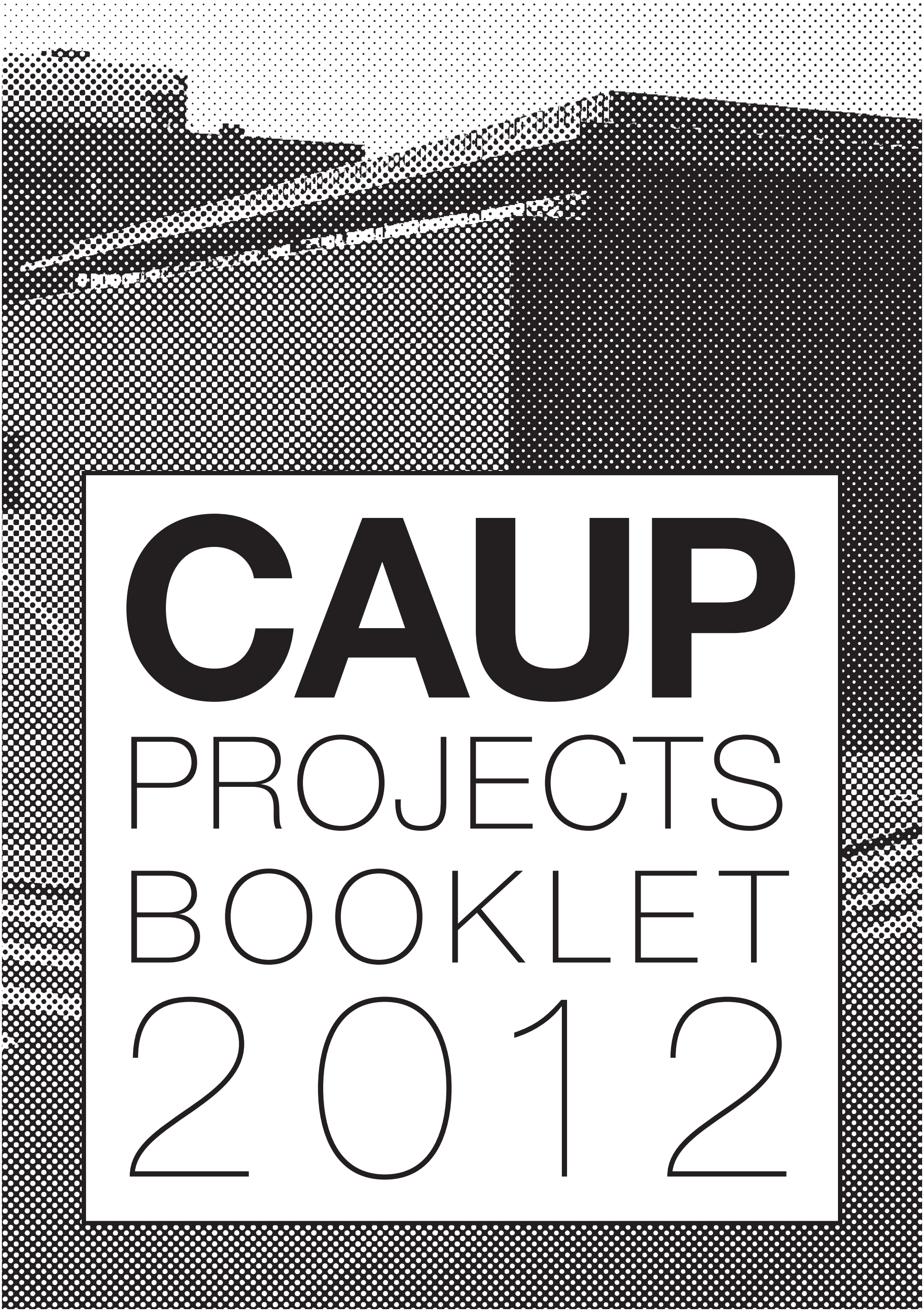

CAUP
PROJECTS BOOKLET 2012

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INTRODUCTION

CAUP is the largest Astronomy research institute in Portugal, with maximum marks in the International Research Assessments in the last 10 years. In its relatively short existence it has provided several world-leading contributions to Astronomy and Astrophysics. As part of our commitment to leadership and excellence, we hereby release a list of research projects proposed by CAUP members as possible Masters or PhD theses in the academic year 2012-13.

