Laboratoire d'Astrophysique de Marseille

PhD Students Day

Abstracts booklet

30 November 2017

LAM Amphitheater

PROGRAM

9:00	Breakfast
9:15	First session of presentations
11:00	Coffee Break
11:20	Second session of presentations
13:00	Buffet

I. GECO

Jesus GOMEZ-LOPEZ – 3rd year

The impact of kinematics on the SFH of the Herschel Reference Survey

The Herschel Reference Survey (HRS) is a complete K-band-selected, volume-limited sample of 323 nearby galaxies spanning a wide range in morphological type and stellar mass. Gathering and analyzing high-resolution 2D Perot-Fabry spectroscopic Hα data for the star forming objects of the sample is providing a complementary kinematical information to the sample. I have been actively participating in a long-term observing campaign started in December 2015 and scheduled for 3 years, at the 1.93m telescope at OHP observatory with GHASP instrument, and at the 2.1m telescope in SPM Observatory using the PUMA instrument.

Combined with multifrequency data spanning the whole electromagnetic spectrum (from UV GALEX to far-IR Herschel, including HI and CO), and multizone chemo-spectrophotometric models of galaxy evolution as well as with the CIGALE SED fitting code, these data are necessary to study the role played by velocity rotation and turbulence down to kpc scales in the process of star formation occurring in normal late-type galaxies. This is being done by comparing the radial variations of the star formation activity of galaxies, corrected for dust attenuation using infrared data, and modulated by the variation of the rotational velocity, to the gas surface density of the galaxies. The multifrequency dataset in hour hands will allow us to determine in a self-consistent way, and with unprecedented precision, the 2D-distribution of the different galaxy components (atomic, molecular, dust masses), the dust attenuation, the typical age and metallicity of the different stellar populations and several other properties critical for the study of the radial variation of the star formation history of these galaxies.

Darko DONEVSKI – 3rd year

Understanding high-z dusty Galaxies selected by Herschel

Until recently, a small number of dusty, star-forming galaxies were detected at z>4, most of them strongly lensed. To increase that sample, recent studies have attempted to exploit the Herschel-SPIRE extragalactic surveys, in order to select sources with fluxes rising from 250 to 500 microns (so-called "500um-risers"). They have led to the discovery of some of the farthest starburst galaxies known, and claimed significant overprediction of observed sources with those expected by existing models. We have developed an innovative method to build the statistical sample of "500um-risers" and fully evaluate its properties (Donevski et al., 2017). This is a crucial step towards the understanding of their physical nature.

Yana KHUSANOVA – 2nd year

The properties of the first galaxies reionizing the Universe

At the end of "Dark Ages", the first stars which form in the Universe start ionizing the neutral primordial hydrogen, a major gas-phase transition in the Universe occured, which is called reionization (see reviews by Barkana & Loeb, 2000; Roberston et al. 2010). The goal of this thesis is to establish a robust statistical description of the galaxy population in the end of this epoch using the VIMOS Ultra Deep Survey (VUDS, see Le Fèvre et al. 2015). VUDS is producing an unprecedented sample of ~130 galaxies with ESO-VLT spectroscopy and confirmed redshifts (5.0<z<6.8) from the latest data acquired in 2016. In addition, plethora of photometric data, including images with HST, is available for this sample. A wide range of physical properties will be measured including stellar masses, star formation rates, or ages, based on these galaxy samples observed in well-defined cosmological volumes. The census of ionizing photons produced by these galaxies will then be computed to verify if they are producing enough photons to reionize the universe or if some population is still escaping detection.

Claudia BUSS – 2nd year

Cosmic web reconstruction in the GAMA Survey

Actual galaxies reside within a complex network of knots, filaments, walls, and voids: the cosmic web (CW). This results from the gravitational evolution of primordial matter density perturbations. Therefore, the cosmic web is a natural environment to investigate the evolution of galaxies with cosmic time. Continuing previous works, we propose a method to identify the CW's structures. Finally, we apply this classifier to the GAMA survey and investigate links among properties of galaxies and nearby structures.

