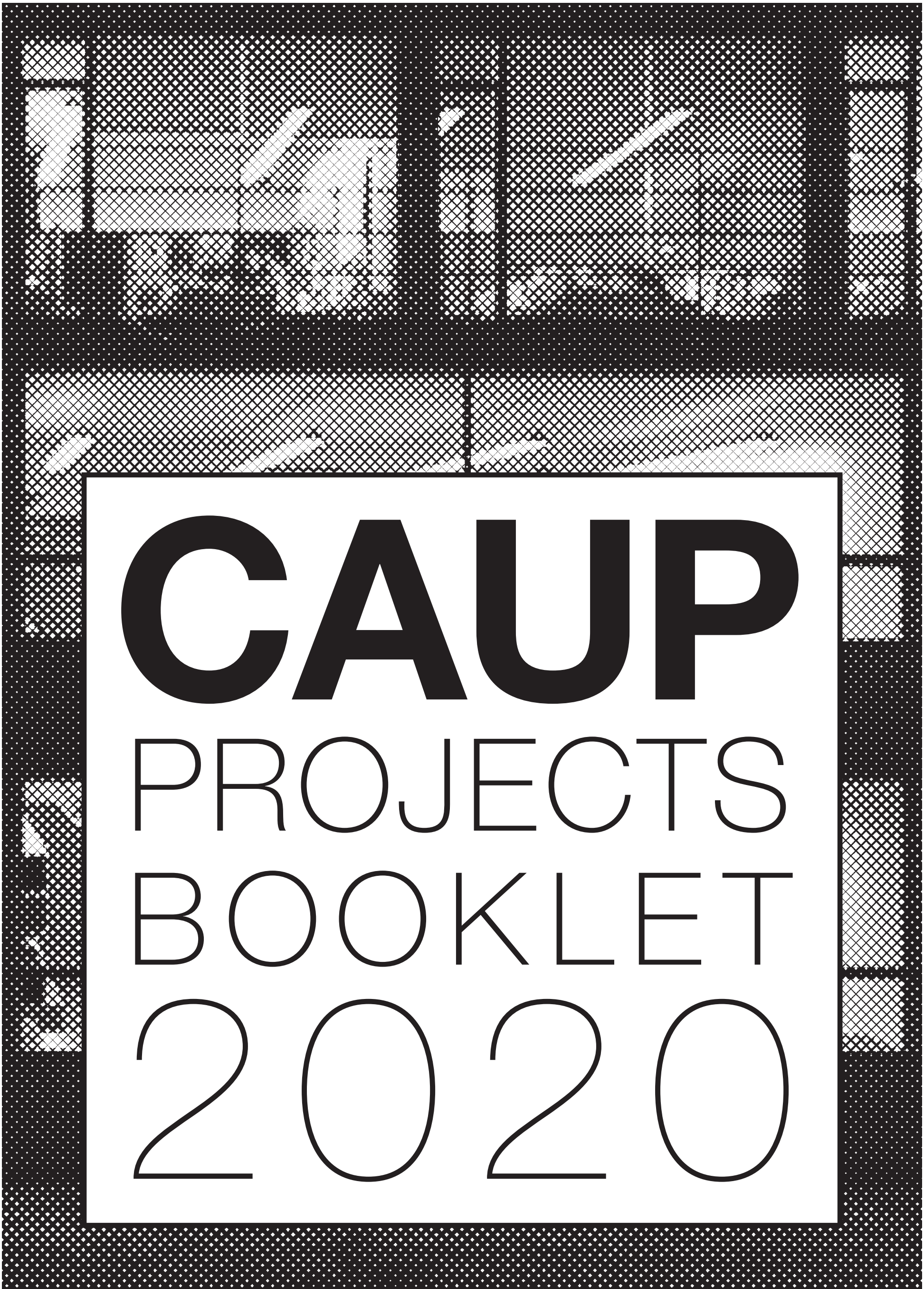

CAUP

PROJECTS BOOKLET 2020

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The CAUP Team, March 2020

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 2020-21.

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 and PhD::SPACE 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 2020

ESA and ESO related projects

Composition of Earth-size planets

Level: PhD or MSc
Supervisor: Susana.Barros@astro.up.pt
Co-supervisor: Olivier Demangeon

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.

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

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

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. It is 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 natureís fundamental couplings, and in particular to confirm or rule out the recent indications of dipole-like variations of the fine-structure constant.

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. PRD 97 (2018) 023522 & MNRAS 488 (2019) 3607, 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 94 (2016) 043001, Martins & Prat Colomer PLB 791 (2019) 230, Martins & Vila Miñana Phys. Dark Univ. 25 (2019) 100301, and Pinho et al. PLB769 (2017) 491.