We start by listing projects done in the context of our participation in ESA and ESO consortia, since leading the national participation in such consortia is one of our long-term strategic priorities. Other projects from CAUP's two research teams are listed subsequently. These tend to represent more specific interests of individual members, although in some cases they also involve non-CAUP collaborations (and external co-supervision).

As an appendix we also list the current CAUP research team and a list of grants that are expected to be the backbone of our research funding in the next academic year. Additional information, including the research interests and recent publications of CAUP members and the scientific goals of the research grants, can be found online at http://www.astro.up.pt.

Although the list is representative of our current interests and priorities, it's by no means exhaustive. Many CAUP members have sufficiently broad interests and expertise to be able to supervise other projects. Any potentially interested student is therefore encouraged to contact us to explore further possibilities.

Carlos Martins
(Head of the CAUP Training Unit)
May 2012

Characterizing dark energy with Euclid data on galaxy clusters

Level: PhD
Supervisor: Pedro Viana

Clusters of galaxies are the largest gravitationally bound structure in the Universe. Their properties shed light not only on the physical processes that have been responsible for the formation and evolution of the large-scale structures in the Universe, but also on its overall dynamics. It is for this reason that clusters of galaxies have been identified within the context of the ESA mission EUCLID, to be launched in 2019, as one of the probes that has greatest potential in helping identify the physical reason why the Universe is now in a state of accelerated expansion. This project will contribute to this aim through the development of methods to be applied to EUCLID data, which make use of the properties of clusters of galaxies. In particular, it would be interesting to determine to what extent data on clusters of galaxies acquired by other means, for example through the ESA X-ray observatory XMM-Newton, could enhance the power of such methods. CAUP is an affiliated institute of the EUCLID Consortium. It will be actively involved both in the pre-launch development of the EUCLID mission and in the post-launch exploitation of the EUCLID data. It is expected that the student will get involved in the activity of the Euclid Science Working Group on Clusters.

Direct Detection of Extra-solar planets with ESPRESSO

Level: Masters
Supervisor: Pedro Figueira
Co-supervisor: Nuno Santos

The number of known Extra-Solar Planets has increasing steadily since the first was found, in 1995 and its research is now a very fast-paced domain in astrophysics. Yet, and in spite of many attempts, the direct detection of the visible spectra of an exoplanet has remained illusive. With a new generation of instrumentation on large-area telescopes, this objective might be finally within reach. In this master project we propose to simulate a planetary spectra as it will be recorded by the forthcoming ESPRESSO spectrograph and test its detectability, using cross-correlation techniques.
The candidate is expected to know the basics of extrasolar planets, be highly motivated and proficient in computer programming languages (e.g. python, c).

Fundamental Cosmology with Euclid

Level: Masters or PhD
Supervisor: Carlos Martins
Co-supervisor (at PhD level): Yves Zolnierowski (Annecy)

Euclid is an ESA medium-class mission, due to be launched in 2019, whose main goal is to understand the physical origin of the accelerated expansion of the universe.
CAUP is an affiliated institute of the Euclid Consortium and is actively involved both in the technical preparation and in the scientific exploitation of the mission. This project will contribute to the latter.
The main goal will be to carry out a detailed assessment of Euclid as a precision tool for consistency tests of the LambdaCDM paradigm and for searches for new physics. Inter alia, we will explore possible synergies with ground-based spectrographs such as ESPRESSO and CODEX. The work will be done in the context of the Euclid Science Working Groups.

