PhD day / Journée des thèses

15 March 2019

Institut d'Astrophysique de Paris

Anphithéatre Henry Mineur

Program

10:00	*Welcoming*	
10:10	Doogesh Kodi Ramanah	Cosmological inference from galaxy redshift surveys
10:30	François Larrouturou	Deriving the gravitational waveforms: a post-Newtonian story
10:40	Simon Rozier	Mapping the stability of stellar rotating spheres via linear response theory
10:55	Matteo Rizzato	Information content of the weak lensing bispectrum for the next generation of galaxy surveys
11:15	Florian Livet	Galaxy evolution modelling with simulated images, Bayesian inference and dimensionality reduction through neural network
11:25	Pierre Boldrini	Cusp-core problem applied to Fornax dwarf galaxy
11:40	Gohar Dashyan	AGN-driven quenching of satellite galaxies
12:00	*Lunch*	
13:30	Lucas Pinol	Multi-field models of inflation
13:40	Shweta Dalal	Polar orbit of a sub-Neptune
13:55	Arno Vanthieghem	The physics of Weibel-mediated relativistic collisionless shocks
14:15	Sandrine Lescaudron	Black holes spin evolution in merging galaxies
14:25	Valentin Decoene	A journey in the life of a high energy neutrino
14:40	Adarsh Ranjan	Probing HI-H2 transitioning clouds in the early universe
15:00	Lukas Furtak	Primeval galaxies through cosmic telescopes
15:10	*Coffee*	
15:40	Quentin Henry	Higher order tidal effects on binary neutron-star system
15:50	Corentin Cadiou	From large scale structures to galactic scales : how does the cosmic web influence galaxy formation ?
16:10	Raphaël Duque	Prospects for neutron star merger electromagnetic counterparts in the gravitational wave era
16:20	Claire Guépin	Chasing the cosmic accelerators with multiple messengers
16:40	Amael Ellien	Detection of intracluster light with wavelets
16:55	Alexandre Barthelemy	High order statistics, from theory to observations
17:10	*Cocktail*	

Doogesh Kodi Ramanah ($3^{rd}\, yr.$) 10:10 – 10:30

Cosmological inference from galaxy redshift surveys

I will present an overview of our recent work in developing the various aspects of Bayesian forward modelling machinery for an optimal exploitation of state-of-the-art galaxy redshift surveys. I will describe the development and application of a novel cosmological parameter inference framework, extracting several orders of magnitude more information from the cosmic expansion relative to classical approaches. In particular, I will showcase our cosmological constraints on the matter density and dark energy equation of state. Moreover, I will briefly introduce our new sophisticated likelihood that is robust to unknown foreground contaminations. Finally, I will provide an overview of our generative model for mapping approximate dark matter simulations to 3D halo fields using cutting-edge deep learning techniques, thereby obviating the need for full N-body simulations and halo finding algorithms.

Back to timetable

Deriving the gravitational waveforms: a post-Newtonian story

The first observation of gravitational waves due to coalescing binary black holes in 2015, and neutrons stars two years later consecrated the birth of gravitational astronomy.

But in order to reach an era of precision gravitational astronomy, we need a more accurate knowledge of the waveform, flux and energy carried by those GW.

This is indeed required to help the detectors (LIGO/Virgo on ground and LISA in space) enhance their sensibilities, but also to improve the determination of the binary parameters (masses, spins, equations of state for neutron stars,...) and have more accurate ways of testing our theory of gravitation.

A way of deriving such quantities is by a double series expansion: a "multipolar-post-Minkowkian" and a "post-Newtonian", ie. by expressing the multipolar structure of the radiation order by order in inverse powers of the speed of light.

In this talk, I will discuss the state of the art of the computation of energy and flux of GW by such a method.

