Astronomy & Physical Cosmology
speciality of the official
Master in Theoretical Physics

Offers for MSc Theses

On the following pages the possible projects for a MSc thesis are listed. Please note that the MSc thesis is not restricted to be selected from this list; this list simply reflects research interests within the Department and its associated members. You always have the option to talk to the members and come up with a new project.

Note that each project has to be a work worth 12 ECTS and the list provided here is ordered by the surnames of the tutor.

Yago Ascasibar (UAM)

A new approach to the N-body problem

There are two traditional approaches to the N-body problem: when the number of particles involved is relatively small, their equations of motion are integrated numerically, sometimes resorting to approximate algorithms in order to avoid evaluating all their mutual accelerations. When the number of particles is very large, it is assumed that the system should be well described by a continuous density field whose evolution is given by the collisionless Boltzmann equation. In order to integrate the latter, the system is represented by a finite number N of discrete tracers, but each of them is no longer a physical particle, but a Lagrangian tracer of the continuous density field. The resulting equations of motion are very similar to those of the discrete N-body problem, with the only addition of a (somewhat arbitrary) softening term to avoid unphysical interactions between the tracers and ensure that their dynamics is dominated by the mean-field gravitational potential.

Here we consider a different approach and investigate the evolution of a system of N particles, initially sampled from a given probability density over the phase space of positions and velocities.
Rather than a continuous phase-space density field, we focus on the evolution of the probability density of finding a particle at a certain location, moving with a certain velocity, after a certain time has elapsed.
Preliminary results in one spatial dimension suggest that the probability density tends to an universal equilibrium distribution, rather insensitive to the actual (finite) number N of physical particles, that is not well described by the collisionless Boltzmann equation.
The goals of the present work are to extract robust conclusions from these results, extend the phenomenological study to three spatial dimensions, and explore the possibility of providing an analytical description.

Yago Ascasibar (UAM) & Martin Stuhlinger (ESAC)

Evaluation of the characteristic X-ray emission of main sequence stars

X-ray observations of the universe reveal the final stages of stellar evolution, often referred to as the violent universe, and space-based X-ray observatories like ESA's XMM-Newton dedicate plenty of time to these kind of special objects. But galaxies mainly consist out of main sequence stars like our sun, and therefore it is important to understand what is the average X-ray emission of the various spectral types of these main sequence stars.

XMM-Newton's EPIC instrument, thanks to its wide field-of-view (comparable to the full moon), has observed many field stars of our Milky Way, despite these were not the dedicated main targets. As the spatial resolution of the X-ray telescopes is less powerful compared to their optical counterparts, the Milky Way areas with high star density can't be included because of possible superposition. As main sequence stars are rather weak X-ray sources, the flux limit will reduce the available stars to a restricted volume around the sun. Also, no other background X-ray source emission must influence the stellar spectra.

In order to successfully carry out this project, the student will have to:
- generate a valid stellar sample by cross-correlating the EPIC source catalogue with other publicly-available databases (specially GAIA).
- determine the available volume where stars can be detected in X-rays.
- extract X-ray data from the world's most powerful X-ray telescopes.
- identify chance coincidences with background sources like AGN.
- model the final merged X-ray spectra.

This project involves close collaboration between the UAM and ESAC, and it will be proposed for the next edition of ESA's Trainee Programme: < http://www.cosmos.esa.int/web/esac-trainees/training-opportunities >.

Yago Ascasibar (UAM) & Patricia Sanchez-Blazquez (UAM)

Influence of optically-selected active galactic nuclei on the evolution of their host galaxies

Active galactic nuclei (AGN), putatively powered by the accretion of matter onto a supermassive black hole at the very centre of the galaxy, is currently believed to play a key role in the formation and evolution of galaxies. The amount of energy emitted by the AGN is so vast that, even if only a tiny fraction were absorbed by the surrounding gas, it would be able to heat it up to very high temperatures and blow it away to large distances in a potentially large-scale galactic wind. According to the most widely accepted scenario, this process should be responsible for the suppression of star formation in high-mass galaxies and cooling flows in galaxy clusters.

However, evidence for this process is scarce, specially on galactic scales. Previous work by our team challenges the current paradigm and proposes that the main difference between the evolutionary histories of low- and high-mass galaxies is that the latter accrete their (cold) gas on much shorter timescales, which may explain many of their observed properties without invoking any other physical mechanism.

This work will focus on the role played by active galactic nuclei and revisit the selection of such objects from the ratios of strong emission lines in the optical spectrum, using a sample of galaxies observed by the Calar Alto Legacy Integral-Field Area (CALIFA) survey. First, the student will use different tools to characterize the star formation histories of different regions within the galaxies, and then correlate them with the emission-line ratios tracing the presence of ionized gas, taking particular care in determining its physical properties (density, temperature, chemical composition) in order to firmly establish causal relations.