Sean MORRISON – 1st year

Large Scale Inhomogeneities in the UV Background

I present a preliminary analysis combining the measurement of the Lyman-alpha forest in both Helium II and Hydrogen I. This combination is thought to be sensitive to large-scale inhomogeneities in the extragalactic UV background (a useful indicator of star formation activity and quasar properties). We test this assertion by making observations of oxygen absorption, which is also sensitive to UV background. In smoothing the ratio of helium to hydrogen and testing its impact on oxygen we measure the dominant physical scale of these effects to be ~7-17 Mpc.

Abhishek MANYIAR – 2nd year

The cosmic infrared background: a tool to connect star forming galaxies to host dark matter halos

ISW dominates on the larger angular scales in CMB power spectrum but is limited by cosmic variance. This is why, cross correlation of CMB with galaxy surveys (which trace the matter distribution up to some bias) are used to detect the ISW with greater SNR. CIB traces the large-scale structure of the universe. Therefore, we cross-correlate CIB with CMB and we find that this method could give the best SNR ever obtained for the measurement of the ISW signal.

We also perform a Fisher matrix analysis to see if we can constrain the cosmological parameters with the ISW signal obtained using the above cross-correlation between CIB and CMB.

Arturo NUNEZ – 2nd year

Indirect searches for Dark Matter towards the Sun with neutrinos

Despite decades of intensive studies, observations and experiments, the nature of Dark Matter remains a mystery. Observations from galactic to cosmological scales leave little room to explanations for Dark Matter other than being a new type of particle relic from the Big Bang. The most attractive candidate for this particle is a Weakly Interacting Massive Particle (WIMP) which naturally arises in many theories beyond the Standard Model which were developed independently to address other questions like the origin of electroweak symmetry breaking or the gauge hierarchy problem.

WIMPs are searched for in variety of ways: by particle production at accelerators, by searching for signals of nuclear recoils (direct detection) and by searching for a signal from secondary products of WIMPs annihilation of decays, in particular gamma-rays and neutrinos. Such annihilation signals are looked for at sources were the WIMPs might be accumulated by gravity: in the core of the Earth or the Sun for neutrino signals; towards the galactic center, the galactic halo, dwarf spheroidal galaxies and galaxy clusters for gamma-ray and neutrino signals. In addition, diffuse signals of WIMP annihilations can be searched for in fluxes of charged cosmic rays, mainly positrons and anti-protons.

Among those, a very promising way to identify the WIMP nature of Dark Matter is to search for an excess neutrino flux from the Sun generated by self-annihilations of WIMPs trapped inside the Sun. The high-energy neutrino flux originating from decay of annihilation products are expected to arrive on Earth and be looked for with neutrino telescopes.

The ANTARES neutrino telescope, located at 2500 m depth in the Mediterranean Sea near Toulon (France), is collecting data with its full configuration since 2008. It is the largest neutrino telescope of the Northern hemisphere, and the only one operated in sea water. Today, ANTARES detected more than 8000 neutrinos above an energy threshold of ~15 GeV, and is planning to collect data until the end of 2016.

This thesis proposal is focused on the study of indirect searches for Dark Matter towards the Sun with neutrinos, both on phenomenological aspects and experimental aspects.

In this thesis, we propose firstly to make a comprehensive review of the uncertainties on the astrophysical parameters playing a role on the capture rate of Dark Matter by the Sun, and their impact on the neutrino signal resulting from self-annihilations of WIMPs trapped in the Sun, such as the local density and the velocity distribution of Dark Matter particles in the neighborhood of the Solar System. The candidate will model the Dark Matter distribution in the MW halo through analytical assumptions and using cosmological simulations of Milky-Way like galaxies, and evaluate the resulting capture rate in the Sun.

