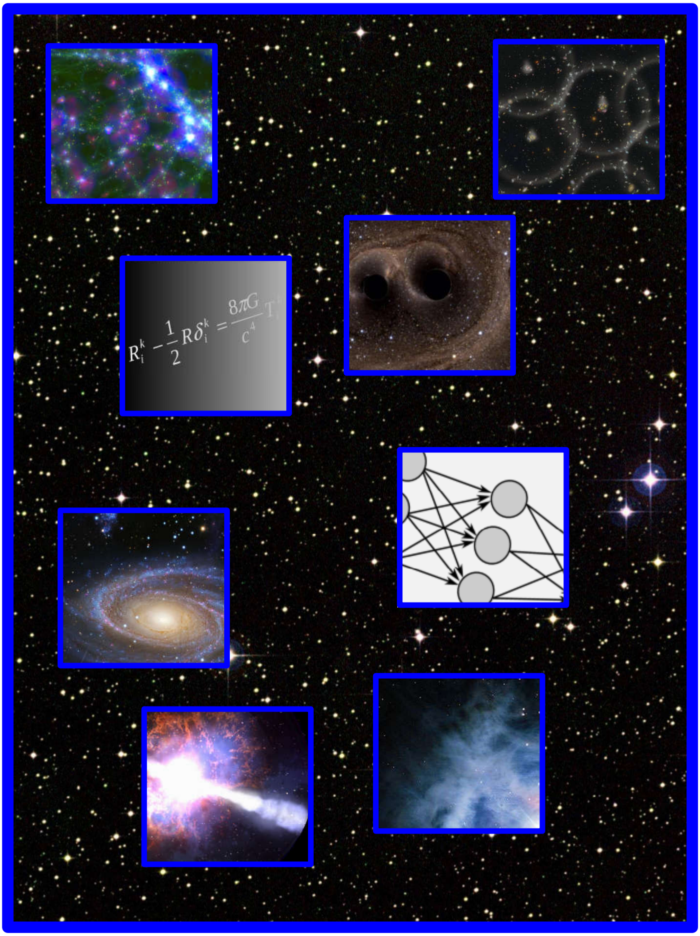
PostDoc Day

16/03/2018



Institut d'Astrophysique de Paris
Amphithéâtre Henri Mineur

PostDoc day

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10:00	*Welcoming*	
10:15	Tom Charnock	Statistics and novel uses of machine learning
10:35	Anne Zilles	Towards the detection of ultrahigh energy neutrinos: a sensitivity study for GRAND (The Giant Radio Array for Neutrino Detection)
10:55	Ricarda Beckmann	From seed to supermassive: the origin and evolution of supermassive black holes
11:15	Stefano Anselmi	The Linear Point: a cleaner cosmological standard ruler in the galaxy correlation function
11:35	Flavien Kiefer	Extrasolar comets : from Beta Pictoris to Tabby's star
12:00	*Lunch*	
13:30	Florian Fuhrer	Massive neutrinos in the Effective Field Theory of Large Scale Structure
13:50	Nicolas Renault-Tinacci	GRAND, an Ultra High Energy Cosmic-Ray Detector
14:10	Alessandro Lupi	Kinematics and dynamics of molecular gas in high redshift galaxies
14:30	Yuichiro Tada	Geometrical Destabilization of Inflation
14:50	Luciano del Valle	The effect of AGN feedback on the migration timescale of supermassive black holes binaries
15:10	Marius Millea	Next-generation CMB delensing and inference of the tensor-to-scalar ratio
15:30	*Coffee*	
16:00	Maxime Trebitsch	Lack of black hole growth in high redshift dwarf galaxies and implications for reionization
16:20	Jacopo Chevallard	Getting ready for JWST with new-generation spectral models and interpretation tools
16:40	Jens-Kristian Krogager	Quasar Absorption Systems as Probes of the High-z Universe
17:00	Antoine Klein	Eccentric gravitational waveforms with precessing spins
17:20	Sebastian Garcia-Saenz	Fluid vortex lines as effective strings
18:00	*Cocktail*	

Statistics and novel uses of machine learning

I will describe a few of the different projects I am involved in at the IAP, where I am applying novel uses of machine learning to a range of problems both inside and outside of the realms of astronomy and cosmology. In particular, I will describe a technique to perform highly efficient, likelihood-free, parameter inference, with great success! I will also give a quick overview of the methods I have been developing to powerfully process data, including finding ways to paint halos from dark matter distributions, generating realistic galaxies from random noise and finding conditional probability distributions of cosmological parameters using mixture density networks.