Probing Fundamental Physics with ESPRESSO and CODEX

Level: Masters or PhD
Supervisor: Carlos Martins
Co-supervisor (at PhD level): TBA (non-CAUP)

ESPRESSO (under construction) and CODEX (under study) are two ESO spectrographs, respectively for VLT and the E-ELT, which have as one of their key science goals the search for evidence of spacetime variation of the fundamental constants of nature. In the case of CODEX, a further goal is to carry out a first measurement of the cosmological redshift drift (a.k.a. the Sandage-Loeb test).

This project will carry out a detailed assessment of the requirements and sensitivity of the two spectrographs for these purposes, and of the impact that these measurements will have as probes of fundamental physics, including the key conundrum of dark energy. The student will also have the opportunity to exploit data from the ongoing ESO UVES Large Program for Testing Fundamental Physics.

The project may have a more theoretical or a more observational focus, depending on the background and interests of the student, and a (foreign) co-supervisor will be chosen accordingly in due course.

Weak Lensing–CMB correlations and forecasts for Euclid and Planck

Level: Masters or PhD
Supervisor: Antonio da Silva
Co-supervisor: Ismael Tereno (CAAUL)

Our understanding of the Universe critically depends on untested assumptions about its origin, the nature of gravity, and also on the existence of dark energy (DE) and dark mater (DM), whose nature and dynamics are unknown to Cosmology and Theoretical Physics. These components cannot be observed directly but leave their imprint on the dynamical properties of visible matter and light. For example, DE is responsible for the accelerated expansion of the universe, whereas DM exerts gravitational attraction that can bend light from faraway objects but does not emit or absorb any radiation. The Planck and Euclid space missions are flagship experiments of ESA designed to address these major scientific unknowns. Planck is presently observing the sky for the relic photons of the Big Bang, the Cosmic Microwave Background (CMB) radiation. Euclid is ìtheî future cosmology mission (to be launched by 2019) to observe lensing deflections of light from galaxies, caused by the distribution matter in the Universe. The main objective of this project is to participate in the preparation of the scientific exploitation of Euclid observations and to develop methods that will allow to combine weak lensing (WL) and CMB observables from Euclid and Planck to constrain Cosmology and Structure Formation mechanisms. Part of the work will involve the development of a ray tracing algorithm that consistently maps WL observables, such as the WL shear and convergence; the primary lensed CMB temperature fluctuations; and secondary CMB effects such as the Sunyaev-Zel'dovich (SZ) effect. The latter effect is the spectral distortion of the CMB primary spectrum by hot gas in galaxy clusters and filaments and therefore provides a unique way to observe the imprint of cosmological structure in the CMB. The simulated maps will then be used to investigate the cross-correlation of WL/CMB and SZ signals and their dependence on Cosmology.

Brown Dwarfs: Testing the ejection embryo hypothesis and re-evaluating the star / brown-dwarf ratio

Level: Masters or PhD
Supervisor: Nanda Kumar

One of the major scenarios proposed for the formation of brown-dwarfs (BDs) is that they are ejected off a multiple system during the early stage of star formation with velocities of 1-2 km/s. If so, they should have left young clusters and be located in the far outskirts or halo which is not observationally investigated thus far. An important consequence of this effect is that the estimated ratio of stars to brown dwarfs in the Galaxy (5:1) may be in error. Recent detections of free floating planets in the field (Sumi et al. Nature, 2011) for example support this theory. The thesis work will comprise of conducting observational investigations mostly in the infrared bands, to test the ejection embryo theory in prototype young clusters and re-evaluate the star to brown dwarf ratio in star forming regions.

