CAUP
PROJECTS BOOKLET 2013

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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 2013-14.

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)
March 2013

A New Generation of Fundamental Cosmology Tests with Euclid and the E-ELT

Level: Masters or PhD
Supervisor: Carlos Martins (Carlos.Martins@astro.up.pt)
Co-supervisor (at PhD level): TBA (non-CAUP)

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 tool to carry out a new generation of precision consistency tests of the LambdaCDM paradigm and for searches for new physics. Particular attention will be given to dynamical dark energy and modified gravity models. Possible synergies with the various E-ELT instruments with science drivers relevant for fundamental cosmology will also be explored. The work will be done in the context of the Euclid Science Working Groups and, at the PhD level only, the student will also be part of the Euclid Consortium.

Direct Detection of Extra-solar planets with ESPRESSO

Level: Masters
Supervisor: Pedro Figueira (Pedro.Figueira@astro.up.pt)
Co-supervisor: Nuno Santos (Nuno.Santos@astro.up.pt)

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 spectrum 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).

Optimizing Observational Strategies for ESPRESSO and HIRES

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

ESPRESSO (under construction) and HIRES (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 HIRES, 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 an 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. This analysis will then be used to derive optimized observational stratrgies for both instruments. 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.

Modelling the interaction between the accretion and outflow regions around YSO's

Level: Masters or PhD
Supervisor: João Lima (jlima@astro.up.pt)
Co-supervisor: TBC (from Observatory of Paris – LUTh)

The evolution of young stellar objets is critically dependent on the balance between the accretion of matter coming from their surrounding disks and the collimated jets outflowing around their poles. The magnetic field plays a crucial role in both channeling these flows of plasma and controlling their dynamics and energetics.

In this project we aim, firstly, at modelling the structure of the magnetosphere of the YSO in which accretion takes place with very simple MHD analytical models. Secondly, we aim at blending such models with existing self-similar MHD models for jets around these objects. These later ones have been developed by a long standing collaboration between CAUP and Paris researchers.

There is the possibility of extending the analytical approach presented here to a numerical one, using existing numerical codes like PLUTO. The advantage of such numerical approach is to enable the study of time dependent solutions. Paris researchers have a long expertise on the use of such codes for modelling MHD flows. Thus, this will be a joint project between CAUP and LUTh (Observatory of Paris).

On the atmospheric properties of transiting planets

Level: Masters

Supervisor: Nuno Santos (Nuno.Santos@astro.up.pt)

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.

Physical requirements for the existence of a convective core in main sequence stars

Level: Masters or PhD

Supervisor: Mario João Monteiro (mario.monteiro@astro.up.pt)

At stellar masses slightly above the solar value we expect stars to develop a convective core. The actual value of the mass at which this transition happens and the period in the main sequence when such a core is present depends critically in some of the input physics in the models.

Asteroseismology is providing precise data on several specific stars that are located inside this no-man-land between the regions of no-core and a fully developed long-lived convective core. In order to fully characterize which are the best targets to clarify the impact of the physics on this issue, a proper calibration of the boundary and its dependence on the input physics is required.

The project aims at using MESA, a modular open source stellar modeling package, to characterize this region of the HR diagram and how it is affected by the input physics and stellar parameters. It seeks to establish the best possible approach to use asteroseismic observations to clarify this critical issue of stellar structure and evolution.

The work-plan will include (1) a period of tests of the MESA code, (2) the identification of the critical aspects of the input physics, (3) the calculation of stellar models for different parameters, and (4) the analysis of the models and the specification of the relevant regions in the HR diagram that can be associated with the presence of a small convective core at the center of the star. Further seismic characterization of the transition may be also developed depending on the outcome of the simulations.

Probing inside strongly magnetic stars

Level: Masters or PhD

Supervisor: Margarida Cunha (mcunha@astro.up.pt)

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 (sousasag@astro.up.pt)
Co-supervisor: Nuno Santos (Nuno.Santos@astro.up.pt)

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.

