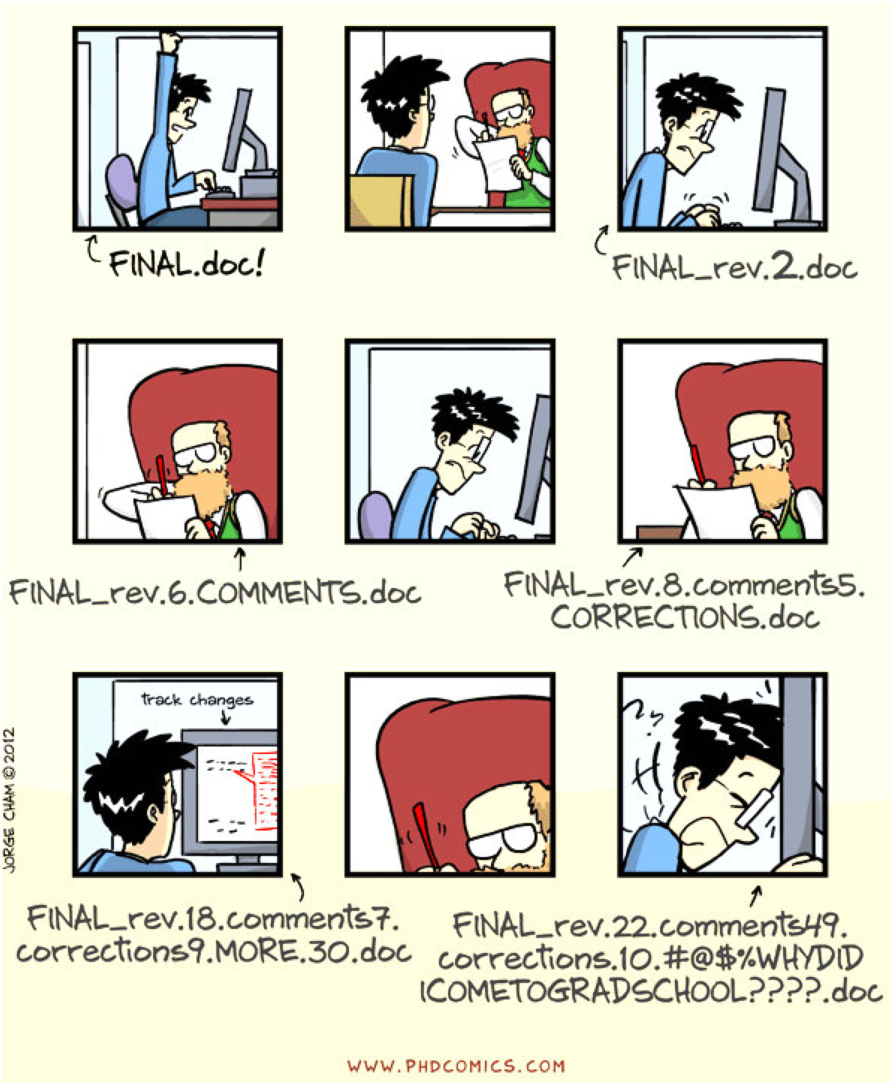
Theses Day

Journée des thèses

24/03/2017

Institut d'Astrophysique de Paris

Amphithéâtre Henri Mineur



Theses day, Journée des thèses

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Institut d'Astrophysique de Paris