Magnetism in solar-like pulsators

Level: PhD
Supervisor: Margarida Cunha
Co-supervisor: TBC (non-CAUP)

Recent data reveled the effect of activity cycles on the oscillations of solar-like stars, but what does that tell us about the properties of the magnetic fields of these stars and the way they vary? Two complementary lines of action will be followed to address this and related questions:

1) The student will develop / improve data analyses tools to identify activity related pulsation frequency variations as well as variations of other stellar activity proxies. These tools will be applied to ground-based spectroscopic time-series acquired on specific targets (bright solar-twins) and to space-based photometric time-series acquired with the NASA Kepler satellite.

2) In addition, the student will model the coupling between oscillations of solar-like pulsators and local perturbations associated with the magnetic field. This will be based on numerical simulations and singular perturbation theory. The aim is to identify characteristic signatures of different magnetic contributions (e.g, strong versus week field) and search for the latter in real data.

The result will be the characterization of stellar activity cycles of solar-like pulsators, in terms of their observational properties, such as cycle length and intensity, along with an improved understanding of the underlying physical causes of the activity.

On the atmospheric properties of transiting planets

Level: Masters
Supervisor: Nuno Santos

Over the last few years the detection of transiting extra-solar planets has allowed us to access, for the first time, the atmospheric properties of planets orbiting other stars. The information available is, however, dispersed, and up to now there were no published statistical analysis of the available data. In this project we propose that the student starts by compiling from the literature all the available observational information about exo-planetary atmospheres, including the observed fluxes and derived albedos and temperatures. The data will then be used to search for correlations between the different planetary parameters, atmospheric parameters, and stellar properties. The results of this study may have important impact for the understanding of planet formation and evolution.

Probing inside binary stars with asteroseismology

Level: Masters
Supervisor: Mario Joao Monteiro
Co-supervisor: Margarida Cunha

With the launch of space-based missions with dedicated programmes in asteroseismology, such as the French-led satellite CoRoT and the NASA satellite Kepler, solar-like oscillations have been discovered in thousands of stars. For a number of these stars the seismic and non-seismic data are so exquisite that in-depth studies of their internal structure, physics and dynamics is possible. In this project the student will model selected solar-like pulsators chosen for the quality and extent of the available data, and based on the latter will make inferences on particular aspects of the stars' interiors.

Probing inside strongly magnetic stars

Level: Masters or PhD
Supervisor: Margarida Cunha

The study of stellar oscillations provides a unique way to see inside stars and study their physics and dynamics. In the case of strongly magnetic stars, the study of the interaction between the magnetic field and the oscillations allows us, in addition, to learn about the stars' magnetic field properties. Recently, significant amounts of excellent asteroseismic data of magnetic stars have been acquired both in dedicated space-based campaigns with satellites such as WIRE, MOST and Kepler and in ground-based campaigns with high-resolution spectrographs, such as UVES at VLT. Nevertheless, theoretical studies of pulsations in magnetic stars still lack the level of detail that is needed to effectively compare with the observational data. In this project the student will develop analytical and numerical tools for studying the coupling between magnetic fields and pulsations and apply them to real data. The ultimate aim is to make realistic comparisons between the theory and the observations possible and, thus, confidently extract information about the magnetic fields and internal structure of these stars.

Spectroscopic characterization of solar-type stars for the GAIA-ESO Survey

Level: Masters
Supervisor: Sergio Sousa
Co-supervisor: Nuno Santos

The Gaia-ESO Survey is a large public spectroscopic survey, targeting more that 100000 stars, systematically covering all major components of our galaxy, from halo to star forming regions, providing the first homogeneous overview of the distributions of kinematics and elemental abundances. This will substantially increase the knowledge of Galactic and stellar evolution. With the Gaia astrometry the survey will quantify the formation history and evolution of young, mature and ancient Galactic populations. With well-defined samples, we will survey the bulge, thick and thin discs and halo components, and open star clusters of all ages and masses.

In this Master's project the student will use the data coming from this Survey and focus only on the solar-type stars(F G K). The student will use our spectroscopic method to derive the spectroscopic stellar parameters and derive the abundances for several elements.