Mitigate stellar activity to characterise Earth-size planets

Level: PhD

Supervisor: Susana.Barros@astro.up.pt

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.

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 incompleteóif not incorrectóand 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: Alves et al. MNRAS 488 (2019) 3607, Amendola et al. LRR21 (2018) 2, Calabrese et al. PRD 89 (2014) 083509, Faria et al. A&A 625 (2019) A127, Marques & Martins, Phys. Dark Univ. 27 (2020) 100416, Martins et al. PRD 93 (2016) 123524 & PRD 94 (2016) 043001, Martins & Prat Colomer A&A 616 (2018) A32, Martins & Vacher, PRD 100 (2019) 123514.

Other astrophysics projects

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 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 PRD 100 (2019) 103517, 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

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 et al. JCAP 1508 (2015) 047, Martins & Vacher, PRD 100 (2019) 123514, and Will LRR 17 (2014) 4.

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 thus 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 can 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. This will be an even bigger problem for next-generation facilities such as CORE and LISA. This thesis will continue the recently started deployment of a new generation of high-scalability GPU-accelerated defect codes that will match the sensitivity of ongoing and forthcoming 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: Achúcarro et al. Phil. Trans. Roy. Soc. Lond. A 377 (2019) 2161.0004, Correia & Martins PRE 96 (2017) 043310, arXiv:1809.00995 & PRD 100 (2019) 103517, Lazanu et al. PLB B747 (2015) 426, Martins et al. PRD 93 (2016) 043534 & PRD 94 (2016) 116017, Rybak et al. PRD 96 (2017) 103535 and Vieira et al. PRD 94 (2016) 096005.

Density amplification at filament junctions and massive star formation

Level: PhD or MSc
Supervisor: Nanda Kumar (nanda@astro.up.pt)

Gravitational collapse of cold, dense gas in the interstellar clouds lead to star formation. How does this collapse produce low mass stars is fairly well understood. A prototypical star form-ing region such as the Orion Nebula or Rosette Nebula will display a spectrum of objects from 0.1 to 100Msun. How does the same cloud produce this spectrum of objects, especially those stars that are 50-100 Msun is the main puzzle that is yet to be understood. We have recently shown that all known massive star formation take place in pockets of highly amplified densities and mass, that occur at junctions of filaments. There is much evidence that these density amplified pockets are capable of driving longitudinal flows of gas, allowing gravity to dominate over turbulence. Magnetic fields are expected to further aid and modify the physical conditions within these pockets.

The goal of this thesis project is to investigate the properties of the density amplified regions, to understand its physics and how it impacts the formation of the most massive monstrous stars of our Galaxy. Using a variety of observational tools and methods, we want to under-stand the density and kinematic structure, role of magnetic field and turbulence, and the mass function of objects that such regions produce.

The candidate student should demonstrate a solid understanding of undergraduate level physics, chemistry and mathematics, a flair to study star formation, a willingness to under-take scientific adventures behind computer displays and on top of the worlds high-rise mountain observatories. During the PhD, the student will specialize in reduction and analysis of sub-millimeter and infrared data, both from single telescopes and interferometer arrays

Determination of age and mass for seismic stars in the ARIEL input catalog

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

An accurate and precise determination of the fundamental properties of host stars is a crucial step towards a comprehensive characterization of their planetary systems. However, such quantities are usually found in the literature as the result of a case-by-case analysis performed by different teams. We aim to combine spectroscopic (Teff and metallicity) and photometric constraints obtained from well established sources, coupled with precise astrometric parallaxes from Gaia satellite. The result will be a homogeneous catalog of ages and masses of exoplanet-host stars which are currently listed as targets for ARIEL* (ESA's future space mission).

The student will participate to this analysis studying a sub-sample of 9 stars for which asteroseismic measurements are also provided. Asteroseismiology, i.e. the study of stellar oscillations, has been fueled by the wealth of high-quality data provided by CNES/ESAís CoRoT and NASAísKepler/K2 satellites and is now making possible to estimate stellar properties with unprecedented precision. During the project, the student will learn to interpreter observational data from many sources in order to characterize individual stars. He/she also familiarizes with our pipeline, named PARAM, that makes use of Bayesian methods to estimate stellar fundamental properties (.g., age, mass, and radius), by matching a set of observational constraints to a pre-computed grid of stellar evolutionary models. The results of this work are expected to appear in a publication leaded by the proponent of this project.

How rare is the Earth and the Solar System architecture?

Level: PhD or MSc

Supervisor: Pedro Viana (viana@astro.up.pt)

Co-supervisor: Olivier Demangeon

The estimation of how rare Earth-like planets are, as well as planetary systems similar to our own, requires the joint statistical characterisation 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. And 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 student will use advanced statistical and machine learning techniques, namely Hierarchical Bayesian Modelling, Approximate Bayesian Computation, Importance Sampling and Gaussian Processes, to characterise 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 analysed 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 characterised through simulations.