Héctor Cánovas (ESAC), Carlos Eiroa (UAM)

The ALMA view of Sz 91: a protoplanetary disk with evidence of planet formation

The study of protoplanetary disks allows to understand the initial conditions of planet formation. ALMA, the most powerful interferometer in the sub-millimeter regime, is revolutionizing our picture of protoplanetary disks. Thanks to its sensitivity and resolution ALMA routinely produces detailed images of the cold dust and gas components of the protoplanetary disks. In 2014, we obtained ALMA Cycle 2 observations of the remarkable disk Sz 91 (a ~0.5 Msun, ~5 Myr star). These observations revealed that the dust in the disk is concentrated in a narrow ring with an inner hole of ~100 au. This ring-like structure is consistent with hydrodynamical models of planet-disk interactions, and the huge inner cavity size is best explained by recently formed giant planets. We have lead the study of this object in the past, with 2 publications and one ALMA Cycle 2 project (Canovas et al. 2015, 2016). In this Master project we propose to analyze the gas (12CO, 13CO, and C18O) ALMA observations of this object, which are not published yet.

Methodology.
Currently we have a set of scripts to analyze the ALMA observations, and a radiative transfer model of the dust in the disk around Sz 91. During the first half of this project the interested student will translate our (IDL) scripts to python to incorporate new utilities developed to analyze ALMA observations. This way the student will become familiar with the data reduction and processing of interferometric observations. In the second part of the project the student will analyze the gas observations and compare them to the dust observations. In particular, the analysis of the gas will help to constrain the total mass of the disk and the gas spatial distribution. These observations are likely to be presented in a scientific publication, and the student contribution will be properly taken into account. During this project the student will benefit from the interaction with observational and theoretical experts on the field of protoplanetary disks, and he/she will gain relevant experience on the analysis of ALMA observations. Given the nature of this project, good programming skills are desirable, and the interested student should start this project in early October.

Interested students do not hesitate to contact us: **hector.canovas@uam.es**

Luis Colina (CSIC Centro de Astrobiología, Unidad Asociada ASTRO-UAM)

Searches for early galaxies during the Reionization Epoch of the Universe

SUMMARY:
The Universe went through a reionization phase at very high redshifts. This phase started at a redshift of about 10 when the Universe was fully neutral and ended at a redshift of about six when the Universe became fully ionized. One of the primary goals of the future James Webb Space Telescope is to identify and study the nature of the ionizing sources and how they evolved into the actual population of galaxies, using very deep imaging and spectroscopy. This work proposes to simulate the expected spectra of these first (proto)galaxies in the Universe and to simulate how they will appear in multi-wavelength broad-band JWST deep imaging.

METHODOLOGY:
Using available software, the stellar continuum spectra of low metallicity young stellar populations and associated ionized emitting gas will be simulated for a range of metallicities, ages and masses. The spectra will then be combined with the filter transmission curves of the NIRCam and MIRI instruments to simulate the expected apparent magnitudes and colors for a range of redshifts (5 to 10) in obtain the observational spectral energy distributions.

Rosa Domınguez-Tenreiro (UAM) & Chris Brook (UAM)

Dust Effects in the SEDs of Galaxies at Different Redshifts

MOTIVATION.- Galaxies are the units of stellar mass distribution in the Universe. They are the locations where the cosmic evolution has proceeded up to a higher degree of complexity, allowing stars and elemets to form, and live to develop. From the cosmological point of view, galaxy emissions trace the Large Scale Structure of the Universe, providing us with unvaluable information about the LSS formation and evolution.
Galaxy emissions are very much affected by cosmic dust (silicates and graphite grains, poli-aromatic hidrocarbons macromolecules). Indeed, dust components are heated as the absorb light at short wavelengths (mainly the very energetic emissions from very young stars at UV) and they re-emit the energy at longer ones (infrared and submilimetric ranges). Therefore, the whole range from UV to submm is needed to characterize galaxy emissions. This explains the huge development of IR astronomy from the space in the last years.
It is very important to have under control the dust effects on galactic physics and emission. The first step is a good characterization of dust properties in local galaxies, where detailed empirical data are now at our disposal (SPITZER IR Normal Galaxy Survey, Dale et al. 2005; Herschel Reference Survey, Boselli et al. 2010; KINGFISH, Kennicutt et al. 2011), but still requiring a deeper understanding in terms of a physically motivated context. The remarkable development of supercomputing technology and programming allows now to simulate galaxy formation in a cosmological context by using physical laws. Moreover, sophisticated models on dust effects are also available.