09:00	*Welcoming*	
09:10	Céline Gouin	Multipolar moments of weak lensing signal around galaxy clusters. Weighing filaments in harmonic space
09:25	Arno Vanthieghem	PIC simulation of relativistic collisionless shocks
09:35	Adèle Plat	Modelization and interpretation of spectral properties of primeval galaxies.
09:45	Florian Sarron	The evolution of the cluster optical galaxy luminosity function up to $z \sim 1$ in the CFHTLS
10:00	Gohar Dashyan	AGN in dwarfs?
10:10	Debika Chowdhury	Three-point functions in the early universe
10:30	*Coffee*	
11:00	Oscar Ramos	Testing Lorentz Invariance by binary black holes
11:15	Adarsh Rajan	Evolution of cold gas in the Universe
11:25	Federico Mogavero	Towards the Statistical Mechanics of Planet Orbits in the Solar System
11:45	Siwei Zou	The cold gas in and around high redshift galaxies
12:00	Nicolas Cornuault	What is the history of gas travelling through intergalactic filaments?
12:20	Doogesh Kodi Ramanah	Statistical data analysis of large & complex data sets for cosmological inference
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14:00	Giulia Cusin	Stochastic background of gravitational waves: an analytic approach
14:20	Hugo Pfister	The birth of a supermassive black hole binary
14:30	Jesse Palmerio	Clues about the long Gamma-Ray Burst progenitors: population model and host galaxies
14:45	Camilia Demidem	Corrugation of relativistic magnetized shock waves
14:55	Tanguy Marchand	4.5 Post-Newtonian order gravitational radiation
15:10	Caterina Umiltà	Improving Planck cosmological results with component separation
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16:00	Matteo Rizzato	High order correlation functions in the large-scale structure of the universe - exploitation of the Euclid mission
16:10	Claire Guépin	High-energy astroparticles and transient sources
16:20	Erwan Allys	Vector- and multi-scalar Galileon theories
16:40	Mo Yang	Comprehensive modeling of exoplanetary atmospheres
16:50	Corentin Cadiou	Exploring the origin of the morphology of galaxies: beyond the mass proxy
17:00	Sébastien Carassou	Simulating galaxy survey images to infer the properties of galaxies through cosmic times
17:20	*Cocktail*	

Multipolar moments of weak lensing signal around galaxy clusters. Weighing filaments in harmonic space

Upcoming weak lensing surveys like Euclid will provide an unprecedented opportunity to quantify the geometry and topology of the cosmic web, in particular in the vicinity of lensing clusters. Characterizing the connectivity of the cosmic web by weak lensing signal, an unbiased mass tracer, was the first goal of my thesis work.

As presented in my first paper (Gouin et al, 2017), I have used the PLUS N-body simulation to measure the projected density around massive galaxy clusters, and I have focused on multipolar moments of this signal to probe the azimuthal shape of clusters (inside and outside the virial radius). Computing the power spectrum of these moments, we observe a chromatic power excess at all scales, which is understood as the contraction of the primordial cosmic web driven by the growth of the cluster potential. Besides this boost, the quadrupole prevails in the cluster core (ellipsoidal shape), while at the outskirts, harmonic distorsions are spread on small angular modes, and should represent the non-linear sharpening of the filamentary structures. We make predictions on the signal amplitude as a function of cluster-centric distance, mass and redshift and present the prospects for measuring it in current and future lensing data sets.

Furthermore, with the advent of high performance computing, it has now become possible to address the problem of the complex interplay of baryons and dark matter on all relevant scales. In this context, we propose to predict the gravitational lensing signal (either strong or weak) with state-of art hydrodynamical cosmological simulation.

Supervisors: Christophe Pichon & Raphaël Gavazzi

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PIC simulation of relativistic collisionless shocks

Among other powerful relativistic astrophysical objects, gamma-ray bursts, blazars, pulsar winds provide an ideal environment to understand the acceleration mechanisms of high energy charged particles. The high-energy electromagnetic spectra of these sources generically follow a power law distribution attributed to synchrotron and inverse Compton radiations of non-thermal particles. These non-thermal spectra can naturally be linked to the presence of relativistic outflows through a conversion of kinetic or Poynting flux in a non-thermal particle energy distribution in relativistic shocks through the development of microscopic plasma instabilities. A deep insight into these phenomena requires an understanding of the micro-physics of collisionless shocks. This can be done via Particle In Cell (PIC) simulations, which provide ab initio numerical experiments of the acceleration mechanism properties and their efficiency.

Supervisors: Martin Lemoine & Laurent Gremillet (CEA-DAM)

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Modelization and interpretation of spectral properties of primeval galaxies.