The second aspect of this proposal is to pursue the experimental search for the indirect search for Dark Matter towards the Sun with neutrinos by exploiting the full data set of the ANTARES neutrino telescope which will take data until the end of 2016. The current analysis of this signal based on the reconstruction of muon tracks, which has been developed in the past years by the ANTARES team at CPPM, will be extended to the electron neutrino channel by adapting the algorithms recently developed within the ANTARES Collaboration to improve the reconstruction and the selection of the shower events. Due to the analysis of the full ANTARES statistics and the developments in the analysis, one can expect an improvement of almost a factor ten in the sensitivity to the solar indirect detection with neutrinos with respect to the current limits of ANTARES, leading to very competitive results with respect to other neutrino detectors or to direct detection experiments.

Finally, some studies of the performances and sensitivities for indirect search for Dark Matter with the next generation KM3NeT neutrino telescope taking into account the improvements developed for the analyses of the ANTARES data will be performed.

Valentina ABRIL – 1st year

Galaxy Kinematics and the Tully-Fisher relation in z~0.7 groups

The goal of this project is to understand the impact of the environment on galaxy mass assembly mechanisms and on the establishment of the Hubble sequence observed in the local Universe. The environment plays an important role in star formation quenching and in the buildup of the red sequence. The influence of the environment seems to begin to be effective between z=0 and z=1, when cosmic star formation begins to decrease. This project is based on the exploitation of a unique sample from GTO MUSE observations targeted on groups between 0.3<z<1. I will present the current morpho-kinematic analysis on a sub-sample of ~100 galaxies in z ~0.7 groups and a preliminary analysis of the Tully-Fisher relationship. The study of the spatial resolved properties of galaxies, and their kinematics in particular, can better constrain the processes of galaxy mass assembly and provides a better understanding on how baryons are accreted in dark matter halos. The comparison with similar studies in low density environments will ultimately allow to probe the impact of the environment on the evolution mechanisms of galaxies.

Paul ADAMCZYK – 1st year

Kinematic and mass distribution in spiral and irregular galaxies

The goal of this PhD is to go beyond actual issues in spiral and irregular kinematics and mass distributions using data as well as models and numerical simulations. The main goal is to study the mass distribution of galaxies using multiple constraints in order to compute the mass-to-light ratio of the different disk populations and the shape of dark profiles halos. Multiple datasets at different wavelength will be used to perform this unique mass model analysis from 2D kinematics over large sample of well resolved nearby galaxies. High spatial and spectral resolution s two-dimensional Fabry-Perot spectro-imagery data, allowing to take into account inner disk non-axisymmetric structures (bars, spiral arms...) and local motion (velocity dispersion...), complemented by HI data cubes and broad-band photometry, will be used to study the kinematic and dynamics of this sample of galaxies. In addition, I will take advantage of those analyses to constrain dark matter distribution in galaxies at higher redshift in comparing with available data obtained with spectro-imagers and in the frame of the preparation of instrument of further generations in the optical, the infra-red and the radio wavelength (First generation of spectro-imagers for the ELT: Harmoni and Mosaic; third generation spectro-imager for the VLT to be defined; and SKA1 for radio emission lines studies).

Minerva MUNOZ – 1st year

The two-dimensional kinematic of ionized gas of edge-on galaxies from Herschel Reference Survey

This PhD thesis is aimed at gathering and analyze high-resolution two-dimensional Fabry-Perot spectro-imagery data for Herschel Reference Survey (HRS) edge-on galaxies in order to provide complementary kinematical and dynamical information to the unique dataset collected so far. The HRS survey includes a significant number of edge-on galaxies. A detailed and systematic study of the kinematics of the gas at different height from mid-plane will allow us to quantify secular evolution and contribution of outflows/in-falls in shaping galaxy evolution.

Siju ZHANG – 1st year

The interplay between ionized regions and star formation

Star formation occurs at the edges of ionized (HII) regions. This phenomenon is observed in the Galaxy and in external galaxies. In our Galaxy it could concern up to half the star formation and up to 1/3 of the massive-star formation. High mass stars play a crucial role in galaxies' evolution. Therefore, we must characterize this phenomenon and understand how their feedback impacts on the surrounding medium.