Back to timetable

Mapping the stability of stellar rotating spheres via linear response theory

Rotation is ubiquitous in the Universe, and recent kinematic surveys have shown that early type galaxies and ellipticals are no exception. Yet the linear response of spheroidal rotating stellar systems has seldom been studied. In my talk, I will present recent results on this topic by considering the behaviour of spherically symmetric systems with differential rotation. Specifically, the stability of several sequences of Plummer spheres was investigated, in which the total angular momentum, as well as the degree and flavour of anisotropy in the velocity space were varied. To that end, the response matrix method was customised to spherical rotating equilibria. The shapes, pattern speeds and growth rates of the systems' unstable modes were computed. Detailed comparisons to appropriate N-body measurements were also performed. The marginal stability boundary was charted in the parameter space of velocity anisotropy and rotation rate. When rotation is introduced, two sequences of growing modes are identified corresponding to radially and tangentially-biased anisotropic spheres respectively. For radially anisotropic spheres, growing modes occur on two intersecting surfaces (in the parameter space of anisotropy and rotation), which correspond to fast and slow modes, depending on the net rotation rate. Generalised, approximate stability criteria of rotating anisotropic spheres are finally presented.

Back to timetable

Information content of the weak lensing bispectrum for the next generation of galaxy surveys

During my presentation I will give a thorough analysis of the forecast gain in terms scientific performance for future weak lensing surveys when properly combining power spectrum and bispectrum. This joint analysis is challenging for different reasons. From the theoretical point of view, we need to model the non linear scales of matter clustering for which analytical approaches do not meet the required precision. Secondly, upcoming surveys will detect the binned redshift position of the sources leading to huge possible datasets in terms of weak lensing spectra. Therefore, to properly exploit all these information, remarkably big covariance matrices need to be computed and manipulated. I developed a tool capable to perform these computations efficiently and I will present my results assuming the detection specificities of a Euclid-like survey. In particular, it allows me to test the efficiency of different data compression techniques heading a fast data analysis and parameters forecast for upcoming surveys.

Back to timetable

Galaxy evolution modelling with simulated images, Bayesian inference and dimensionality reduction through neural network

The study of galaxy evolution has shown the existence of a great variety of morphologies: ellipticals, lenticulars, spirals with or without bar and irregulars. We are seeking to understand how each morphological type has evolved and what are the links between the different populations. The inverse modelling is the common approach to study galaxy evolution: catalogs of fluxes and sizes of galaxies obtained from deep field surveys (e.g. CFHTLS) are used to understand the evolution history of galaxy population. Unfortunately, the observed galaxies are subject to a lot of selection biases: cosmological dimming $(1+z)^{-4}$, Malmquist, Eddington, expansion of the Universe, dust extinction, occultation and confusion. The main difficulty of this approach is to correct these highly correlated biases. Therefore, the models derived from inverse modelling are extremely sensitive to these corrections and they are likely to be biased.

The approach used during my PhD and which I will talk about is called forward modelling: the parameters of the evolution history of galaxy population (i.e. spectral energy distributions, evolution, luminosity functions) are optimized through Bayesian inference in order to reproduce the diversity of galaxies in the surveys. We start from a randomly initialized model of galaxy evolution (Stuff, Pegase) and we use a generator of images (SkyMaker) to simulate realistic deep fields. The great advantage of this approach is that the simulated and the observed images contain exactly the same selection biases. Therefore, we are able to compare the simulations to the observations but since it is very complicated, we adopt deep learning methods to reduce the dimension of the images in order to keep only the essential information. We use the neural network algorithm developped by Charnock et al. (2018) which seeks to maximize the Fisher information of the images. In doing so, we can understand the statistical impact of each parameter of our model on the information content of the images, thus we can optimize the model of galaxy evolution. Finally, the models derived from this approach are unbiased.

Back to timetable

Cusp-core problem applied to Fornax dwarf galaxy

Observations seem to indicate an approximately constant dark matter density in the inner parts of galaxies, while cosmological computer simulations indicate a steep power-law-like behavior. This difference has become known as the "core/cusp problem". I will discuss this problem particularly in the context of Fornax dwarf galaxy using observational results on the spatial and mass distributions of its globular clusters. Finally, I will report on our recent results from high-resolution N-body simulations.