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Towards the detection of ultrahigh energy neutrinos: a sensitivity study for GRAND (The Giant Radio Array for Neutrino Detection)

The detection of ultrahigh energy neutrinos would help us resolve long-standing mysteries of the violent universe. The future Giant Radio Array for Neutrino Detection (GRAND) will cover an area of ≈ 200.000 km^2 in a mountainous site with an antenna density of 1 per km^2. This setup is primarily aimed at detecting these high-energy neutrinos via the measurement of air showers induced in the atmosphere by decaying tau/-/leptons, produced by the interaction of the cosmic neutrinos under the Earth surface. To determine the preliminary design sensitivity, we developed a new method to calculate the radio signal from air showers. After a short introduction to GRAND, I will present the method of Radio Morphing and show our first results on the GRAND sensitivity.

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From seed to supermassive: the origin and evolution of supermassive black holes

There first supermassive black holes were observed as quasars at redshift z=7, at which point they had already reached a mass in excess of a billion solar masses. To become so massive, seed black holes must a have grown by orders of magnitude through gas accretion or mergers, with particularly gas accretion expected to play a major role in the gas rich early universe. How much mass a black hole is able to gain via gas accretion is determined both by the global gas supply, and by the detailed structure of gas in the black hole vicinity. The origin and evolution of these supermassive black holes is therefore a problem that requires tracking gas flows over many orders of magnitude, from cosmic filaments on Mpc scales to the last stable orbit and event horizon of a few astronomical units. Using the black hole zoom algorithm to resolve the immediate black hole environment by orders of magnitude above that of that of the host galaxy, the hydrodynamical simulations presented here are able to follow the early black hole evolution in great detail. This work demonstrates the importance of sub-pc size gas features for the accretion duty cycle of the black hole, highlights the importance of dynamics of the black hole within its host, and sheds light on the early co-evolution between supermassive black hole progenitors and their host galaxies at redshift z>10.

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The Linear Point: a cleaner cosmological standard ruler in the galaxy correlation function

Cosmology has made fundamental progress thanks to the role of standard rulers: objects of known size that are constant in redshift. The acoustic peak in the large scale structure clustering correlation function is one of them. However, in the era of precision cosmology, its power has been highly challenged by late time non-linear effects that shift its position in a redshift dependent way. To overcome this problem currently the distance measurements based on Baryon Acoustic Oscillations are realized at the price of highly increasing the difficult-to-quantify theoretical priors that may overestimate the precision and accuracy of the distance estimates. Fortunately this is not the end of the story! I will explain how we can evade non-linearities identifying a scale in the correlation function, called the ‚Äúlinear point‚Äù, that is an excellent cosmological standard ruler. Hence we measure the location of the linear point in the galaxy correlation function in the Twelfth Data Release (DR12) of the Baryon Oscillation Spectroscopic Survey (BOSS) collaboration. We estimate cosmological distances without relying on the traditionally employed theoretical priors. Our remarkable result suggests that all the distance information contained in the Baryon Acoustic Oscillations can be conveniently compressed into the single length associated with the linear point.

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Extrasolar comets : from Beta Pictoris to Tabby's star

Extrasolar comets, or exocomets, were first observed in the system of Beta Pictoris, a young star surrounded by a debris disk. Comets are thought to be formed during the planet formation phase that the Beta Pictoris system just quit. In the solar system, it is commonly accepted that comets are made of pristine material from the primitive solar nebula, before the planets were even fully formed. Observing extrasolar comets might give us an opportunity to constrain the comet and planet formation timeline in planetary systems. Long photometric monitoring space missions such as Kepler, Tess and Plato will allow a broad survey of exocomet transit detections, allowing for exocomets occurence rate determination in solar-like systems. In my talk, I will review our current state of knowledge concerning exocomets around young and solar-like stars, thanks to spectroscopy and photometry.

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Massive neutrinos in the Effective Field Theory of Large Scale Structure

Free-streaming massive neutrinos suppress the growth of structures in the universe on small scales, allowing us to constrain or even "measure" the total neutrino mass. However, achieving this goal hinges on our ability to make accurate predictions in the mildly non-linear regime. After, reviewing both, the effect of massive neutrinos on the large-scale structure and the effective field theory formalism, I will describe how the effective field theory can used in the presence of massive neutrinos. I will argue that a simple approximation for the neutrino density contrast is sufficient to calculate the total density contrast.

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GRAND, an Ultra High Energy Cosmic-Ray Detector

The Giant Radio Array for Neutrino Detection (GRAND) aims primarily at detecting ultra-high energy (UHE) extraterrestrial neutrinos via the extensive air showers induced by the decay of tau leptons created in the interaction of neutrinos under the Earth's surface. Consisting of an array of 200000 radio antennas deployed over 200000 km^2, GRAND plans to reach a sensitivity to neutrinos above 10^{17} eV beyond the reach of other planned detectors. But it will also be the largest UHE cosmic-ray (CR) detector ever built. After decades of data-taking, former and current experiments have collected a few hundreds of events above $4 \cdot 10^{19}$ eV. GRAND should improve event statistics ten-fold within a few years. With these level of statistics, many UHECR open questions (e.g.: anisotropies, mass composition, ...) could be effectively addressed. After a brief introduction to GRAND, I will present my work on the estimation of the performances of the instrument in regard to UHECR detection.