The Dynamics of Stars in Young Clusters

Level: Masters or PhD
Supervisor: Nanda Kumar

Young stellar clusters are dynamic entities under the influence of various physical forces. Indeed most stars are born in clusters which slowly dissolve into the Galactic field over time. Although we know that young stars do move, we do not know exactly how and why their motion happens and which physical forces control it. Proper motion studies of young stars is needed to understand this process. Measuring proper motion require observations taken with a large time baseline, which is traditionally done using DSS plates and new images in the optical. But young stars are mostly invisible in the optical. The earliest infrared observations with modern cameras are obtained during 90's which will be used in conjunction with new data, and adopting rigorous analysis method, this project aims at examining the dynamics of young stars in clusters.

The internal structure of evolved stars

Level: PhD
Supervisor: Margarida Cunha

The discovery of solar-like oscillations in subgiant and red-giant stars, as well as of signatures of internal gravity waves in these oscillations, has opened new perspectives in the study of the late stages of stellar evolution. In fact, seismic data of exquisite quality acquired with the satellites CoRoT and Kepler on individual evolved stars show signatures of particular features of their interiors. But to what degree of detail can we infer the structure of an evolved star and constrain the physics and dynamics of its interior? In this project two different approaches will be used to address this question. Based on simulations, the student will explore the potential of the observed waves to reveal the extent of convective envelopes, to constrain the mixing processes at convective borders, and to characterize the deepest layers of evolved stars. In addition, the student will evaluate the detail to which information on the internal structure of subgiant and red-giant stars can be inferred, by assessing the potential and limitations of linear inversions of the data.

The nature of disks around massive stars

Level: Masters or PhD
Supervisor: Nanda Kumar

One of the most enigmatic issues in star formation today is understanding the formation of massive stars. Although there is general evidence that they form through accretion, the exact accretion mechanism is quite different and may involve both molecular and ionized accretion flows. Further, the disks are thought to be large, with a complex morphological structure involving Rayleigh-Taylor instabilities, and also non-Keplerian motions. Using a suite of sophisticated infrared and millimeter observations, the goal is to identify and conduct quantitative studies of accretion and disks around young massive stars.

A Census of AGN Activity in Moderate Redshift Galaxies

Level: Masters
Supervisor: Mercedes Filho

In the framework of current cosmological models, the mass of the universe is dominated by cold dark matter. Galaxies form at the center of dark matter halos via cooling and condensation of baryons in such a manner that the overall properties of galaxies are intrinsically related to the halos in which they reside. On small scales, the assembly of baryonic matter into galaxies is known to be regulated by several physical processes, merging being one fo these. From the observational point of view, nearby (z~1) systems are ideal for studying AGN/stellar feedback processes and star formation efficiency as a function of individual galaxy (mass, color, morphology, activity) and merging (distance, timescale, total mass) properties. In order to understand how galaxies acquire their characteristic properties – mass, color, morphology, activity – and their relation to the dark matter halos in which they reside – merging, density, clustering, halo properties – it is imperative to study the processes that form and transform them. The analysis of the activity (AGN, star formation, accretion, feedback), interaction, as well as the analysis of the large-scale environments (density, clustering) where different galaxy types reside, can provide valuable insight into galaxy formation and evolution.