Back to timetable

AGN-driven quenching of satellite galaxies

I will explain my current work on the effect of active galactic nucleus (AGN) feedback from central galaxies on their satellites. We compare two sets of cosmological zoom-in runs of halos with masses ranging from 10^{12} to $10^{13.4}$ $M_\odot$ at $z = 0$, with (wAGN) and without (noAGN) AGN feedback. I will show that the inclusion of AGN feedback from the central galaxy significantly affects the star formation history and the gas content of the satellite galaxies. AGN feedback starts to affect the gas content and the star formation of the satellites as early as $z = 2$. The mean gas rich fraction of satellites at $z = 0$ decreases from 15% in the noAGN simulation to 5% in the wAGN simulation. The difference between the two sets extends as far out as five times the virial radius of the central galaxy. We investigate the quenching mechanism by studying the physical conditions in the surroundings of pairs of satellites matched across the wAGN and noAGN simulations and find an increase in the ram pressure, temperature and relative velocity of the intergalactic gas.

Back to timetable

Multi-field models of inflation

During this talk, I will briefly review the facts that motivate cosmological inflation, and remind its major outcome: the prediction of the primordial power spectrum for the perturbations in the Early Universe. The simplest model of inflation (a single scalar field slowly rolling down its potential) is however motivated more phenomenologically than theoretically. How to embed inflation in a realistic high-energy theory? I will introduce multi-field models of inflation, with a non-trivial internal space, as possibly more realistic theories. I will particularly focus on a specific setup called hyperinflation that attracted a lot of attention recently. Although very attractive, we show that this model suffers a number of problems.

Back to timetable

Polar orbit of a sub-Neptune

In the last two decades, the study of exoplanets has led to many unexpected discoveries that challenged the classical theories of planetary systems formation and evolution. One such discovery is the presence of misaligned systems with very large obliquity, i.e. the angle between the spin of the planetary orbit and the the planet host star rotation. The distribution of obliquity can explain the reasons behind planet migration and address some fundamental questions of planet formation and evolution. Most of the obliquity measurements available today are limited to close-in giant planets as it is easier to determine obliquities for such systems. However very little is known about smaller exoplanets. I will talk about a sub-Neptune in a multi-planet system for which we determined sky-projected obliquity. We used three methods to find the sky-projected obliquity and measured a nearly polar orbit.

Back to timetable

The physics of Weibel-mediated relativistic collisionless shocks

Relativistic outflows produced in the vicinity of powerful astrophysical objects (e.g., gamma-ray bursts, blazars, pulsar winds, etc.) provide ideal environments for the generation of very high energy particles through the formation of collisionless shocks. The high-energy electromagnetic spectra from those objects generically follow power-law distributions attributed to synchrotron and inverse Compton radiations. The relativistic collisionless shocks underlying those processes result from plasma micro-instabilities induced by the interpenetration of the background plasma and the suprathermal beam accelerated at the shock front. This presentation will address various aspects of the shock dynamics through comparison of a comprehensive analytical model with large-scale, ab initio kinetic simulations.

Back to timetable

Black holes spin evolution in merging galaxies

Most of the galaxies host a supermassive BH in their centre and we observe a co-evolution of the galaxy and its central BH. The BH is expected to have a key role in the regulation of the quantity of gas and stars : it accretes matter from its surrounding and releases a fraction of this rest-mass energy into the host galaxy, providing "feedback". The BH angular momentum or spin directly influences the fraction of energy released and radiated during accretion events. On the other hand galaxy mergers have a crucial role in triggering peaks of central BH activity, allowing strong gas accretion. The spin of the BH changes with the combination of gas accretion and the possible coalescence of BHs. Models of spin evolution during BHs merger will allow gravitational waves predictions.