The James Webb Space Telescope (JWST, to be launched in 2018) will enable the direct exploration of primeval galaxies near the Epoch of Reionization, at the end of the Dark Ages. To best interpret these upcoming observations in terms of constraints on theories of galaxy formation and evolution, we require models of the light emitted by the first galaxies. A particularly critical task is to identify spectral diagnostics of the different ionizing sources capable of powering the first galaxies, such as young massive stars and accreting black holes, and of the leakage of ionizing radiation into the intergalactic medium. This is the focus of my thesis.

Supervisor: Stéphane Charlot

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The evolution of the cluster optical galaxy luminosity function up to $z \sim 1$ in the CFHTLS

There is some disagreement in the literature about the evolution with redshift of the galaxy luminosity function of clusters of galaxies, especially its faint-end. However, large samples of galaxy clusters up to medium-high redshift and studies of galaxy populations within them have been rare so far.

In this talk, I will present an updated version of the Adami and MAzure Cluster FInder (AMACFI), a cluster detection algorithm based on kernel density estimation to detect galaxy clusters using photometric redshifts (photo-z). I will emphasize the modifications I brought to the algorithm to drastically improve its performances.

Using AMACFI on the Canada France Hawaii Telescope Legacy Survey (CFHTLS) Wide1 field - covering more than 60 deg2 - we detected about a thousand candidate clusters/groups up to $z \sim 1.1$. I will briefly discuss the performances of our candidate cluster catalog and then present preliminary results on the galaxy luminosity function of clusters obtained from the study of this sample. We will particularly focus on redshift evolution of cluster galaxy populations.

Supervisors: Florence Durret & Christophe Adami (LAM)

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AGN in dwarfs?

Dwarf spheroidal (dSph) galaxies are the most dark matter dominated objects known, and because of their low luminosity, they represent the final frontier to understand galaxy formation and evolution. dSph galaxies are, however, still poorly understood. Indeed, the ΛCDM model has proven successful at reproducing the large scale universe, however, disparities exist between the theory and observations on small scales: the model predicts too many small galaxies and cuspy dark matter profiles that are not yet convincingly observed, and the most massive dwarfs predicted by ΛCDM simulations are rarely observed. Baryonic feedback, especially supernovae feedback may be a resolution to all these difficulties. Ram pressure stripping, tidal stripping, harassement, are alternative or complementary mechanisms, and one must also consider that the progenitors of dSph galaxies probably form efficiently before the epoch of reionization. It is, however, still not clear whether these mechanisms can reconcile theory and observations at the low mass end of the galaxy luminosity function.

Before embarking into dynamical analyses of the dSph galaxies around the Milky Way and of cosmological hydrodynamical simulations of the formation and evolution of dSph galaxies, we analytically explore the possibility feedback from Active Galactic Nuclei (AGN) in dwarf galaxies. Considering the presence of an intermediate mass black hole within low mass galaxies, we use simple scaling relations and model the propagation and properties of the blast wave to reveal a critical condition for global gas loss. Doing the same calculation for supernovae, we compare the ability of outflows from AGN and supernovae to drive gas out of galaxies.

Supervisors: Gary Mamon, Yohan Dubois & Joseph Silk

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Three-point functions in the early universe

Inflation has been widely regarded as the most promising scenario to explain our observations of the early universe. However, the existence of a large number of inflationary models that are in concordance with observational data has made it difficult to arrive at a unique model of inflation. In such a situation, it seems worthwhile to investigate alternative scenarios of the early universe, specifically the so-called bouncing models. In this talk, I shall discuss the evaluation of three-point functions in a specific inflationary model and a particular class of bouncing models. I shall consider the axion monodromy model of inflation and discuss the evaluation of the scalar-scalar-tensor cross-correlation in this model. I shall also analytically establish the consistency relation (in the squeezed limit) for this three-point function. I shall then consider a specific class of bouncing models, namely the matter bounce, and discuss the analytical evaluation of the tensor modes and the tensor bispectrum in this scenario. Further, I shall show that the consistency relation corresponding to the tensor bispectrum is violated in a matter bounce. The behavior of the three-point functions can hence be used to highlight the primary differences that can arise between the inflationary and bouncing scenarios.