The scope of the project will be adapted depending on whether it is chosen by a Master or a PhD student.

Probing the architecture of multi-planetary systems

Level: PhD or MSc
Supervisor: Susana.Barros@astro.up.pt
Co-supervisor: Olivier Demangeon

The Kepler satellite has revealed that a large percentage of the known transiting exoplanets are in multi-planetary systems (ca. 40). 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.

Star-formation history and chemical evolution of LSB and BCD galaxies

Level: MSc
Supervisor: Patricio.Lagos@astro.up.pt
Co-supervisor: Tom Scott

Dwarf galaxies (low luminosity, low mass and small sizes compared to normal massive galaxies) are the most numerous galaxies in the Universe. The less chemically evolved of these systems are of special importance, since they are the closest analogues of the low-mass galaxy building blocks that are thought to have formed in the early Universe. Several evolutionary scenarios suggest that some types of dwarf galaxies form an evolutionary sequence. Such a sequence would require a substantial loss or redistribution of angular momentum, which could potentially be driven by interactions and/or accretion. From the literature we have compiled a sample of low surface brightness dwarf (LSBD) and blue compact dwarf (BCD) galaxies and our analysis indicates the properties of these two classes of star-forming dwarfs, including angular momentum, are distinctly different.
BCDs are characterized by low stellar mass, low luminosity, low chemical abundances, intense star-formation (SF) activity in compact physical sizes and faint blue optical continua. LSBDs also have blue colors but only low level on-going SF. LSBDs typically have a high HI mass to luminosity ratio but a central low surface brightness, indicating that to date they have been unable to transform a significant fraction of their gas to stars. For both classes of dwarfs blue colors indicate the presence of a relatively young stellar component although more evolved underlying stellar populations are also present (e.g. BCDs: Papaderos et al. 1996, LSBDs: van Zee et al. 1997). For LSBDs this suggests low intensity SF during several Gyrs and for BCDs that they are currently undergoing an intense SF episode after a long quiescent period.
Critical tests of the hypothesis that BCDs are evolved LSBDs are comparisons of their gas kinematics, chemical (oxygen abundance) distribution and most critically SF histories (SFHs). Recently, we observed the LSBDs UGC695 and J0015+0104 using SALT/RSS long-slit spectroscopy to which we will apply spectral synthesis codes to extract their SFHs for comparison to BCDs. Our immediate objectives, in this project, are: 1) Chemical Evolution: N2 (e.g., Denicolo et al. 2002), R23 (e.g., Kobulnicky et al. 1999) and direct (T_e) methods will be used to infer the oxygen abundance profiles. These observations will provide valuable information on the degree of homogeneity of the ISM (Lagos & Papaderos 2013, Lagos et al. 2018); 2) LSBD SFHs: The key to understanding the evolution of LSBDs and BCDs are their SFHs. Applying population synthesis codes (eg., Starlight, Cid Fernandes et al. 2005 and FADO, Gomes & Papaderos 2017) to the SALT spectra provide much more reliable SFHs for LSBs than photometric based SFHs (van Zee et al. 1997, Bell et al. 2000, Schombert et al. 2015); 3) LSBD kinematics: Halpha and stellar kinematic profiles will provide key information on the SF process and mass distribution within LSBDs.

The role of feedback of massive stars on star formation

Level: PhD
Supervisor: Pedro.Palmeirim@astro.up.pt
Co-supervisor: Nanda Kumar

This PhD project aims to understand how the impact of feedback from massive stars can enhance or disrupt star formation by performing a detailed study of the star formation rate and efficiency in HII regions.

For this purpose, nearby (<3kpc) HII regions will be selected from the large sample studied by the supervisor. The PhD student will conduct a variety of observations: Sub-millimetre continuum observations (Herschel) to probe the cold gas compressed in the shell and how it fragments into cores and protostars; IR observations (Spitzer, 2MASS and the upcoming JWST) to analyse the more evolved YSO population; single-dish millimetre observations to analyse the velocity dispersions in the dense part of the shell structure and constrain the level of infall motions onto the dense cores.

Follow-up high-resolution interferometric observations with ALMA, SMA or IRAM PdB based on the selection of massive dense cores in HII regions are foreseen.

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.

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/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.

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/1911.03163

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/1903.04310 | https://arxiv.org/abs/1904.07896
https://arxiv.org/abs/1911.10821 | https://arxiv.org/abs/2001.01787
https://arxiv.org/abs/2003.07627

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/1806.07653
https://arxiv.org/abs/1905.02792 | https://arxiv.org/abs/1911.08232
https://arxiv.org/abs/2001.09129

APPENDIX

The CAUP Team, March 2020

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