AIM.- Improving our understanding about the rol of cosmic dust in the formation, evolution and emissions of galaxies. Specifically, our aims are:
• Quantifying in simulated galaxies at very low redshift how dust content varies with galaxy properties such as: stellar mass, HI and molecular gas content, specific star formation rate, metallicity, surface density, and colors, among others. Particular attention will be paid to the FIR/submm colours, and to the properties and shapes of the FIR/submm SEDs, as tracers of dust properties in nearby galaxies in the mass range 108 < M_* < 1011 solar masses.
• Comparing the results above to the increasing body of observational data available for local galaxies.
• Extending the analysis to galaxies at intermediate and high redshifts, where observational data are rarer.

METHOD.- We will interface the new spectrophotometric code, GRASIL-3D, with the outputs from hydrodynamical cosmological galaxy formation codes to get the spectral energy distributions (SED) and the images, from UV to FIR, of simulated galaxies. Moreover, other galaxy properties will also be measured. GRASIL-3D (Domınguez-Tenreiro et al. 2014) is an entirely new model based on the formalism of an existing classical spectrophotometric model, GRASIL (Silva et al. 1998), but specifically designed to be applied to galaxies calculated by theoretical hydrodynamical galaxy formation codes.
As simulated galaxies we will use a sample of disk galaxy systems identified in simulations run with both, P-DEVA (Serna et al. 2003) and GASOLINE (Stinson et al. 2006) smoothed- particle hydrodynamic codes. Their main galaxies have been previously analysed and their structural and kinematical properties, among others, have been found to be consistent with observational data (Brook et al. 2013, Domenech et al. 2012, Domınguez-Tenreiro et al. 2014, Obreja et al. 2014).
The student will be trained to apply the GRASIL-3D code to these numerical galaxies to calculate their luminosities and images in different photometric bands. Other properties (metal, atomic and molecular gas, stellar distributions, surface densities, sizes ...) will also be measured. Their analysis and comparison to empirical data for local galaxies will quantify different dust properties. In addition, different dust properties will be found for galaxies at higher redshifts.
CONTACT.- For more details, please contact Rosa Domınguez (rosa.dominguez@uam.es, M15-room 303).

Rosa Domınguez-Tenreiro (UAM), Enrique Perez (IAA-CSIC) & Chris Brook (IAC)

Software Telescopes: Metallicity distributions in spectral cubes from numerical simulations of galaxy evolution

MOTIVATION.- Chemical abundance of the elements trace the evolution of star formation in the universe and their main constituents, stars and galaxies. This is one of the most important parameters tracing the structure and evolution of galaxies. State of the art numerical simulations of galaxies, such as those carried out in our group, include improved star formation and chemical evolution algorithms, following element formation along stellar evolution and their injection in the interstellar medium through stellar winds and explosions. In order to test the adequacy of the physics included in the simuations, and of these algorithms in particular, the results of the simulations need to be contrasted with observational results on the element abundances in the stellar populations of galaxies. These abundances are measured from each galaxy Spectral Energy Distribution (SED) through different techniques, the population spectral synthesis code STARLIGHT, widely used in successful projects such as CALIFA, being a very efficient and well known one. However, no tests has been carried out up to now to test how well these observational techniques work at retrieving the true metallicity of stellar populations in galaxies.

AIM.- The aim of this Master Thesis (TFM) is to measure the distribution of stellar metallicities of simulated galaxies out of their SEDs, by using the same techniques that are used by observers. These values obtained from the SEDs will be compared with the known distribution of metals reached in the simulations themselves. This will provide insight on the goodness of the analysis tools used by observers, and a comparison of simulation results with observational ones, both obtained using the same analysis techniques.

METHOD.- We will apply the spectrophotometric code GRASIL-3D to galaxies identified in hydrodynamical simulations run in a cosmological context, to get their high resolution SEDs in the visible range, including dust effects. Simulated galaxies we are interested in are MW-, M31-, and M33- like. The resulting 3D spectral cube corresponding to a given galaxy will be analysed with the STARLIGHT code, to obtain the present day spatial distribution of stellar properties (mass, metallicity, etc), and its star formation history. Specifically, in this TFM the student will focus in the case of the metallicity.
The student will be trained to apply the STARLIGHT code to the 3D spectral cube of simulated galaxies. He/she will also be trained to run GRASIL-3D to get these cubes. From the STARLIGHT outputs, the distribution of stellar metallicity will be computed, and compared with the known direct distribution the simulations provide. Thus the student will be able to assess the goodness of the techniques used by observers to measure metallicity from SEDs, but contrasted with the known values from the numerical simulations.
GRASIL-3D (Domínguez-Tenreiro et al. 2014), based a the classical spectrophotometric model, GRASIL (Silva et al. 1998), is specifically designed to be applied to simulated galaxies. As simulated galaxies we will use a sample of disk galaxies identified in runs made with both, P-DEVA (Serna et al. 2003) and GASOLINE (Stinson et al. 2006) SPH codes. Their main galaxies have been previously analysed and their properties have been found to be consistent with observational data (Brook et al. 2013, Domenech et al. 2012). We will focus in the three galaxies that are a proxy for the Milky Way, M31, and M33, identified in a CLUES run (Brook et al. 2016). The effect of galaxy inclination will be studied by carrying out the experiment with the same numerical galaxy viewed face-on and edge-on.