Visitor from Indian Institute of Technology Madras working with Jérôme Martin
Supervisors: Prof. Lakshmanan Sriramkumar at Indian Institute of Technology Madras

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Testing Lorentz Invariance by binary black holes

The recent detection of gravitational waves has opened a new avenue towards the highly-relativistic and dynamical strong-field regime of the Einstein equations. It's therefore possible to test GR in a new arena characterized by velocities comparable to the speed of light and by large, dynamical curvatures. After describing how gravitational waves and binary black holes can be used to test GR, we will focus upon one particular alternative: Lorentz-violating gravity. Although Lorentz-invariance is at the heart of theoretical physics, it's violation in the gravitational sector may lead to a quantum theory of gravitation, for instance. Thus, we will show the first steps towards the ambitious project of using GW signals to test Lorentz-violating theories.

Supervisors: Luc Blanchet & Enrico Barausse

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Evolution of cold gas in the Universe

Damped Lyman-alpha absorption systems are pockets of high density (about 2 $\times 10^{20}$ atoms/cm^2) gas which are detected in quasar absorption spectra. When a quasar spectra passes through the a gas cloud, It creates a damped lyman-alpha absorption at a redshift inherent to the gas. We can study this absorption along with lyman-beta and lyman limit absorption to understand the HI column density of the cloud. Apart from this, we can also detect lines for metals present in the gas and molecular hydrogen. If we fit the absorptions with a voigt profile, we can estimate the column density and intrinsic velocity(and hence temperature) of the gas. My project involves with analyzing the observed spectra from DLA systems and estimate the given parameters for all the atoms and molecules mentioned above. Since molecular hydrogen is strongly connected to star-formation, we can predict properties of star-formation in the early universe just by observing galactic gas clouds at high redshift. Apart from this, we can also predict metallicity of different DLAs found. I specifically use tools like VPFIT to fit the voigt profile to an observed spectra.

Supervisors: Patrick Petitjean & Pasquier Noterdaeme

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Towards the Statistical Mechanics of Planet Orbits in the Solar System

The chaotic nature of planet dynamics in the solar system suggests the relevance of a statistical approach to planetary orbits. In such a statistical description, the time-dependent position and velocity of the planets are replaced by the probability density function (PDF) of their orbital elements. It is quite natural to set up this kind of approach in the framework of statistical mechanics. Indeed, Tremaine (2015) has recently addressed the statistical mechanics of terrestrial planet formation. In the present study, I focus on the collisionless excitation of eccentricities and inclinations by gravitational interactions in a planetary system. The prototype of such a dynamics are the future planet trajectories in the solar system. I thus address the problem of constructing the statistical mechanics of the solar system planet orbits by investigating an ergodic ansatz based on the integrals of motion. I compare the resulting predictions to the PDFs numerically constructed by Laskar (2008). I also revisit his random walk ansatz to account for the time dependence of these PDFs. Such a statistical theory could be combined with direct numerical simulations of planet trajectories in the context of planet formation, which is likely to be a chaotic process.

Supervisor: Jean-Philippe Beaulieu

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The cold gas in and around high redshift galaxies

We study a complete sample of 66 neutral atomic carbon (CI) quasar absorption systems, to investigate the cold gas in the interstellar medium of high-redshift galaxies ($1.5 < z < 3.1$). Such absorbers arise in DLAs and probe highly shielded gas in which molecules are expect to form. We reobserved 17 CI absorbers with VLT-Xshooter. Thanks to the large wavelength range of Xshooter, we detect NaI and CaII in the near infrared arm (NIR), which have rarely been investigated at such redshifts. The preliminary results indicate that metallicities are close to solar and the dust content is high. We compare our results with studies in the local universe.