Using 4 publicly available data samples (COSMOS, AEGIS, GOODS, GEMS) we have assembled a comprehensive galaxy catalog (~35 000 sources) containing multiwavelength photometry and galaxy parameters, including SÈrsic fits, for sources up to a redshift of 1. Our aim is to use this catalog to perform a comparative study of AGN-type activity in different galaxy populations by morphology: pure disk, disk plus bulge, bulge-dominated – classified via SÈrsic fits and visual morphological classification, color: red, green, blue – classified via multiband photometry and stellar mass: dwarf, intermediate, massive. To complement the above data we are in the process of obtaining new observations and will analyze archival data of selected subsamples. We are particularly interested in investigating AGN characterstics as a fucntion of BH mass, accretion, feedback, star formation and host galaxies properties. Publicly avaliable spectral information will provide the tools to classify AGN (Seyfert, LINER, transition, Type 1 and 2) via diagnostic diagrams, estimate BH masses from reverberation-calibrated relations and run stellar population synthesis models. Radio data will be used to study the gas kinematics (CO and HI line emission) and to look for evidence of tidal interactions, while the CO line width (proxy for v_sigma) will provide a BH mass estimate. IFU data will allow to spatially explore the gas dynamics (Halpha, [OIII], [NII]) and stellar populations (Hbeta, Mg).

Characterizing dark energy using the baryon abundance in galaxy clusters

Level: Masters
Supervisor: Pedro Viana

The abundance of baryons in clusters of galaxies has been used to constrain the relation between redshift and distance, which holds information about several cosmological parameters, like the Hubble parameter, the density of matter or the density and equation of state of the dark energy. However, up until now, the effect of the way the galaxy clusters used in the analysis are selected has not been taken into account, which could bias the conclusions reached. The main objective of the thesis will thus be to determine the magnitude of such bias, for the type of cluster samples that have been used as well as future ones, and ways through which such a bias could be minimized.

Circumnuclear star formation in Seyfert galaxies

Level: PhD
Supervisor: Jean Michel Gomes
Co-supervisor: Polychronis Papaderos

Active Galactic Nuclei (AGN) galaxies are thought to host a super-massive black hole of several million solar masses, capable of producing a powerful non-thermal ionizing continuum and accelerating the gas to velocities of ~10^4 km/s in the surroundings of its accretion disk. An additional, much weaker ionizing source is due to circumnuclear star formation. One important sub-class of these objects are Seyfert galaxies, discovered by Carl Keenan Seyfert in 1943. They are broadly subdivided into Seyfert 1 and 2, depending on the viewing angle to the nucleus and its surrounding obscuring torus. These are the kind of objects proposed for a study in this PhD program.

Cosmic Superstrings in the Planck Era

Level: Masters or PhD
Supervisor: Carlos Martins
Co-supervisor: TBA (non-CAUP)

Topological defects necessarily form at phase transitions in the early universe. Being non-linear objects, their study requires a combination of phenomenological analytic modeling and complex numerical simulations. Among the possible defects, superstring networks are particularly interesting, and recent work suggests their unavoidable formation at the phase transition that ends inflation.

Although cosmic superstrings share many of the properties of standard strings that have been studied in the past, there are important differences: most notably they do not always intercommute when they intersect and the formation of junctions occurs naturally as a result the interaction between the string. Hybrid networks containing various types of defects can also form. Understanding the cosmological evolution of such realistic networks is an open problem that warrants further study, since it has a direct impact on the observational signatures of (and searches for) these objects. The upcoming availability of high-precision data from the ESA Planck Surveyor (with temperature data released in 2013 and polarization data in 2014) makes this study particularly timely.

Field Theory applications to Astrophysics, Cosmology and High Energy Physics

Level: Masters or PhD

Supervisor: Pedro Avelino

The student will be expected to work on one or more of the following topics: evolution and cosmological consequences of cosmic defects including domain walls, (super)strings and other p-brane networks; non-gaussian models for structure formation; reionization history of the Universe; interacting dark energy models; modified gravity; extra dimensions and variation of fundamental couplings; inflationary models and viable alternatives as a solution to the problems of the standard cosmological model; abundance of primordial black holes; interface dynamics in cosmology, condensed matter and biology; mass inflation inside black holes.