Interested students please contact rosa.dominguez@uam.es, eperez@iaa.es

Rosa Dominguez-Tenreiro (UAM)

Tracing the evolution of the stellar halo

MOTIVATION.- The oldest stars of disc galaxies are found in an almost spherical structure which extends far from the disc region. This structure is called the stellar halo. These stars in the stellar halo were born at a very early time in the history of the Universe, and thus contain information about the conditions at the early times, as well as information about how galaxies form and evolve. This project will compare observations of stellar halos at different epochs, i.e. present day halos as well as those observed at high redshift, with stellar halos formed in fully cosmological simulations of galaxy formation. The simulated galaxies will be used to better understand the observations of stellar halos and the evolutionary path of disc galaxies.

AIM.- The aim of this work is to analyse the stellar halos at early times, soon after they formed, and compare this to the present state of the stellar halos of our won Galaxy, the Milky Way, and that of our nearest neighbour, Andromeda. These comparisons will be used to constrain the evolutionary path way of these types of massive disc galaxies.

METHOD.- The simulations used for the study model the main processes of galaxy formation and evolve them from the very earliest time in the Universe, until the present. The simulations include processes such as gas hydrodynamics, star formation, supernova explosions within a cosmological context that includes dark matter and dark energy. As simulated galaxies we will use a sample of disk galaxy systems identified in simulations run with both, P-DEVA (Serna et al. 2003) and GASOLINE (Stinson et al. 2006) smoothed- particle hydrodynamic codes. These suimulated galaxies have been previously analysed and their structural and kinematical properties, among others, have been found to be consistent with observational data (Brook et al. 2012, Domenech et al. 2012).

We will use the spectrophotometric code, GRASIL-3D (Domínguez-Tenreiro et al. 2014), in order to make mock observations of the simulated galaxies, allowing more direct comparisons with the observations. The student will be trained in understanding and analysing galaxy formation simulations, as well as understanding how the analysis of galaxy evolution can shed light on larger questions pertaining to the evolution of the Universe. Their comparison of observations to observational data will aid in understanding and better interpreting the data, and increasing our knowledge of the evolutionary path of disc galaxies. A mix of theoretical and observation astrophysics will be covered.

CONTACT.- For more details, please contact rosa.dominguez@uam.es

Carlos Hoyos (UAM)

Controlled Galaxy Merger Experiments

Galaxy mergers are known to be a main driving mechanism of galaxy evolution, especially in the case of massive, early type systems, whose number density and mass evolution can be almost exclusively accounted for by means of galaxy mergers. However, this knowledge comes from luminosity function evolution and models for galaxy growth, and an unambiguous diagnostic to detect galaxy mergers remains elusive.

In this work, we propose to analyze images of simulated galaxy mergers with two particular scenarios in mind:

1) Target galaxy is a gas-rich, late type spiral. Projectile is a dwarf galaxy.
2) Target galaxy is a gas-poor, early type elliptical. Projectile is a dwarf galaxy.

The simulated galaxy mergers will be either directly obtained from the Galmer database of merger simulations, or created by the student using the Gadget code.

These simulated images will then be further analyzed using structural analysis techniques, with the aim of answering the following questions:

1) What are the most relevant structural parameters to determine whether a spiral/elliptical galaxy is undergoing a merger episode? Elliptical galaxies develop shells and ripples when disturbed, while spiral galaxies develop other structures. Diagnostics need to be tuned accordingly.

2) What are the timescales in which the various parameters are sensititive to the merger phenomenon? Ellpiticals should process new material much faster, and then the window of opportunity for merger detection should be narrower. How much (if at all) narrower?

3) What are the most relevant photometric bandpasses to detect mergers? How should deep galaxy surveys be designed, if detecting galaxy mergers is deemed to be a goal?

Alexander Knebe (UAM)

Galaxy Clusters: (2 offers, each 12 ECTS)

Galaxy clusters are the largest gravitational bound objects in the Universe and lie on the cross-roads of astrophysics and cosmology. On the one hand, by studying their masses and number density they provide insights of the cosmological background. On the other hand they constitute an ideal astrophysical environment to study all the processes that take place during the formation of galaxies. We have used 11 different simulation codes for modelling the same galaxy cluster in a cosmological context in- and excluding all the relevant physical processes. For some of the proposed MSc projects this existing and unique dataset should be used to investigate various scientifically interested topics. But we also have at our disposal a suite of cosmological simulation that allow the study of galaxy clusters in a statistical sense.

