.3594 We are looking for a candidate who is enthusiastic about learning and has good communication and organization skills. The project does not require prior knowledge of astronomy and/or exoplanets. The candidate is expected to have good knowledge of a scientific programming language such as Python or C/C++.

The computational backbone for the discovery of Earth-like planets

Level: PhD
Supervisor: Joao.Faria@astro.up.pt
Cos-supervisor: Pedro Viana

Over the past 25 years since the first discovery, approximately one exoplanet has been discovered every two days. This incredible success stems, in great part, from dedicated photometric and spectroscopic surveys providing transit and radial velocity detections. Despite this, it is still very challenging to detect the small low-mass planets similar to the Earth that may have favourable conditions for life. Part of the difficulty resides in the host stars themselves and the effects of their magnetic activity, which can easily hide or even mimic true planetary signals.

This project aims to develop a holistic approach to mitigate the effects of stellar activity and to improve the planet detection capabilities of future surveys. The student will approach the problem from a computational perspective by developing a physically motivated model for the joint analysis of photometric and spectroscopic data, thereby constraining not only the parameters of the planetary system but also those of the host star. In part, the model will consist of standard modules for the calculation of orbits and observable effects, but it will also include information on the already-known population of planets. This information will be used within a hierarchical model, using what we already know about the full exoplanet population to improve the constraints imposed on each of the individual planetary systems. Moreover, recent developments in Bayesian statistical inference will be incorporated into the approach ab initio, such as the use of dedicated Gaussian process kernels or Bayesian decision theory.

At the end of the project, the student will have developed new techniques to fully exploit the high-precision data becoming available from planet-finding instruments such as ESOís ESPRESSO spectrograph and ESAís CHEOPS and PLATO missions.

The enigma of Li-rich giants and its relation with stellar activity

Level: MSc
Supervisor: Elisa.Delgado@astro.up.pt
Co-supervisor: Joao Gomes da Silva

Although the relationship between lithium abundance in stars and their magnetic activity is commonly accepted, it is still unclear how the different phenomena related to it can increase the amount of Li, reduce its depletion, or be a source of bias for the measurements. Several works have found a correlation between stellar activity signals, such as spots, with the variability of Li abundances, especially in young and active dwarf stars.

We propose to study the correlation of Li abundances with stellar activity in a sample of young but evolved stars (intermediate mass red giants), for which we have observed enhanced Li abundances. This kind of stars that have atypical high Li abundances are called Li-rich giants and it is still not clear if the Li enhancement is produced by nuclear reactions within the stars or can be of external origin such as caused by planetay engulfment.

The goal of this project is to determine Li abundances, stellar activity indicators (such as Halpha emission) and effective temperature variations in a sample of red giants where planets have been searched. These stars have been observed during several years and thus we can study the temporal variation of the previously mentioned parameters and their possible correlations with radial velocity variations and brightness variations. The results of this project will shed some light on the origin of stellar activity (e.g. spots) and its duration across rotational periods of the stars.

Tracing the distribution of metals in galaxies across cosmic time

Level: PhD

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

The abundance of heavy elements in a galaxy provides a record of the past history of star formation and death in that galaxy. The distribution of metals within the galaxy, usually summarised by the metallicity gradient, provides a more detailed look at how metals and star formation has been distributed within galaxies over time. Despite this central role, we have a very patchy picture of how this has evolved along cosmic time.

In the coming years there will be a massive influx of resolved data on distant galaxies that will allow us make big strides forwards here, but to do so it is necessary to develop new methods to combine space- and ground-based data. This PhD project will develop the necessary forward modelling tools to combine the future state-of-the-art space- and ground-based data and use data from MUSE, HST, JWST and Euclid to build up a picture of how metallicity gradients in galaxies have been built up.

Education, outreach and undergraduate projects

Asymmetric radial velocities for the detection of exoplanets

Orientador: Joao.Faria@astro.up.pt

Perfil do Candidato:
The project does not require prior knowledge of astronomy and/or exoplanets. The candidate is expected to have basic knowledge of numerical methods and computer programming (with preference for the Python language).

Objectivos e actividades:
On the quest for an Earth-like exoplanet, one big obstacle is the host star itself: active regions on the stellar surface can produce similar effects to those of planets, making it harder to observationally disentangle the two signals. With the radial-velocity technique, we measure the stellar spectrum and how it changes due to the presence of the planet. The only clear difference between signals coming from stellar activity and planets is that stellar activity deforms the spectral lines while a planet only shifts them in wavelength.