We propose to use multi scale and multi wavelength, ground-based and space- based data, to characterize this phenomenon. A particular attention will be drawn on characterizing the physical interaction between the HII region and young stars that form at their edges: shocks, compression, turbulence? High mass dense cores that form the high mass stars will be study throughout their evolution sequence, from the core formation up to the stars (clusters) formation. The way all generations of high mass stars influence their surroundings will be studied to quantify the impact they have on the Star Formation Rate (SFR) and the Star Formation Efficiency (SFE), key ingredients for galaxies' evolution models.

Observations will be compared to the most recent models (shock-induced compression, turbulence and ionization feedback, etc...) to characterize the key ingredients that control the physics of the interaction between HII regions and young stars forming in their immediate vicinity. The dynamics of the interaction will be studied carefully using spectroscopic data and together with a fine modeling of expected line emission profiles.

Data already exist to start the project and new pertinent ones (including lines and continuum from the ALMA and NOEMA millimeter interferometers) will be acquired in the process of the PhD. The part dedicated to shocks and study of the young high mass star clusters will be studied with proposed programs on the James Web Space Telescope, to be launched at the end of 2018. The study (data & modeling) will concern also nearby external galaxies, i.e. the Small and Large Magellanic Clouds.

Grzegorz GAJDA – 3rd year *– Poster*

Tidally induced bars in dwarf galaxies

Dwarf galaxies are believed to form in isolation, as objects having a stellar disc along with a dark matter halo. Later on, they are accreted by larger galaxies, such as our Milky Way. After the first pericenter passage, a bar forms in the disc of the dwarf. During the further evolution the disc gradually evolves into a spheroid. I am focusing on the intermediate stage, when the bar is present. It allows us to understand how the initially flat distribution of the baryonic matter is transformed into a round object. In the first part, I studied the stellar orbits in such a bar and their impact on the kinematics of the dwarf. In the second part, using N-body simulations, I analyzed impact of the two factors: size of the initial orbit of the dwarf and inclination of its stellar disc. Currently, in the last part, I am studying how bars are influenced by the presence of the interstellar gas and star-forming processes.

Elena SARPA – 1st year *– Absent*

Reconstruction of cosmological density and velocity fields by Fast Action Minimization method

Cosmological massive spectroscopic surveys benefit from an accurate modeling of the density and velocity fields, ideally down to the high-density regions in which the gravitational clustering attains the non-linear regime. This can be achieved by so-called reconstruction techniques, modeling backward-in-time the trajectories of galaxies, or any point-like particles interacting only by gravity in an expanding Universe. Nowadays those techniques are regularly used to improve the analysis of Baryonic Acoustic Oscillations (BAO), providing an useful tool for non-parametric modeling of Redshift Space Distortion (RSD). We are developing a new version of the Fast Action Minimization method (FAM, Nusser & Branchini 2000), dubbed extended-FAM or eFAM, intended to reconstruct the trajectories of more than 10^5 particles in a generic cosmology. Particular attention is dedicated to the application of the eFAM to n-body simulations in order to show its potentiality in improving the measurement of the BAO peak by reconstruction of the density field back to an epoch prior non-linear evolution. Moreover, we'll present the ability of eFAM in recovering the velocity field.

Olivier KAUFFMANN – 1st year

The first galaxies reionizing the Universe at 6<z<15 as seen with JWST and Euclid

At the end of "Dark Ages", the first stars which form in the Universe start ionizing the neutral medium of primordial Hydrogen, a major gas-phase transition in the Universe called reionization (see reviews by Barkana & Loeb, 2000; Roberston et al. 2010). The goal of this thesis is to establish a robust statistical description of the galaxy population which produced this reionization.

Observations of the cosmic microwave background (CMB) by the Planck satellite indicate a mean redshift for the reionization of z=8.8-1.5 but does not provide the length of this phase, nor the time when it ended. The fraction of galaxies with a strong Lyman-α line emission continuously increases up to z~6 (Cassata et al., 2014) but suddenly seems to drop when going to higher redshifts z>7 (e.g. Stark et al., 2010). This is interpreted as the signature of the end of the reionization epoch at z~6.