Please note that each of the points listed below is for *one* single MSc thesis of 12 ECTS.

Signing up for one of these projects will further open the possibility to join an existing international group of researchers working on both this comparison and galaxy clusters, respectively; see http://popia.ft.uam.es/nIFTyCosmology/week1.html for more details.

<u>MSc thesis #1: cluster outskirts</u>
The plan for this project is to study differences in the properties of the brightest cluster galaxy (i.e. the central galaxy), the luminosities of the satellite galaxies as well as any intra-cluster light. For this purpose it appears adequate to make use of the single cluster simulation performed with aforementioned 11 different simulation code: how stable are results with respects to the numerics?

<u>MSc thesis #2: the influence of baryons</u>
This project aims at investigating how the baryons included in the simulation affect the shape, angular momentum, and general distribution of matter when compared against dark matter only simulations. For this project we should again use the suite of single cluster simulations as this is available to us with and without gas physics.

Alexander Knebe (UAM)

Galaxy Formation: (4 offers, each 12 ECTS)

Understanding galaxy formation within a full cosmological context is one of the prime fields of research in astrophysics. While a lot of effort is going into directly modeling galaxies by means of hydrodynamical simulations, another route to the subject is to defer to dark matter only cosmological simulations, and then populating the haloes emerging in them with galaxies in a semi-analytical fashion. And there are currently various such models out there all aiming at producing the same observational predictions.

Besides of performing direct simulations of galaxies, we have also used 13 different semi-analytical codes (basically all existing) for running their model over the same cosmological simulation. The question now is whether they all give the same results when compared amongst each other or against direct simulations. For some of the proposed MSc projects the existing and unique dataset of galaxy catalogues should be used to investigate various scientifically interested topics. But we also have at our disposal a suite of cosmological simulation that allow the study of galaxies in a statistical sense.

Please note that each of the points listed below is for *one* single MSc thesis of 12 ECTS.

Signing up for one of these projects will further open the possibility to join an existing international group of researchers working on both this comparison and galaxy clusters, respectively; see http://popia.ft.uam.es/nIFTyCosmology/week2.html for more details.

<u>MSc thesis #1: Intra-Halo Light</u>
Galaxies falling into and then orbiting a larger host galaxy experience tidal forces which will tear them apart (see, for instance, the two Magellanic clouds are orbiting our Milky Way). First their dark matter halo will be stripped, but eventually also stars will be removed and deposited into the halo of the host galaxy. These stars are then free-floating and constitute the so-called "intra-cluster light". The aim of this project is to investigate how different semi-analytical models for galaxy formation treat and predict these halo stars. Will we be able to distinguish different models via the intra-cluster light? Or will we be able to even improve models?

<u>MSc thesis #2: Environmental Effects - 12 ECTS</u>
We aim to study the difference (between different SAMs) in the degree of environmental effects on galaxy properties. Environmental effects are observed and predicted, but whether its degree is in quantitative agreement with SAM prediction and how robust the SAM prediction is have not been addressed in good detail. This is part of the goal of this project.

<u>MSc thesis #3: Cold/Hot Gas in Galaxies - 12 ECTS</u>
Gas cooling and heating are competing processes during the formation of galaxies: cool gas is able to form stars, but feedback mechanisms heating part of the gas again are required to prevent an overproduction of stars. For this project the evolution of hot and cold gas shall be studied in the various different semi-analytical models.

<u>MSc thesis #4: Mbh-sigma Relation - 12 ECTS</u>
The Mbh–sigma (or simply M–sigme) relation is an empirical correlation between the stellar velocity dispersion of a galaxy bulge and the mass M of the supermassive black hole at the galaxy's centre. Here we plan to study how this relation differs amongst the various semi-analytical models of galaxy formation. There have recently been claims that this relation is different at higher redshift. As different SAMs might use different prescriptions on the growth of BH and bulge (AGN FB, merger, starburst prescriptions, etc) we can check how this very important relation varies with redshift in all the models available to us. Will we be able to use this rule out or confirm some of the models?