Validation of small transiting exoplanets with PASTIS

Level: Masters
Supervisor: Alexandre Santerne (Alexandre.Santerne@astro.up.pt)

Since they pass in front of their host stars, transiting planets are providing us numerous key informations about the diversity of planets in the galaxy. Only for these planets, it is possible to measure their mass, their radius and thus constrain their bulk density which then can be used to understand their internal structure. It is also possible to measure their orbital obliquity and to probe their atmosphere. Nearly 300 transiting planets have been confirmed so far, thanks to space missions like CoRoT or Kepler. These two space telescopes observe simultaneously thousands of stars to catch small dip in the stellar flux that are called transit of planet-candidate. Unfortunately, various configurations of eclipsing stellar systems can also mimic the transit of a planet. To be confirmed, the planetary nature of a candidate need to be established. This can be done by measuring the planet's mass using high-accuracy spectrographs, but not for the smallest planets (e.g. Earth-size planets). For these small candidates a new technique have been developed to statistically validate the planet.

PASTIS (Planet Analysis and Small Transit Investigation Software) is a software, being developed in Laboratoire d'Astrophysique de Marseille (France) and CAUP that is capable to validate planets. PASTIS compares the available data with models of planet or models of the various stellar configurations to determine if the observed transit is caused by a planet or by a so-called false positive.

A motivated student with skills in programing (python and C or fortran) will be involved in the development and analysis of the PASTIS software, in close collaboration with the Marseille team and CAUP researchers. Depending on the skills and preferences of the student, the objective of the these can be:

– Development of new PASTIS functions to analyze new type of data or to model yet unconsidered effects.
– Test and improve/optimize existing PASTIS functions to speed up the validation process.
– Improve/optimize the PASTIS user-configuration widget tool and/or visualization widget.
– Analysis of small planet-candidates among the CoRoT or Kepler candidates, also using radial velocity data from SOPHIE and/or HARPS.

Cosmic Superstrings in the Planck Era

Level: Masters or PhD
Supervisor: Carlos Martins (Carlos.Martins@astro.up.pt)
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 (Pedro.Avelino@astro.up.pt)

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.

Probing the Formation of Galaxies using Lyman-Alpha Emission and Absorption

Level: Masters or PhD
Supervisor: Andrew Humphrey (andrew.humphrey@astro.up.pt)
Co-supervisor: Polychronis Papaderos (papaderos@astro.up.pt)

The Lyman-alpha transition of neutral hydrogen at 121.6 nm is one of the key observables through which we can get information about gas associated with high-redshift galaxies. Lyman-alpha emission can be powered by a variety of phenomena, including starbursts, quasars, or the accretion of cold gas from inter-galactic space. Lyman-alpha photons are also readily absorbed by neutral hydrogen, allowing detection of gaseous structures that may be too faint or diffuse to be seen in emission.

This project will begin with an analysis of long-slit spectroscopy, obtained from the Spanish 10.4 m GTC telescope, for a sample of 14 high-redshift ($z>2$) quasars known to be associated with large Lyman-alpha emitting nebulae. As a means to elucidate the origin, nature, and fate of this gas, the student will characterize its the kinematic, spatial, and excitation properties and, using ionization models, will determine its metallicity. In addition, the incidence, properties and origin of associated Lyman-alpha absorbing structures will also determined, and their possible connection with the central galaxy and the Lyman-alpha emitting nebula will be examined.

Beyond this, the project can evolve depending on the early results and the interests of the student.

Structural investigations of dwarf galaxies in the local Universe

Level: PhD
Supervisor: Polychronis Papaderos (papaderos@astro.up.pt)

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 fields) 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 spectral 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.

The formation history of pseudo-bulges

Level: Masters or PhD
Supervisor: Polychronis Papaderos (papaderos@astro.up.pt)
Co-supervisor: Jean Michel Gomes (jean@astro.up.pt)

Contrary to genuine galaxy bulges, pseudo-bulges are thought to assemble gradually over several Gyrs in the course of secular galaxy evolution. However, little is known as yet about the formation history of pseudo-bulges, and its possible dependence on the properties of their galaxy host. The goal of this project is to investigate these issues with integral field unit (IFU) data from the CALIFA Galaxy Survey (http://califa.caha.es).

At a first stage, a sample of pseudo-bulge galaxies from the CALIFA Data Release 1 will be selected on the basis of photometric criteria and analyzed using bulge/disk decomposition techniques. The sample galaxies will then be investigated with the IFU spectral synthesis pipeline Porto3D with respect to their spatially resolved star formation- and metal enrichment histories, as well as their stellar and ionized gas kinematics.

APPENDIX 1

The CAUP Team, March 2013

Researchers
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APPENDIX 2

Funding ID for 2013-14

List of currently funded grants active during all or most of the 2013-14 academic year

An exploration of the Assembly History of Galaxies
PI: Polychronis Papaderos

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

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

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