In the past years considerable progress was made in finding galaxies in the reionization epoch (see e.g. Bouwens et al., 2015; Bowler et al., 2015). However, the number of galaxies identified at these high redshifts remains small, so that the population-average properties of galaxies at this epoch remain poorly defined, and the end of reionization poorly constrained (Robertson et al., 2015).

This PhD subject proposes to conduct one of the first systematic and statistically representative study of galaxies in the reionization epoch from the first surveys which will be conducted with the new James Webb Space Telescope, using the guaranteed time of the MIRI instrument (co-investigator: Le Fèvre). MIRI is one of the few instruments on-board JWST performing imaging and spectroscopy in the wavelength domain 5<λ<25 microns. In the framework of the guaranteed time observations (GTO), ~130h of observations will be devoted to the identification and study of galaxies during the reionization, combining images with MIRI and NIRCAM (the camera in the 1<λ<5 microns domain) and MIRI spectra. MIRI is the only instrument capable to identify the first light galaxies, the first being formed, from galaxies already evolved. It will also follow the Hydrogen Hα emission line, the main tracer of star formation, well into the reionization epoch.

The student will participate to the preparation of the observations planned right after the launch in October 2018, including the careful simulation of the expected observational signatures. The very high redshift candidates will be identified from the MIRI image processing. Detailed analysis will involve the development of specific tools, leading to the measurement of key physical parameters (stellar mass, star formation rate, age, …). Luminosity functions will be built from the observed luminosities of the sources identified, including the Hα luminosity, and a census of the number of ionizing photons will be produced. These results will be confronted to the constraints on the reionization from the Planck satellite. The student will therefore have a unique opportunity to participate to the deep fields JWST program on the MIRI GTO, and be among the first to analyze these exceptional data.

The knowledge accumulated working on the reionization with JWST will then be used to produce detailed predictions on the deep survey of 40 square degrees of the ESA-Euclid space mission, and supported by CNES. The emphasis will be placed on predicting the number of galaxies expected in different redshift domains into the reionization epoch, the properties of galaxies which will be detected, and how these galaxies will contribute to understanding the reionization process in the universe. Software tools will be developed to analyze these galaxy populations and the associated number of ionizing photons.

The student will work in the following phases: (1) bibliography and consolidation of the core investigation to be carried out, (2) realistic simulations of distant galaxies to be observed with MIRI (3) data analysis of the MIRI GTO data, identification of the "firs light" galaxies and census of galaxies in the reionization epoch, (4) measurement of physical parameters and statistical functions (luminosity function, mass function, age function,…), (5) census of ionizing photons and comparison to $\tau_{reionization}$ from Planck.

The successful applicant will join the LAM team working in JWST-MIRI and Euclid international collaborations, also with COSMOS, VUDS and UltraVista, offering opportunities for a career path in Astrophysics after PhD.

II. GRD

GRD

R&D Optics &
Instrumentation

Cédric HÉRITIER – 2nd year

Calibration and Optimization of complex Adaptive Optics Systems for Extremely Large Telescope

The future Extremely Large Telescopes (ELT), with diameters up to 39 meters, will provide details about our Universe with a precision never achieved before for ground-based observation. However, in order to fully benefit from the potential of these telescopes, the scientific instruments will rely on complex Adaptive Optics Systems (AO) to correct for the optical aberrations due to the atmospheric turbulence. These AO systems require a fine tuning before and during the operations to ensure the best correction. The situation, however, will be completely new for the European Large Telescope (E-ELT), as the particular design of the telescope will provide a constraining environment for the AO calibration.