Supervisors: Patrick Petitjean & Pasquier Noterdaeme

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What is the history of gas travelling through intergalactic filaments?

Formation of galactic halos implies anisotropic accretion. Knowledge of the thermal and dynamical properties of gas in those halos is not yet accurate enough to complete the picture of galaxy evolution: Why do we overpredict baryonic masses in halos? Are feedback processes the only reasons for a statistically decreasing star formation rate between $z \sim 1$ and $z \sim 2$? Do current models for radiative shocks fully cover the plausible regulation of gas accretion? Analytical modelling and numerical simulations help in the understanding of gas physics accompanying the process of accretion. After having considered the importance of turbulence and thermal instabilities driven by filamentary accretion, we explored the structure, dynamics and thermodynamics of those streams prior to their entry into the halo, at $z \sim 2$. In the light of those investigations, we can reasonably postulate that, apart from geometrical peculiarities, gaseous halos and filaments share a common history, in that the flows that contribute most to their growth (respectively filaments and sheets) are likely, not only to form a condensed structure, but also to surrounding turbulent and thermally fragmented gas. Confirming this hypothesis would be a major step in answering the aforementioned questions.

Supervisors: Matthew Lehnert, François Boulanger (IAS) & Pierre Guillard

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Statistical data analysis of large & complex data sets for cosmological inference

The data analysis of state-of-the-art cosmological data sets with unprecedented levels of sensitivity and resolution poses complex numerical challenges. Fast, robust and sophisticated methods are therefore required to render the data analysis computationally tractable and optimise the scientific returns of the missions. The Wiener filter has emerged as one such standard tool for the inference of high dimensional signals, such as the large scale structures and cosmic microwave background (CMB) problems. We present a new fast and robust iterative solver, via a formulation that is dual to the recently developed messenger technique, to efficiently calculate the Wiener filter solution of large and complex data sets. Like its predecessor, this new dual messenger algorithm does not require a preconditioner and can account for inhomogeneous noise distributions and arbitrary mask geometries, while being unconditionally stable. We demonstrate the capabilities of this hierarchical scheme in signal reconstruction by applying it on a simulated CMB temperature data set to investigate the effectiveness of reconstruction and convergence properties. We also present a brief description of our current work involving the development of a large-scale Bayesian inference framework to constrain cosmological parameters using galaxy redshift surveys, via an application of the Alcock-Paczyński (AP) test. This hierarchical approach relies on efficient Wiener filtering to derive a new self-consistent AP test, exploiting the full complexity of galaxy redshift surveys.

Supervisors: Guilhem Lavaux & Benjamin Wandelt

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Stochastic background of gravitational waves: an analytic approach

The presence of unresolved sources of gravitational waves (e.g. SN, merging and inspiralling binary systems) is at the origin of the existence of a stochastic gravitational wave background. While its mean density has been computed in many works, the computation of its anisotropies requires to understand the coarse graining from local systems, to galactic scales and then to cosmology. I shall present the computation of the gravitational wave energy density valid in a general spacetime. I then specialize to a Friedmann-Lemaître universe and I compute the angular power spectrum of this stochastic background as well as its correlation with the distribution of galaxies and weak lensing.

Visitor from University of Geneva working at IAP with Jean-Philippe Uzan and Cyril Pitrou
Supervisor: Michele Maggiore at University of Geneva

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The birth of a supermassive black hole binary

Supermassive black holes (SMBHs), which can be found in the center of most of the most massive galaxies today, are thought to play a crucial role in galaxy evolution. However their growth and dynamics is still poorly understood. In this presentation we focus on how, in galaxy mergers, SMBHs reach small separation to form a bound binary. The main difficulty in tackling this issue is the range of scales involved: from sub-pc scales to hundreds of kpc scales. We zoom in on an already very high resolution (20 pc) simulation of major mergers and reach pc resolution, allowing us to understand what drives the dynamics of BHs from kpc to pc scales.