Alexander Knebe (UAM)

Gravitational Lensing

The deflection of light by gravity, i.e. gravitational lensing, has established itself as an extremely useful astrophysical tool with remarkable successes. Gravitational lenses have been a precious mean of probing the matter distribution in the Universe: from the search of matter in the Galactic halo to the study of the large-scale structures of the Universe, the gravitational lens effects offer a unique alternative to light surveys and are now widely used. For this project the student should gain a basic understanding of the lensing theory by studying the relevant literature. He should further investigate several very simple lens systems by numerically solving the lens equation: the idea is to generate the lensed picture of a certain image in the source plane by shooting rays backwards from the observer passing the lens into the source plane. Each of these rays will be deflected by the lens and hence 'move' a source pixel to a different position. Only simple lenses (e.g. a single (or several) point masses) shall be considered for this project. This method is called the inverse ray-shooting method described in more detail in Refsdal & Stabell (1986) and Schneider & Weiss (1986).

Alexander Knebe (UAM)

The Dark Universe

There is mounting evidence that the Lambda-cold dark matter (LCDM) structure formation scenario provides the most accurate description of our Universe (cf. Komatsu et al. 2009). However, the currently favoured model rests upon some important assumptions, i.e. the Universe consists of 72% dark energy and 24% dark matter. While we have no conclusive theory for either of them, there is the additional possibility that these two putative ingredients of the Universe also interact with each other. We just finished performing state-of-the-art simulations of cosmic structure formation where we ran - besides of the fiducual LCDM model - models including said interactions. We are now in the process of analysing these simulations with an emphasis on the cosmic web and in particular void regions in the Universe: first results indicated that we might find the greatest differences in those zones that have so far been ignored both observationally and theoretically.

The work to be undertaken for the MSc thesis is to analyse our set of simulations studying the formation and evolution of cosmic structures (e.g. galaxy clusters) with a focus on the orbits and dynamics of galaxies inside of them.

Ignacio Mendigutía (CAB)

Herbig Ae/Be stars; unravelling the missing link in star and planet formation

Herbig Ae/Be (HAeBe) objects are intermediate-mass young stars surrounded by circumstellar disks where planets form. With stellar masses between 2 and 10 times the mass of the Sun, HAeBes' properties bridge the gap between low- and high-mass star formation, being excellent targets to detect proto-planets from state-of-the-art instrumentation. Despite of their great interest, HAeBes are not as well known as other types of young stars. For this reason, we are building an online archive of HAeBe stars including data from ground- and space-based observatories that will serve as a reference tool for the study of star and planet formation.

This master project will allow the student to develop his/her skills in two complementary fronts that are of relevance for future professional activity:
1) Technically, the student will help in the construction of an astrophysical archive. He/she will make use of Virtual Observatory tools to implement new physical data, including those from the second release of ESA's Gaia space observatory (scheduled for April 2018).
2) Scientifically, the student will exploit the online archive to study the evolutionary properties of HAeBe stars based on the most complete sample and database of such type of stars known to date.

In addition, the student will have the opportunity to interact with professional astrophysicists and engineers in an international environment at the European Space Astronomy Centre (ESA-ESAC, Madrid).

For more details please contact imendigutia@cab.inta-csic.es

Maria Morales Calderon (CAB)

Completing the view of Collinder 69

CONTEXT:
Stars and brown dwarfs (BDs) in the ~1–15 Myr age range occupy a pivotal position in the stellar evolution sequence, characterized by emergence from molecular cloud birthplaces, ongoing dissipation of primordial circumstellar disks, and assembly of planet systems. This evolutionary stage also involves dramatic changes in internal structure as well as radius and angular momentum. Some circumstellar and stellar changes during this epoch are interconnected, through deposition of accreting material on the central object, as well as possible transfer of angular momentum to the surrounding disk.

In the last years we have studied some of these processes by conducting a thorough study of Collinder 69, the 6 Myr old central cluster of the Lambda Orionis Star Forming Region. We carried out several surveys at different wavelengths, from the optical to the submillimeter. The main goal of these studies was to characterize the population of low-mass stars and brown dwarfs, obtain a stellar and substellar census, specially identifying and characterizing members with disks using infrared (IR) excesses, and derive the initial mass function (IMF).

AIM:
Now we aim at detecting periodic variability in a sample of very low-mass stars and brown dwarfs members of the 6Myr old Collinder 69, using data from observations that will be performed from the Javalambre Observatory. We will derive rotation periods for around a 100 members that will be used to test current models of angular momentum evolution. As a secondary goal we will be testing the possibility that the observed variability arises from pulsations due to Deuterium burning.