Starburst activity and galactic winds in luminous infrared galaxies

Level: Masters
Supervisor: Patricio Lagos
Co-supervisor: Polychronis Papaderos

Luminous and Ultra-Luminous Infrared Galaxies (LIRGs and ULIRGs) are galaxies emitting more than 10^{11} solar luminosities in the far-infrared. Most LIRGs and all ULIRGs show signs of recent or ongoing interactions or merging. They undergo intense starburst activity, and some also contain an active galactic nucleus. ULIRGs allow us to study a variety of important astrophysical phenomena, such as the formation of quasars and massive elliptical galaxies. While rare in the local Universe, ULIRGs are frequent at high redshift and they have been responsible for approximately 50% of the star formation rate at z=1 and above. Rapidly expanding galactic winds in many ULIRGs witness the importance of star formation feedback on the evolution of these systems and the growth of their supermassive black holes. However, how this feedback regulation occurs is still very poorly understood. The kinematics of galactic winds can be mapped using emission line spectroscopy, providing important insights into the impact of starburst activity on the evolution of ULIRGs. In this project we propose to use archival integral field unit spectroscopic data in order to study the kinematics and excitation mechanism(s) of the ionized gas in a sample of nearby LIRGs/ULIRGs.

Structural investigations of dwarf galaxies in the local universe

Level: PhD
Supervisor: Polychronis Papaderos

While many lines of evidence highlight the role of dwarf galaxies in the cosmic scenery, as possible building blocks of Hubble-type galaxies and important contributors to the chemical enrichment of the universe, the formation and evolution of this overwhelmingly numerous extragalactic population is only sketchily understood. The nearby universe contains a diversity of dwarf galaxies spanning a wide range in their mass, star-forming activity and chemical abundances. A basic prerequisite for further advancing our understanding on dwarf galaxy evolution is the derivation and systematization of the photometric and structural properties of their stellar component using refined surface photometry techniques. Such studies are fundamental for elucidating dwarf galaxy evolution in different environments (galaxy clusters, compact galaxy groups, extreme field) and placing tight constraints on theoretical models on dwarf galaxy formation. The prime goal of this PhD project is the derivation and interpretation of surface brightness profiles (SBPs) for an unprecedentedly large probe of the nearby dwarf galaxy population, using multi-band imaging data from the Sloan Digital Sky Survey (SDSS). The PhD student will be acquainted with one-dimensional and two-dimensional surface photometry techniques and various methods for SBP fitting and decomposition. Additionally, he/she will use evolutionary synthesis models to determine radial stellar age gradients and put constraints on the star formation history (SFH) of dwarf galaxies.
The SFH of a selected sub-sample of emission-line galaxies will be investigated in detail using longslit or Integral Field Unit spectroscopy.

APPENDIX 1

The CAUP Team, May 2012

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Guilherme D. C. Teixeira
José P. P. Vieira
Pauline Vielzeuf

APPENDIX 2

List of currently funded grants active during all or most of the 2012-13 academic year

A Space-Based Probe of Stellar Interiors
PI: Margarida Cunha

Astrophysical Tests of Fundamental Physics
PI: Carlos Martins

Exploitation of Space Data for Innovative Helio – and Asteroseismology (SPACEINN)
PI: (Non-CAUP)
CAUP contact Mario Monteiro

ESPRESSO: a new spectrograph for the VLT (part III) – on Coudé Train
PI: Nuno Santos

EXtra-solar planets and stellar astrophysics: towards the detections of Others Earths (EXOEarths)
PI: Nuno Santos

EXtra-solar planets: towards the detections of Others Earths (EXOEarths)
PI: Nuno Santos

Gaia Research for European Astronomy Training (GREAT-ITN)
PI: (Non-CAUP)
CAUP contact Nuno Santos

Jets in Young Stellar Objects
PI: Joao Lima

Sounding Stars with Kepler (ASK)
PI: (Non-CAUP)
CAUP contact Mario Monteiro

Testing Fundamental Physics with Planck
PI: Carlos Martins

The Dark Side of the Universe
PI: Carlos Martins

CAUP

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