Supervisor: Marta Volonteri

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Clues about the long Gamma-Ray Burst progenitors: population model and host galaxies

Gamma-Ray Bursts (GRBs) are short, intense bursts of electromagnetic radiation in the hard X-rays and soft gamma-rays originating from space. Because of their detectability up to very high redshift ($z > 9$) and their transient nature, GRBs and their afterglows offer unique tools to probe the distant universe. Because of their link to Star Formation, one of the key challenges today is to identify the progenitors of Long GRBs (LGRBs). I aim to address this question in my PhD by studying a complete sample of their host galaxies and with a LGRB population model. In this talk I will describe these two complementary approaches and present my first results .

Supervisors: Frédéric Daigne & Susanna Vergani (GEPI/IAP)

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Corrugation of relativistic magnetized shock waves

Good candidate sites for cosmic rays' acceleration are collisionless shocks (ie governed by em interactions) encountered in supernovae remnants of pulsar wind nebulae for eg. One of the key ingredients for Fermi acceleration to occur is turbulence but it remains poorly understood, all the more in the magnetized and relativistic regime. In this context, I study through relativistic MHD simulations how a shock reacts to incoming upstream waves. I check that for low amplitude waves, we observe the behavior expected from linear analytical calculation, in particular a larger corrugation of the shock for some specific wave vectors. I also investigate the non-linear regime, out of the range of theoretical calculation.

Supervisors: Fabien Casse (APC) & Martin Lemoine

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4.5 Post-Newtonian order gravitational radiation

Post-Newtonian theory enables us to predict the waveform of the gravitational waves emitted by a system of two compact objects coalescing in its inspiral phase. State-of-the-art works provide the phase of the expected signal up to 3.5PN (i.e. up to $1/c^7$). Comparison with numerical relativity, as well as the promising evolution of gravitational wave detectors incite us to pursue this computation to a higher order. In our current attempt to reach phase of the signal at the 4.5PN order (i.e. $1/c^9$). For this purpose, the flux emitted by such a system has to be known at 4.5PN. One difficulty of this computation is the high-order interactions - commonly called tails- between the mass of the system and its mass and current multipole moments during the propagation of the signal. In [1], we have computed the contribution of all the tails entering the flux at 4.5PN, and in particular the third-order mass-quadrupole interactions known as "tails-of-tails-of-tails". Our work enables to fully determine the 4.5PN coefficient of the flux (while the 4PN coefficient is still unknown).

Supervisor: Luc Blanchet

[1] Marchand T., Blanchet L., Faye G. Class.Quant.Grav. 33 (2016) no.24, 244003

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Improving Planck cosmological results with component separation

The Planck satellite observed the whole sky at various frequencies in the microwave range. These data are of high value to cosmology, since they help understanding the primordial universe through the observation of the cosmic microwave background (CMB) signal. To extract the CMB information, astrophysical foreground emissions need to be removed via ”component separation” techniques. The Planck Collaboration delivered a set of foreground-cleaned CMB maps to the scientific community. While being useful for other purposes, the residual foreground contamination in these maps is too high for cosmological parameters estimation.

In this presentation I will show the strategies we employed to do a cosmological exploitation of component separation products. In particular I will present how we adapted the component separation technique SMICA to target unresolved point sources and the noise bias.

Supervisors: Karim Benabed & Jean-François Cardoso

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High order correlation functions in the large-scale structure of the universe - exploitation of the Euclid mission

At present time, dark matter and dark energy account for the largest fraction of Universe's components. Even if we still lack a consistent theoretical framework capable to describe their properties, a plethora of effective models has been proposed that needs to be tested with upcoming observations of the large-scale structure of the universe. The purpose of my work is to develop statistical tools to study the predictive power of these different theoretical approaches. In order to accomplish this task, we need to get an unbiased information on the statistical distribution of dark matter through gravitational lensing. Moreover, the gravitational collapse induces non linearities coupling different modes in the dark matter field. This feature makes high order correlation functions important to describe the non gaussian component of the present distribution of the matter field. After a short review on these topics, I will show you how I am getting acquainted with these tools and I will point out possible further developments of my present work.