This will be particularly true concerning the Interaction Matrix of the system that defines the link between the Deformable Mirror (DM) actuators and the Wave-Front Sensor (WFS) signals. Indeed, the telescope will include a complex concept of a DM integrated in the telescope itself, with a new geometry, a large number of actuators and mostly no calibration source. The DM location will also require to regularly update the Interaction Matrix during the operation, as the registration between the two systems may evolve dynamically with the telescope (shifts, rotation, magnification or higher order of pupil distortion) and depend on the seeing conditions.

In this context, developing new methods and optimizing the calibration procedures becomes necessary to overcome these constraints. Some strategies based on synthetic models and/or on-sky measurements have already been identified and tested on 8-meters facilities. The first results of these experiments seem to lead to a Pseudo-Synthetic method, merging on-sky measurement for the accuracy and synthetic models for fast computation. This highlights two critical goals for the AO calibration in the ELT context: developing accurate and complex models and fast mis-registrations tracking methods, if possible with no impact on the observations.

Anne-Laure CHEFFOT – 1st year

Phasing strategies for segmented Telescopes

In order to go for bigger than 8-meter light collectors, we need to segment our mirrors. This does not come for free. Once you segmented your mirror you need to make sure it behaves like if it was a monolithic mirror. To do this you need a technic that allow you to detect your mirror is misbehaving. This is the entire topic of my PhD, what is the state of the art in technologies to monitor discontinuous surface and which one is the most suited to an ELT.

Grégoire Hein – 1st year

Segmentation of focal planes

One of the parameters dimensioning imagery systems in low orbits for planetary observations is the physical size of the focal plane, using the TDI pushbroom technology.

This thesis aims at consolidating the development of an innovative focal plane layout, allowing to significantly reduce the size and mass of future low-orbit systems. This focal plane layout suggests the segmentation of linear focal plane, and then the rearrangement of the segments on a square matrix.

Sabri Lemared – 1st year

High performance large lightweight mirrors for Space and Earth observations

The future generation of space telescopes will allow to reach high angular resolutions thanks to the increase of the primary mirrors size. This increase, coupled with the constraints of mass and volume for the launch, as well as the constraints of performances bound to the needs for high angular resolution, leads to the development of technologies used for the realization of large diameter mirrors.

My PhD work is to be able to combine lightweight mirrors and surface quality to assure the correct functioning of the future active space telescopes. An optical fabrication method based on the stress-polishing, enable to minimize the defects of medium and high spatial frequency aberrations, is developed in partnership with the LAM and the industrialist Thales-SESO. Combining these two techniques will allow to reach production capacities of large lightweight mirrors, with unequalled performances. This method will be essential for high angular resolution emergence of the future space observatories, observation of the Earth (OTOS / TANGO projects) or observation of the Universe with the post-JWST generation (ATLAST, TALC).

Mélanie Roulet – 1st year

3D printing for astronomical mirrors

The advent of additive manufacturing offers a new set of capabilities in the field of optical manufacturing. The objectives of this thesis are to develop innovative manufacturing process making use of 3D printing advents, we interest in two different application ways. The first method makes use of 3D printing in the fabrication of warping harnesses for stress polishing, and we apply that to the fabrication of the WFIRST coronagraph off axis parabolas. The second method considers a proof of concept for 3D printing of lightweight X-Ray mirrors, targeting the next generation of X-Ray telescopes such as the US Decadal Survey study LYNX.

Mathieu VACHEY – 1st year

Next generation compact spectro-imagers for Universe and Earth observation

The main subject of my thesis is the conception of new instruments for Universe observation, Earth observation and planet exploration by using breakthrough technologies, such as Micro-Opto-Electro-Mechanical Systems (MOEMS). This will include work such as optical design, performance evaluation and possible breadboard realization of the promising design and will be done.

This work is based on a current study of a MOEMS-based instrument, developed by LAM and Italian laboratories and observatories and called BATMAN, which is a new generation spectro-imager. It will be placed on the Telescopio Nazionale Galileo in the Canarias Islands by the end of 2018.