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Kinematics and dynamics of molecular gas in high redshift galaxies

Molecular hydrogen (H2) is a fundamental component of galaxies, being the most abundant element in molecular clouds, where stars form, and an important source of radiative cooling at low temperature. With the advent of the ALMA telescope, a large amount of data about the distribution of H2 in galaxies has become available. However, the large majority of numerical simulations on galactic and cosmological scales still lacks the ability to directly follow the formation and dissociation of H2, and must rely on pre-calibrated sub-grid models to compare the results with observations. I will present a new model to self-consistently track the evolution of H2, including gas and dust shielding, H2 self-shielding, star formation (SF), supernova feedback, and extragalactic and local stellar radiation. I will discuss the results of a suite of hydrodynamic simulations of an isolated gas-rich galaxy at z=3, showing that the model can naturally reproduce the observed correlation between SF and H2 surface densities, without assuming any a priori dependence of SF on the H2 abundance. I will finally present a study of the kinematics and dynamics of molecular gas in high-redshift quasars (z=6), where we investigate whether a central accreting black hole (BH) can significantly affect the H2 distribution in the host galaxy and generate molecular outflows.

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Geometrical Destabilization of Inflation

The inflationary dynamics in non-trivial field spaces has been focused on recently. In particular, a negative field-space curvature can cause tachyonic instability even for massive spectator fields, known as "geometrical destabilization". To analyze such a destabilization, we formulate the so-called stochastic formalism in non-trivial field spaces and point out several subtleties related with the field-space covariance. Also we numerically investigate the inflationary dynamics well after the destabilization, dubbed "side-tracked inflation".

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The effect of AGN feedback on the migration timescale of supermassive black holes binaries

The gravitational interaction at parsec to sub-parsec scales between a circumbinary gas disc and a super massive black hole binary (SMBHB) is a promising mechanism to drive the migration of SMBHBs toward coalescence. The typical dynamical evolution can be separated in two main regimes: I) Slow migration ($T_{\rm mig} \sim 10^{3-4} \times T_{\rm orb}$), where viscous torques are not efficient enough to redistribute the extracted angular momentum from the binary, leading to the formation of a low density cavity around the binary. II) Fast migration ($T_{\rm mig} \sim 10^{1-2} \times T_{\rm orb}$), in which the redistribution of angular momentum is efficient and no low density cavity is formed in the circumbinary disc. Using N-Body/SPH simulations we study the effect of AGN feedback in this phase of a SMBHB evolution. We implement an AGN accretion/feedback model in the SPH code Gadget-3 that includes momentum feedback from winds, X-ray heating/radial-momentum and Eddington force. Using this implementation we run a set of simulations of SMBHB+disc in the two main shrinking regimes. From these simulations we conclude that the effect of the AGN mechanical feedback is negligible for SMBHBs in the slowly shrinking regime. However, in the fast shrinking regime the AGN wind excavate a "feedback cavity" leaving the SMBHB almost naked, thus stalling the orbital decay of the binary.

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Next-generation CMB delensing and inference of the tensor-to-scalar ratio

The next generation of CMB experiments are slated to measure the CMB polarization to noise levels and angular resolutions never before probed. One of the most exciting and revolutionary possibilities for this data would be a discovery of the non-zero tensor-to-scalar ratio r, i.e. the first detection of the background of gravitational waves produced by inflation. These gravitational waves are detectable via their impact on CMB B-mode polarization, however the B-modes also receive a large contribution from the effect of gravitational lensing of the CMB which converts E-modes into B-modes. Removing this lensing-induced B-mode foreground (called ”delensing”) will be necessary to obtain the tightest possible constraints on r. While methods exist that work at present-day noise levels, it is an open question how to perform delensing at the noise-levels of these future experiments. In this talk, I discuss an optimal Bayesian delensing method which I've developed while here at IAP (in collaboration with Ben Wandelt and others), which provides a solution to this optimal delensing problem.

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Lack of black hole growth in high redshift dwarf galaxies and implications for reionization

The first billion years of evolution of the Universe has been marked by the formation of the first stars, galaxies, and black holes. The energetic radiation they produce will ionize the surrounding gas, and these ionized region will grow until the whole Universe was reionized, around $z \simeq 6$.