This project aims at finding new ways to measure those deformations of the spectral lines, with the ultimate goal of discovering new diagnostics for stellar activity. To do this, the student will focus on the cross-correlation function (CCF), which represents an average spectral line, and will test different asymmetric functions to fit observed CCFs of active stars. Using data from the HARPS and ESPRESSO spectrographs, this analysis will help develop new corrections for stellar activity, which can open the door for the detection of low-mass planets. A relevant reference is Simola et al. 2018, https://arxiv.org/abs/1811.12718

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 preferęncia a alunos de mestrado de ensino. Experięncia prévia de programaįão, análise e visualizaįão de dados é útil. Espera-se uma dedicaįão 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 investigaįão científica financiado pela FCT que inclui uma componente (com orįamento prķprio) de educaįão e divulgaįão 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 colaboraįão com os investigadores e alunos de doutoramento da equipa científica do projecto e com professores de escolas secundárias parceiras do projecto;
3) Implementaįão destes conteúdos em pequenos grupos de alunos do ensino secundário das escolas parceiras;
4) Organizaįão e publicaįão destes conteúdos, e dos resultados obtidos.

Espera-se que os resultados do estudo sejam apresentados, entre outros locais, no Encontro Nacional de Astronomia 2022.

Developing a new tool for the estimation of spectroscopic redshifts for the MOONS/VLT spectrograph

Orientador: Jean Michel Gomes (jean@astro.up.pt)

Perfil do Candidato:
Candidates in areas related to astronomy/astrophysics. Not necessary any background in extragalactic courses. Knowledge on Python computing language.

Objectivos e Actividades:
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 a Python redshift tool, for the assessment of spectroscopic redshifts of galaxies. Additionally, we aim at furnishing 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 determinations and tools available; ii) The student will learn the foundations of a redshift tool, help to develop it and test on large galaxy samples; iii) The student will apply the new redshift tool to a mock-galaxy catalog with redshifts up to 4 and determine the redshift confidence levels as a function of Signal-to-Noise and star formation history; iv) The student will apply the newly created redshift tool 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 as a function of Signal-to-Noise, star formation history and redshift.

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 provectos 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 projeto 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 pelo instrumento ELT-HIRES, cuja Fase B de construção está em curso. 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 possíveis estratégias observacionais do ELT-HIRES;
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/1709.02923 | https://arxiv.org/abs/1902.01783
https://arxiv.org/abs/1907.05151

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 2022.

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

Supervisor: Jean Michel Gomes (jean@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:

Preferable computing languages are Fortran & Python.

Objectivos e Actividades:

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.

In this project, the student will study, implement and test distinct model predictions for the extinction and emission of dust grains, for instance, models available in the literature, such as Desert et al. (1990), Draine & Li (2001,2007), Compiegne et al. (2011), Jones et al. (2013) and Koehler et al. (2014).

Scientific literacy and astronomy teaching

Level: PhD or MSc

Supervisor: Carlos.Martins@astro.up.pt

We have previously 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 caracterizajão 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 vídeos 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/1911.03163 | https://arxiv.org/abs/2005.14454
https://arxiv.org/abs/2007.12008 | https://arxiv.org/abs/2011.09700

Solving Kepler's equation

Orientador/Supervisor: Joao.Faria@astro.up.pt

Perfil do candidato:
The project does not require prior knowledge of astronomy and/or exoplanets. The candidate is expected to be comfortable with a scientific programming language such as Python or C.

Objectivos e actividades:
Because exoplanets follow elliptical orbits around their stars, Kepler's laws of motion can be used to calculate the velocity of the host star along the line of sight. This quantity is known as the radial velocity (RV) and can be measured by observing the stellar spectrum. However, the theoretical calculation of the RV for a given planet involves one particularly interesting step: finding a solution for Kepler's equation $E = M - e \sin(E)$. Although it may look simple, this equation cannot be solved (for E) analytically, which has led to the development of a number of different numerical algorithms.

In this project, the student will study the numerical solution of Kepler's equation by implementing and comparing different algorithms. The solutions will be thoroughly tested and the performance of each method will be measured using real RV observations. We will also explore the use of Graphics Processing Units (GPUs) to develop more efficient methods for repeatedly solving Kepler's equation. These new methods will allow us to efficiently analyse RV datasets with thousands of observations and to predict the best future times to obtain new measurements.

Testes astrofísicos da física fundamental

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 estudar as consequências observacionais de modelos cosmológicos inspirados em teoria de cordas ou gravitação quântica, graças a uma nova geração de instrumentos, tais como o Euclid, o ELT e o SKA, que alargarão a gama de redshifts para os quais o comportamento gravitacional da energia escura é bem conhecido e possibilitarão também testes completamente novos. Actividades específicas incluem:
1) Estudo semi-analítico de modelos de física fundamental baseados em campos escalares ou outros graus de liberdade 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/1806.07653 | https://arxiv.org/abs/1905.02792
https://arxiv.org/abs/1911.08232 | https://arxiv.org/abs/2001.09129
https://arxiv.org/abs/2012.10513 | https://arxiv.org/abs/2101.08584

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/1709.02923 | https://arxiv.org/abs/1801.08089
https://arxiv.org/abs/1911.10821 | https://arxiv.org/abs/2003.07627
https://arxiv.org/abs/2012.10505 | https://arxiv.org/abs/2101.08584

APPENDIX

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