My work as a PHD student is to deepen and find new concepts for these instruments, study their ability to go in space environment and their performance with respect to the scientific requirements. I will also have to develop an end-to-end spectro-photometric model of BATMAN, in order to address the different science cases and be able to optimize the instrument design.

Romain FETICK – 1st year

Toward efficient data processing techniques for high-angular resolution images in the visible: Application to satellite and astronomical observations

The era of adaptive optics (AO) allows high resolution imaging through the atmospheric turbulence. However, the Point Spread Function (PSF) is still not diffraction limited and induces some additional image blurring. Image deconvolution allows to de-blur AO image and retrieve further details in the observed object. Deconvolution process is known to be an ill-posed problem that requires an accurate knowledge on the PSF.

However observational constraints arise when imaging a PSF, limiting its quality for deconvolution process. Technics such as blind or myopic deconvolution have been developed to take into account the poor knowledge on the PSF, letting the algorithms retrieving both objects and its associated PSF. Nevertheless, these algorithms converge slowly and with reduced accuracy due to the higher number of parameters to estimate for the couple object and PSF. We propose here to use a parametric PSF to drastically reduce the number of parameters to estimate. Our function of parametric PSF allows high accuracy in describing a PSF, and is made of few parameters leading to a fast and accurate fitting of the observed PSF. This parametric PSF is then incorporated in a myopic deconvolution algorithm to increase its efficiency. We use the algorithm MISTRAL (developed by LAM/ONERA) particularly adapted to perform deconvolution on sharp edged objects, such as asteroids or low altitude satellites. We tested with success our model of PSF both on simulated data and several imaged asteroids from the VLT SPHERE Zimpol instrument. Our deconvolution method permitted to detect smaller asteroids' craters, a better estimation on asteroids' volume and in consequence a better knowledge on their density or chemical composition.

III. GSP

Thomas Ronnet – 3rd year

Formation of satellites around planets: the case of Jupiter's icy moons in the context of the ESA JUICE mission

All the giant planets of our Solar System possess a cortege of regular satellites and two out of four terrestrial planets also have their own moon(s). Of particular interest, the four massive moons of Jupiter, known as the Galilean satellites, present a great diversity in their composition and activities. Two of them, Europa and Ganymede, have confirmed liquid water ocean underneath their icy crust, making them of peculiar biological interest. The potential habitability of these small icy worlds have made them the targets of both a NASA (Mission to Europa) and an ESA (JUpiter ICy moon Explorer, JUICE) mission. This also raised the interest in an active search of massive moons around extrasolar planets, although none have been detected so far.

The aim of this PhD is to investigate the conditions of formation of satellites around planets, with an emphasis on the Jovian system. We try to provide constraints on the origin of the moons of the Solar System to better apprehend the data that will be collected by in situ mission such as JUICE (or the JAXA mission to Mars' moons). We also attempt to unveil general mechanisms at play during satellites formation to constraint their presence around extrasolar planets.

Bastien Brugger – 3rd year

Modeling the interior of small exoplanets: from Super-Earths to mini-Neptunes

Thousands of extrasolar planets have been discovered over the last two decades. These worlds come in a huge variety of sizes and orbits, however our knowledge of their composition remains extremely limited. Modeling the interior of such bodies is necessary to go further than the first approximation given by their mean density. We present a numerical model aiming at computing the internal structure of Super-Earths and mini-Neptunes (up to ~10 Earth masses), two exoplanet families that fill the gap between the terrestrial and the giant gaseous planets present in our solar system. By connecting this model to data from the next generations of space missions (CHEOPS, PLATO) – who will provide exoplanets parameters with an unrivaled precision –, we should be able to break the remaining degeneracies on the possible exoplanets compositions.

Melissa Hobson – 2nd year

Optimize exoplanet detection around M stars with nIR spectrograph

The detection of exoplanets around M-dwarf stars is a rapidly growing field. Since these stars are faint in the visible, the SPIRou nIR spectrograph is being developed to exploit their infrared radiation. In this thesis, I will study how to best extract radial velocities from the data, avoiding telluric contamination and identifying variations induced by stellar activity, in order to robustly detect exoplanets. I participated in the validation tests of SPIRou at IRAP, Toulouse. With Isabelle Boisse and François Bouchy, I am currently working on the development of the SPIRou data reduction system (DRS).

