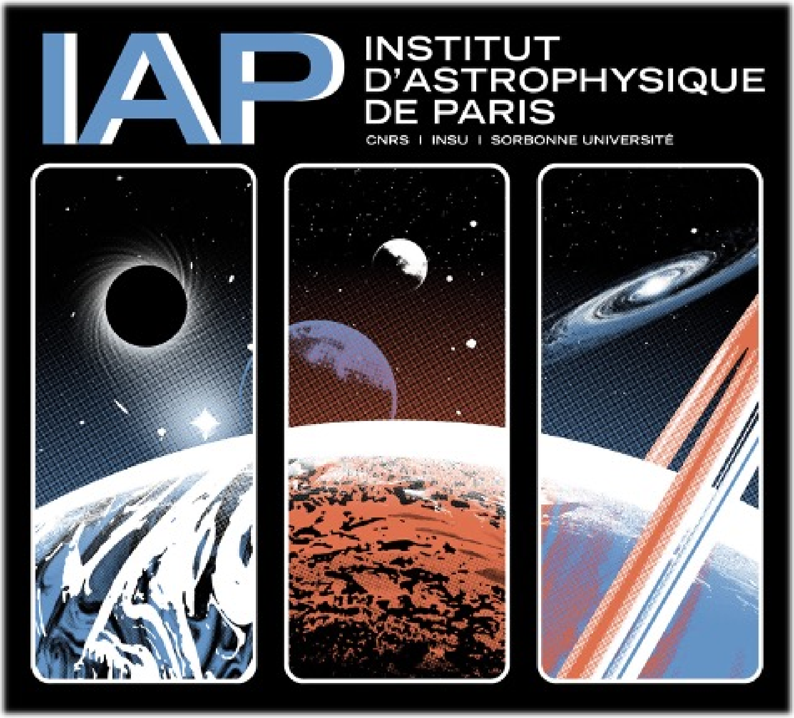
Journée des thèses / PhD day



Friday, 12 May 2023 10:00 - 16:35

Institut d'Astrophysique de Paris

Amphitheater Henri Mineur

Hosts: Emma Ayçoberry & Marion Guelfand

Planning

10:00	*Opening*	
10:05	Louis Quilley	Aging and scaling of galaxy bulges and disks along the Hubble sequence
10:20	Hugo Lévy	Guiding the hunt for fifth forces with numerical simulations
10:30	Clément Pellouin	Binary Neutron Star Mergers in the Multi-Messenger Astronomy Era: Population study and Afterglow Modelling
10:40	Axel Lapel	Cosmological field-level inference using forward modeling of weak-lensing magnification
10:55	Alice Maurel	Atmospheres on rocky exoplanets : TRAPPIST-1b
11:05	*Break*	
11:30	Léonard Lehoucq	Stochastic Gravitational-Wave Background from compact binary mergers
11:45	Marion Guelfand	Particle content of inclined cosmic-ray air-showers for radio signal modeling
11:55	Simon Ding	Fast realistic, differentiable halo generation for wide field galaxy surveys using physically constraint models
12:10	Marie Lecroq	Modelling of primeval galaxies at the JWST era
12:25	Denis Werth	The Cosmological Flow
12:35	Xiaosheng Zhao	Quantitative Comparison of Image Generation between Diffusion Model and GAN: Application in 21 cm Images
12:45	*Lunch buffet*	
14:00	Emma Ayçoberry	Thermal Sunyaev-Zeldovich power spectrum: analytical model and measures in simulations
14:15	Tianxiang Chen	Exploring the impact of recent episodes of star formation in the Milky Way disk
14:25	Simon Chiche	Loss of coherence and synchrotron emission for radio signals from inclined cosmic-ray air showers
14:40	Emilie Panek	A re-analysis of equilibrium chemistry in five hot Jupiters
14:50	David Trestini	The gravitational wave phase at 4.5PN order
15:00	Fransesco Bollati	Does anisotropic AGN feedback hamper the migration of massive black hole binaries?
15:10	*Break*	
15:40	Chi An Dong Paez	Multimessenger study of merging massive black holes in the Obelisk simulation: gravitational waves, electromagnetic counterparts, and their link to galaxy and black hole populations
15:55	Etienne Camphuis	Cosmological parameters with CMB primary anisotropies observed by the SPT-3G instrument
16:05	Louise Paquereau	Building the COSMOS-Web galaxy catalog: A key resource for tracing galaxy evolution with JWST observations
16:15	Mathieu Roule	Long-term relaxation of self-gravitating systems
16:25	Iryna Chemerynska	Observing z>9 galaxy candidates through lensing cluster Abell 2744 with JWST
16:35	Abhner Pinto de Almeida	What drives the corpulence of galaxies? The formation of compact and diffuse dwarf galaxies in TNG50
16:45	*Closing remarks*	