In this context, I performed idealised simulations of galaxy mergers including mass and spin evolution of supermassive black holes, using the cosmological code Ramses, an hydrodynamical and N-body code with adaptive mesh refinement developed by Romain Teyssier (2002). These simulations are run for different configurations of the angular momentum orientation of the galaxies, varying the angle between the galactic angular momenta and the orbital angular momentum. The orbital configuration influences the BHs encounter history, mass growth and spin evolution, which happen either on the primary or on the secondary BH.

Back to timetable

A journey in the life of a high energy neutrino

High-energy neutrinos are produced by the interaction of ultra-high-energy cosmic rays (charged nuclei that bombard the Earth with energies $> 10^{17}$ eV, and that are routinely detected), with astrophysical backgrounds. The sources of these neutrinos, detected with IceCube up to energies $\sim 10^{15}$ eV, have not been identified yet. Motivated by the recent multi-messenger observations of GW170817/GRB170817, I will first explore the production of ultra-high-energy cosmic rays and secondary high-energy neutrinos in neutron-star mergers. I will focus on the production of neutrinos via cosmic-ray interactions on the surrounding kilonova ejecta and the associated diffuse neutrino flux integrated over the full neutron-star merger population.

At the extreme energy end ($> 10^{17}$ eV) neutrinos have not been observed yet. Because of their low flux, their detection requires to build gigantic detectors. The recent progress on the detection of astroparticles using radio-techniques has launched a novel idea: deploying 100,000s of radio antennas over 100,000s of km^2 in order to achieve the required sensitivities. I will briefly introduce the GRAND (Giant Radio Array for Neutrino Detection) project, and show with a geometrical modelling how different array layouts and ground topologies can enhance the neutrino sensitivity. I will also present the first results on the angular resolution based on this layout, and show how we expect it to be sensitive enough to perform neutrino astronomy.

Back to timetable

Probing HI-H2 transitioning clouds in the early universe

My project aims at studying the transitioning HI-H_2 clouds at high redshift ($2 < z < 3$) by looking at absorption lines created in the background quasar light in a specific line of sight. High column density atomic gas leads to saturation of the QSO light at specific wavelengths (like Lyman-alpha, beta, etc.) creating a damped voigt profile. A specific class of these systems called the Extremely Strong Damped Lyman-Alpha Absorbers (or ESDLAs with N(HI)$> 10^{21.7}$) are tracers of very high-column density neutral gas. ESDLAs are statistically anti-correlated with the impact parameter, hence, probe gas closer to the associated galaxy. Due to gravitational potential of a galaxy, any accreted gas will be denser in the center. Dense neutral gas, among other environmental factors, are responsible for creation of molecular gas (H_2). In the local universe, molecular gas seems to be formed in the same environmental conditions as pre-stellar cores. Hence, probing ESDLAs with the highest HI column density, we are likely to detect HI-H_2 transitioning gas in the inter-stellar medium(ISM)/molecular clouds(MC) (in absorption at Lyman-Werner bands) and possibly star-forming regions (in Lyman-alpha emission, optical emission lines), at high redshift, in a way which is independent of the emission strength of the associated galaxy. Using X-Shooter, we have observed a set of 11 ESDLAs (in 2015-2016) selected based on high HI column density. We would like to emphasize results of very interesting ESDLA spectra (along the QSO line of sight, SDSS J1513+1352) which contains the highest H_2 column density ever seen in absorption at high redshift. Apart from this, the ESDLA also has active star-forming signature. I would also present statistical results briefly obtained by analysing the entire ESDLA sample.

Back to timetable

Primeval galaxies through cosmic telescopes

It is through the gravitational magnification of galaxy clusters on the high-mass end of the cluster mass function that we can observe and study star forming galaxies at the highest redshifts (z > 6). I will discuss how I aim to use new HST observations around the six Hubble Frontier Fields, the BUFFALO program, to detect and study unprecedented quantities of high-redshift galaxies in the outskirts of the HFF clusters. Combining HFF cluster core and BUFFALO data, I will construct the stellar mass functions of z > 6 galaxies in order to gain insight into the stellar mass buildup in the Universe.