I also participated to observations with SOPHIE@OHP as part of the RPE consortium, in order to acquire experience with exoplanet searches via high-resolution spectroscopy in the visible. I re-analyzed the M-dwarf data obtained by the RPE consortium with NAIRA (an algorithm developed for M-dwarf data analysis by Astudillo-Defru, 2015), adding corrections for the CTI effect and long-term instrumental variations. I examined the RV periodograms to identify planetary candidates; I also calculated activity indices in order to search for possible contamination by stellar activity.

Théo LOPEZ – 1st year

Revealing the diversity of small worlds with K2 and HARPS

Small exoplanets exhibit a surprising diversity in terms of composition. Their bulk density, derived by combining space-based transit photometry and high-precision Doppler spectroscopy, is ranging from low-density mini-Neptunes to massive super-Earths. So far, no clear transition between rocky and gaseous planets have been observed. These objects are challenging all planet-formation theories and no example of them is known in the solar system.

The exploration of these small exoplanets is currently limited by the precision achieved on their fundamental properties. While about a hundred super-Earths have been characterized so far, it is possible to determine unambiguously whether they are rocky or gaseous only for a dozen of them.

The objective of this PhD is to reveal the diversity of these small worlds by combining the two most powerful exoplanet-hunter instruments: the Kepler space telescope and the HARPS spectrograph at the European Southern Observatory. The first goal is to exploit and interpret the data from a 2-year large programme on HARPS within a European consortium composed by world experts in the exoplanet field. In this context, observing runs are carried out on HARPS in Chile but also on SOPHIE at the Haute-Provence observatory (France). The PhD work also focus on developing new methods to correct for stellar variability in both high-precision radial velocity and photometry.

Indeed, the substraction of the stellar signal contained in the data is primordial in order to identify low-amplitude planetary signatures. The correction of stellar activity will also be of prime importance for the success of the future space missions TESS and PLATO as well as the new generation of spectrographs: SPIRou and ESPRESSO.

Alexis DROUARD – 2nd year – *Poster*

Probing the use of spectroscopy to determine the meteoritic analogues of meteors

Determining the source regions of meteorites is one of the major goals of current research in planetary science. Whereas asteroid observations are currently unable to pinpoint the source regions of most meteorite classes, observations of meteors with camera, radio networks and the subsequent recovery of the meteorite may help making progress on this question. The main caveat of such approach, however, is that the recovery rate of meteorite falls is low (<20 %) implying that the meteoritic analogues of at least 80% of the observed falls remain unknown. Spectroscopic observations of incoming bolides may have the potential to mitigate this problem by classifying the incoming meteoritic material. To probe the use of spectroscopy to determine the meteoritic analogues of incoming bolides, we have collected emission spectra in the visible range (320-880 nm) of five meteorite types (H, L, LL, CM, eucrite) acquired in atmospheric entry-like conditions in the plasma wind tunnel at the Institute of Space Systems (IRS) at the University of Stuttgart (Germany). A detailed spectral analysis including a systematic line identification and mass ratio determinations (Mg/Fe, Na/Fe) was subsequently performed on all spectra. Results. It appears that spectroscopy, via a simple line identification, can allow us to distinguish the three main meteorite classes (chondrites, achondrites, irons) but it has not the potential to distinguish for example an H chondrite from a CM chondrite. To conclude, the source location within the main belt of the different meteorite classes (H, L, LL, CM, CI, etc..) should continue to be investigated via fireball observation networks. Spectroscopy of incoming bolides will only marginally help classifying precisely the incoming material (iron meteorites only). To reach a statistically significant sample of recovered meteorites along with accurate orbits (>100) within a reasonable timeframe (10-20 years), the optimal solution maybe to extend spatially existing fireball observation networks.