Patricia Sanchez-Blazquez (UAM) & Pablo G. Perez-Garcia (UCM)

Distribución espacial de las poblaciones estelares en galaxias a z = 2 – 3

Este Trabajo Fin de Máster pretende analizar las imágenes en el óptico e infrarrojo cercano tomadas por el Telescopio Espacial Hubble dentro de los Proyectos de Legado GOODS y CANDELS para analizar las poblaciones estelares en galaxias con formación estelar activa a redshifts z = 2–3. El estudio se hará en 2 dimensiones, comparando tambien con los resultados obtenidos para la galaxia completa. El trabajo consiste en la selección de galaxias con formación estelar a z = 2–3 usando la base de datos Rainbow para los catálogos CANDELS en los campos GOODS, la medida de fotometría en distintas zonas de cada galaxia en hasta 10 bandas fotométricas, y la comparación con modelos de poblaciones estelares para determinar distribuciones de masa, edad, extinción, etc... en los progenitores de galaxias masivas.

Patricia Sanchez-Blazquez (UAM) & Javier Gorgas Garcia (UCM)

Modelado de poblaciones estelares en galaxias a redshift z ~ 2 usando métodos de Markov Chain Monte Carlo (MCMC)

Este Trabajo Fin de Máster pretende crear un código sencillo de análisis de poblaciones estelares en galaxias a desplazamientos al rojo en torno a z ~ 2 a partir de datos fotométricos tomados por telescopios como GTC, Hubble y Spitzer. El método incluirá el manejo de modelos de Bruzual y Charlot (2003), los más utilizados en la literatura, y tendrá como novedad la programación y aplicación de métodos bayesianos basados en Markov Chain Monte Carlo (MCMC). Estos métodos, apenas explotados hasta la fecha en este campo, tienen el potencial de explorar con una gran eficiencia el espacio de parámetros (edad, metalicidad, extinción, etc.) y producir resultados muy robustos. Se valorarán conocimientos de programación en R o Python.

Patricia Sanchez-Blazquez (UAM) & Pablo G. Perez-Garcia (UCM)

Estudio de calidad de software de modelado de poblaciones estelares con datos del survey J-PAS

Este Trabajo Fin de Máster pretende testear dos códigos de análisis de poblaciones estelares ampliamente usados en la literatura (synthesizer y FAST) con el objetivo de optimizar los resultados de la exploración cosmológica J-PAS. J-PAS es un survey que llevará a cabo el Observatorio de Javalambre en Teruel, y que pretende observar 8500 grados cuadrados de cielo con 59 filtros fotométricos. El TFM servirá para determinar la mejor estrategia de análisis de los datos J-PAS con el objetivo de obtener las estimaciones más fiables y robustas de las propiedades físicas de galaxias a desplazamientos al rojo intermedios.

Montserrat Villar Martín (CSIC Centro de Astrobiología, Unidad Asociada ASTRO-UAM) & Rosa Dominguez Tenreiro (UAM)

SUPERVIENTOS (OUTFLOWS) EN LAS GALAXIAS ACTIVAS MÁS POTENTES: ¿QUÉ LE OCURRE AL GAS?

Los cuásares (QSO) son las galaxias activas más potentes que albergan en el centro un agujeros negro de masa gigantesca. Este está siendo "alimentados" por material acumulado en su vecindad, lo cual activa mecanismos que se manifiestan en fenómenos observables asociados con energías extremas. La energía que el agujero negro es capaz de generar puede ser transferida al gas de su entorno, modificando sus propiedades de manera dramática. Así, el gas nuclear presenta con frecuencia movimientos extremos debidos a la presencia de outflows o supervientos generados por la intensa actividad del agujero negro. Dichos outflows no sólo perturban los movimientos, si no que cabe esperar que impriman cambios importantes en sus propiedades físicas, como la temperatura (por efecto de calentamiento producido por choques) y la densidad (por efecto de la compresión del gas). El objetivo de este proyecto es investigar este aspecto.

Las propiedades físicas del gas y el impacto de los outflows en ellas, pueden ser diagnosticados de manera sencilla a partir de la información contenida en los espectros de los cuásares, que se caracterizan por líneas de emisión del gas ionizado de luminosidades muy altas. Estas líneas espectrales contienen la información clave para medir densidades y temperaturas.

Se han seleccionado los espectros de unos 30 cuásares oscurecidos obtenidos del archivo del Sloan Digital Sky Survey (SDSS): 15 presentan una cinemática extrema, indicativa de la presencia outflows y 15 presentan cinemática quiescente (no hay outflows o son muy débiles). Se asignará el tipo de cinemática a partir de la medida de la anchura a mitad de altura (FWHM) de [OIII]5007 en kilómetros/segundo. Se cuantificarán la densidad y temperatura electrónicas del gas ne y Te para cada cuásar y se investigará si los dos grupos presentan diferencias.