Back to timetable

Higher order tidal effects on binary neutron-star system

The form of gravitational waves emitted by a binary neutron-star system is impacted by the internal structure of neutron-stars. We can link their internal structure to the wave form through tidal effects.

The detection of GW170817 coming from the coalescence of two neutron-stars allowed us, by combining the analytical models with the analysis of the signal, to constrain the equation of state of neutron-stars. The post-Newtonian formalism played a crucial role in the extraction of the signal but more precision on the waveform modelling tidal effects is required.

The goal of this talk is to show the recent work done to increase the precision on the waveform of tidal effects in the binary system in order to better constrain the equation of state of neutron-stars.

Back to timetable

From large scale structures to galactic scales : how does the cosmic web influence galaxy formation ?

In the context of galaxy formation, the impact of the anisotropic environment – the cosmic web – is often neglected, as it is often assumed that the large scale do not couple to the small scale involved in galaxy formation. During this talk, I will present the impact of large-scale filamentary structure on dark matter assembly. I will then show some evidences that this in turn affects the assembly of galaxies. In a second time, I will focus on the baryon acquisition and will present how baryons flow anisotropically onto galaxies and contribute to disk formation.

Back to timetable

Prospects for neutron star merger electromagnetic counterparts in the gravitational wave era

The binary neutron star inspiral signal GW170817 was a historical event and inaugurated the era of multi-messenger astronomy with gravitational waves. It was accompanied by electromagnetic counterparts, namely a kilonova, a weak and short gamma-ray burst and a long-lasting multi-wavelength afterglow. Altogether, these brought a wealth of information on the unraveling of the merger and strengthened the link between neutron star mergers and the short gamma-ray bursts. During the next science runs of the gravitational interferometer network, more such electromagnetic counterparts are expected. This talk will concern the population of mergers we expect to detect jointly in the gravitational wave and electromagnetic domains. We will describe the afterglows and kilonovae to come and explore the new insights they will provide on the environments of neutron star mergers, the geometry of their ejectas and the physics of short gamma-ray bursts.

Back to timetable

Chasing the cosmic accelerators with multiple messengers

The advent of multi-messenger astronomy is giving new insights into the most powerful particle accelerators of the Universe. Despite the recent breakthroughs in observation and modeling of energetic phenomena, long-lasting mysteries still obscure the high-energy Universe, as the origins of ultra-high energy cosmic-rays and high-energy neutrinos are still unknown. Deciding between the various candidate sources requires a precise modeling of the propagation, acceleration and interactions of cosmic-rays. Pulsar magnetospheres are good laboratories to study precisely particle acceleration and we show that accelerated ions can escape from these environments. This could lead to various observational signatures, as for instance a diffuse gamma-ray emission in the galactic center region.

Back to timetable

Detection of intracluster light with wavelets

The Intracluster light (ICL) is a diffuse component of galaxy clusters or groups, composed of stars that do not belong to any specific galaxy, but that are more related to the global gravitational potential of their cluster/group. The very low surface brightness of this diffuse component (few percent of the sky background) and the various sources of contamination (scattered light in the detector, blending into galaxy light profiles...) make its detection a challenge. Here we choose a multiscale approach to the problem and create DAWIS, a Detection Algorithm with Wavelets for Intracluster light Surveys. We apply it to MACSJ0717, a massive galaxy cluster which is part of the target selection of a very deep photometric survey, the Hubble Frontier Field.

Back to timetable

High order statistics, from theory to observations

With the advent of large galaxy surveys like Euclid, astronomers have ventured into the era of statistical cosmology and big data. There is thus a dire need for theorists to build tools that can efficiently extract as much information as possible from these huge data sets. In particular, this means being able to do predictions in the non-linear regime of structure formation. I will here briefly present recent development in modelling galaxy clustering in the non-linear regime (counts in cells) and show how this can be extended in the context of weak-lensing.

Back to timetable