Quantifying the amount of ionizing radiation produced in high-redshift galaxies that escapes in the IGM is one of the main challenges in understanding the sources of reionization. While star forming dwarf galaxies are often considered as the primary driver of reionization, their actual contribution to the cosmic ultraviolet background is still uncertain, mostly because of the uncertainty on the escape fraction of ionizing radiation.

While it has been shown previously that supernovae can carve holes in the gas distribution through which ionizing photons can escape, the effect of AGN feedback on the escape fraction is still a relatively unexplored area. In relation with the issue of understanding black hole growth in high-redshift dwarf galaxies, I will discuss how this extra source of feedback could (or not) enhance the escape fraction of stellar ionizing radiation in these galaxies.

Using radiation-hydrodynamic simulations performed with Ramses-RT we study how the energy and momentum input from supernovae and black hole activity modulates the properties of the interstellar medium and therefore how, and how many, photons can escape from the galaxy.

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16:20 – 16:40 Jacopo Chevallard

Getting ready for JWST with new-generation spectral models and interpretation tools

The James Webb Space Telescope (JWST), scheduled for launch in April 2019, will open a largely unexplored observational window at near- to mid-infrared wavelengths (0.6-28 micron). In particular, the Near-InfraRed Spectrograph (NIRSpec) on board JWST will allow the detection of standard UV and optical emission lines out to redshift 10 and beyond for large samples of galaxies. This will provide unique insight into, for example, the star formation activity and early chemical enrichment of galaxies, the co-evolution of galaxies and AGNs, the impact of stellar and AGN feedback, and the main drivers of cosmic reionization. One of the first large programs to exploit the new observational capabilities of JWST will be the NIRSpec Guaranteed-Time-Observations (GTO) program, which includes a multi-layered survey in Multi-Object-Spectroscopy (MOS) mode targeting 104 galaxies at 1.5 $< z <$ 10, as well as an Integral-Field-Unit survey targeting 60 galaxies and AGNs out to $z \approx 9$. In this talk, I will present a set of physically-motivated simulations of NIRSpec and NIRCam (Near-Infrared Camera on board JWST) observations, which we have used to optimise the survey design, and which are available to the community. I will also discuss a new set of state-of-the-art population synthesis+photoionization models, developed in collaboration with the NEOGAL team at the IAP, tailored to the interpretation of high-redshift galaxy observations. I will show how these models, incorporated into our new-generation analysis tool "Beagle", successfully reproduce a broad range of UV and optical features from high-quality spectra of nearby galaxies, as well as the high-ionization UV lines observed in galaxies at $z > 6$. The ability to self-consistently measure the physical properties of gas and stellar populations across a broad range of redshifts and stellar masses will be crucial to maximise the scientific return of JWST and gain unique insight into the evolution of galaxies across cosmic times.

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Quasar Absorption Systems as Probes of the High-z Universe

The most efficient way to study the neutral gas reservoir at high redshift is through the absorption of the hydrogen Lyman-alpha line in background sources, typically quasars. During the last 3 decades these HI absorbers have been used to constrain the evolution of neutral, warm HI gas and the associated metals. Thanks to large samples (e.g., SDSS), we are now able to probe the cold gas phases in a subset of these absorbers through neutral species (carbon, chlorine, etc) and molecules (CO and H2). This allows us to directly measure the gas properties at large lookback times in as high detail as is achieved locally. In particular, I will highlight a case where we observe cold gas absorption in a lensed quasar towards both sightlines. This allows us to put limits on the size and covering fraction of cold gas clouds.

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Eccentric gravitational waveforms with precessing spins

With gravitational wave detectors increasing in sensitivity and detecting more and more systems, it is important for us to develop fast and accurate waveforms that capture important physical effects to help us characterize black hole and neutron star populations. In particular, being able to measure simultaneously the orbital eccentricity and the spin alignment of the systems' components could help us discriminate between binary formation models. Indeed, depending on the density of the environment in which the binaries form, we expect different distributions for those parameters. In order to enable that, we developed a family of Fourier-domain eccentric waveforms with precessing spins.

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Fluid vortex lines as effective strings

Thin vortices in fluids and superfluids admit an effective field theory (EFT) description in which they can be treated as one-dimensional extended objects, or strings. In this theory, vortex lines can interact among each other as well as with the "bulk" fluid by the exchange of phonons, whose dynamics can be described by a simple scalar effective theory. The coupling between vortices and sound is however more complicated, as it requires switching to a magnetic-type dual formulation in which the phonon field is encoded by a gauge two-form. After a review of the theory and its applications, I will discuss recent work where we show that the EFT can be recast into the simpler scalar field language - essentially a systematic expansion of the original theory, with the string being now regarded as a point-like source with degrees of freedom given by the string's multipole moments.

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