Será necesario:

- Medir los flujos de las líneas de interés en todos los espectros (H-alpha, H-beta, [OIII]4363, [OIII]5007, [SII]6716,6731)
- Calcular los cocientes de líneas con sus errores H-alpha/H-beta, [OIII]5007/[OIII]4363, [SII]6716/6731
- Determinar la corrección de enrojecimiento a partir de H-alpha/H-beta corregir el cociente [OIII]5007/[OIII]4363 de enrojecimiento
- Determinar la temperatura electrónica Te a partir del cociente [OIII]5007/[OIII]4363 y la densidad ne a partir de [SII]6716/6731

¿Existe alguna diferencia en enrojecimiento, Te y ne dependiendo del tipo de cinemática nuclear extrema, intermedia o quiescente?

Interpretación de los resultados: ¿Quedan de manifiesto cambios en las propiedades físicas del gas como consecuencia de los outflows?

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ESTUDIO CON IMÁGENES DE GTC DE LAS REGIONES IONIZADAS EXTENSAS ASOCIADAS CON CUÁSARES OSCURECIDOS CERCANOS

Los cuásares son las galaxias activas más potentes. A menudo están asociados con regiones ionizadas de tamaños variables de unos pocos kiloparsecs (kpc) hasta más de 100 kpc en los casos más extremos. Estas nebulosas gigantescas contienen valiosa información sobre la historia de formación y evolución del cuásar.

Las regiones ionizadas se identifican a partir de las líneas de emisión que emite el gas, tanto permitidas como prohibidas ([OIII]4959,6563, H-alpha, H-beta, etc). El proyecto consiste en producir imágenes de H-alpha de siete cuásares oscurecidos (QSO2) cercanos (redshift z~0.1) a partir de imágenes obtenidas con GTC, el telescopio español de 10 metros. Para ello se contará con imágenes de continuo e imágenes de continuo +Halpha. Será necesario:

- Alinearlas
- Escalarlas en flujo utilizando estrellas en el campo de las imágenes
- Sustraerlas

Se estudiarán:

- la morfología de las galaxias de los QSO2 a partir de las imágenes de continuo
- la existencia (o no) de regiones ionizadas extensas asociadas con los siete cuásares
- sus propiedades espaciales (tamaño, morfología)
- su origen en base a estas propiedades (¿colas de marea, regiones de formación estelar en la propia galaxias, conos de ionización, otros?)

Los resultados se pondrán en contexto de estudios relacionados de cuásares.

El/la estudiante se familiarizará con algunas rutinas básicas de análisis de imagen del software astronómico IRAF (podrá utilizar programas alternativos, si le fueran ya conocidos).

Eva Villaver (UAM) & Alexander Knebe (UAM)

Testing N-body simulations of planetary systems using cosmological codes

There are a number of problems in planetary system formation that require high-resolution numerical simulations. Magnetohydrodynamical (MHD) simulations of proto-stars and protoplanetary disk formation show that multiple planetary-mass objects are formed early in the disk. These planetary-mass objects migrate inwards but following the long-term evolution of these objects remains computationally infeasible using MHD integrations. On the other hand, SPH and N-body simulation allow to set up the problem from a different perspective. N-body problems are a common tool use in cosmological studies. Within this TFM we will explore the feasibility of using cosmological codes to planet formation problems. In particular, the student will apply it to understand the effects of i.e. hot Jupiters in terrestial planet formation.

Gustavo Yepes (UAM)

Studying the baryon content of galaxy clusters in different cosmologies using hydrodynamical simulations.

Known to be the most massive gravitationally bound objects existing, galaxy clusters are fundamental to test cosmological models and to study the evolution of the Universe. A detailed description of their internal structure is therefore needed to match theory and observations.

The purpose of this project is to study the impact of different cosmologies on the baryon content of galaxy clusters. Learning how to manage and analyze numerical simulations, the student will do a detailed study of the clusters formed in the same cosmological box simulated with different sets of cosmological parameters. and baryon physics. The main point of the work will be the analysis of the evolution of the baryon, gas and star fraction at different redshifts and mass, aiming to check whether the new cosmological parameters measured by Planck can introduce any significant change in the cluster properties described by previous observations. An important issue to look at will be how the mass function depends on the baryonic content.

Gustavo Yepes (UAM)

Studying the richness-mass relation of galaxy clusters using numerical simulations

Measuring the mass of galaxy clusters is one of the most challenging goals of cosmological experiments. To this scope, scaling relations are useful as they allow to establish a simple connection between integrated properties of clusters (such as X-ray luminosity or temperature), which can be calculated with observations, and the mass.

The aim of this project is to explore a possible connection between the cluster richness (i.e. the number of bright galaxies inside the virial radius) and the mass, employing hydrodynamical simulations of galaxy clusters. Studying the richness of clusters is important not only to improve the use of scaling relations to measure the mass of clusters, but also to identify clusters via the observation of their brightest objects in large sky surveys. The student will learn how to manage and analyse numerical simulations, and how these can be used to better understand observational results.