Supervisors: Francis Bernardeau & Karim Benabed

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High-energy astroparticles and transient sources

In addition to the emergence of time domain astronomy, the advent of multi-messenger astronomy opens up a new window on high-energy sources. The new generation of powerful instruments are reaching sensitivities and temporal resolutions that will allow a multi-messenger detection of transient phenomena. Through the multi-messenger study of such powerful objects -amongst the most energetic in our universe- , two fundamental questions can be addressed: what are the sources of ultra-high energy cosmic rays and the sources of very-high energy neutrinos?

In a first axis, considering a broad range of explosive transients, we study the detectability of neutrino flares associated with photon flares. We provide the minimal photon flux necessary for neutrino detection based on two main observables, the bolometric luminosity and the time variability of the emission. In a second axis, we concentrate on one particularly promising source (tidal disruption event). We model and simulate the propagation and interaction of high energy nuclei in jetted TDE in order to evaluate their signatures in cosmic rays and neutrinos.

Supervisor: Kumiko Kotera

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Vector- and multi-scalar Galileon theories

Galileon models follow the Horndeski systematic construction to couple additional fields to gravity in order to modify the Einstein equations. They were first investigated in 2009 in the case of a single scalar field. Since then, there has been an increasing interest in similar models involving either a vector field, either several scalar or vector fields. These models have several interesting phenomenological applications, ranging from inflation to dark energy. During this talk, I will discuss the basic concepts of this approach of modified gravity, starting from the initial single scalar case up to its later extensions. I will then present the motivations and results of the works I have been involved in.

Supervisor: Patrick Peter

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Comprehensive modeling of exoplanetary atmospheres

To date, there are many exciting discoveries of exoplanetary atmospheres from the extensive observations. Combining with the numerical simulations, we can further reveal the properties of exoplanets, such as thermal structure, composition and even habitability. In this talk, I will start with a brief introduction to the previous modeling work of exoplanetary atmospheres, which are focus on separate regions or different physical processes. Then I will present our plan of establishing a comprehensive framework for the study of exoplanetary atmospheres. At last, I will give an example of how we compare our modeling with observations and what we can learn from this work.

Supervisor: Lotfi Ben Jaffel

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Exploring the origin of the morphology of galaxies: beyond the mass proxy

It is now commonly accepted that the main process driving the morphology of galaxies is their mass. However, current theories fail to fully predict the scatter of morphology observed at a given mass bin. Observations and simulations show that the properties of galaxies depend not only on the local density but also on their large-scale environment.

During this talk, I will show that a local analysis of the density of matter in the Universe is not enough to predict the scatter in the morphology of galaxies ; one need to use the shear as the density is only encoding the isotropic part of the gravitational field. To account for the anisotropies one need to have the extra information stored in the traceless part of the shear.

I will argue that an analysis in the vicinity of the saddle of a filament accounting for the induced anisotropy in the shear predicts that indeed the accretion rate, the time of half formation and the concentration of halos is conditional to the relative location of the filament.

Supervisors: Christophe Pichon & Yohan Dubois

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Simulating galaxy survey images to infer the properties of galaxies through cosmic times

After 20 years of large scale galaxy surveys (SDSS, CFHTLS, UDF etc.), the field of galaxy evolution has entered the realm of Big Data. We can now extract the spectrophotometric and morphometric properties of millions of galaxies, over a period that covers more than 9 billion years of cosmic history. But current constrains on models of galaxy evolution suffer from selection effects that, if not taken into account carefully, can lead to contradictory predictions.

To adress this issue, we are developing a new approach combining machine learning techniques (using an Approximate Bayesian framework) and empirical modeling with realistic image simulation using measured point-spread functions that reproduce a large fraction of these selection effects. This will allow us to perform a direct comparison between observed and simulated images and therefore to infer robust constraints on model parameters predicting the evolution of bulges and disks from $z \sim 2$ to $z \sim 0$.

Supervisors: Valérie de Lapparent, Emmanuel Bertin & Damien Leborgne

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