Aging and scaling of galaxy bulges and disks along the Hubble sequence

My thesis work uses galaxy morphology as a lens to gain insight into their evolution, thanks to the EFIGI morphological catalog of 4458 nearby galaxies. I perform multi-band bulge and disk decomposition with SourceXtractor++ and SED fitting with ZPEG to obtain the absolute colors, stellar masses and star formation rates of galaxies as well as for their bulges and disks. In the NUV-r color vs stellar mass plane, I bring to light the continuous sequence of Hubble types, which appears governed by the bulge-to-total luminosity or mass ratios, as well as the disk color. Across the Green Valley, galaxies undergo a systematic disk reddening and a marked bulge growth of a factor 2 to 3, excluding a sudden quenching scenario. By examining bulges, disks, bars and spirals arms, I paint a picture of galaxy evolution suggesting that internal dynamics, likely triggered by mergers or flybys, may be the key to the bulge growth and aging of galaxy disks from the Blue Cloud to the Red Sequence. The Hubble sequence can then be considered as an inverse sequence of galaxy physical evolution. I also remeasure the scaling relations between size, luminosity and surface brightness of Kormendy (1977) and Bingelli et al. (1984) for ellipticals, and show that similar relations exist for bulges and depend on Hubble type (or B/T ratio). I bring to light analogous scaling relations for disks. Finally, this study provides size-luminosity relations as a function of morphology that can be used to create realistic mock images.

Supervisor: Valérie de Lapparent

Back to timetable

Guiding the hunt for fifth forces with numerical simulations

Scalar-tensor theories are one of the most natural alternatives to general relativity (GR), where gravity is mediated by both a tensor field and a scalar field. Among the wide variety of scalar-tensor models proposed over the past decades, some are already ruled-out by lab experiments or astrophysical observations while others remain viable by means of screening mechanisms that dynamically suppress deviations from GR in classical fifth force searches. The hunt for such hypothetical scalar fields thus requires designing novel and intelligent experiments. Alas, this task is partly impeded by the difficulty to accurately model their effects in complex setups. In this short talk, I will introduce you to *femtoscope* — a PYTHON numerical tool based on the finite element method for computing scalar fifth-forces in the presence of arbitrary sources. The novelty and most important feature of *femtoscope* is that it includes a careful treatment of asymptotic boundary conditions — that is when the behaviour of the field is only known infinitely far away from the sources — which is essential to obtain a physically-meaningful numerical approximation.

Supervisors: Jean-Philippe Uzan & Joël Bergé (ONERA)

Back to timetable

Binary Neutron Star Mergers in the Multi-Messenger Astronomy Era: Population study and Afterglow Modelling

I will present an overview of the doctoral work I have conducted at IAP in the last 3 years. My focus is double: model the electromagnetic counterparts that follow neutron star mergers and supernovae, in particular the gamma-ray bursts (GRB) afterglows; and probe the population of binary neutron stars detectable with gravitational waves using population synthesis algorithms. I will present a refined model of GRB afterglows which for the first time combines in a self-consistent framework emission from a structured jet, while accounting for synchrotron emission and synchrotron self-Compton diffusions in both Thomson and Klein-Nishina regimes. I will then discuss the impact of binary stellar evolution on the properties of the population of binary neutron stars, in particular the merger rate. For a (much) more complete discussion, you will all be welcome to attend my PhD defence in September!

Supervisor: Frédéric Daigne & Irina Dvorkin

Back to timetable

Cosmological field-level inference using forward modeling of weak-lensing magnification

Weak-lensing serves as a powerful tool for investigating the Universe's large-scale structure and constraining key parameters of structure formation. While the shear effect has been extensively studied, the magnification causing distortions in the position and flux of background tracers, has been less explored and mainly considered as a bias for clustering analyses.

In this talk, we introduce a forward numerical model for simulating the weak-lensing magnification effect in terms of the deflection of distant tracers. It is part of a broader framework aimed at reconstructing the Universe's initial conditions and constraining cosmological parameters at the field level using a data-driven approach. We wish to demonstrate that incorporating magnification enhances precision in cosmological parameter constraints and reduces systematic uncertainties in reconstructing initial conditions when combined with other probes. We emphasize the importance of new statistical methods to fully harness upcoming cosmological data and extract maximum information from large-scale structure surveys beyond standard summary statistics. This work underscores the untapped potential of weak-lensing magnification in contributing to a comprehensive understanding of the Universe's composition and evolution.

Supervisors: Karim Benabed, Guilhem Lavaux & Pauline Zarrouk (LPNHE)

Back to timetable

Atmospheres on rocky exoplanets : TRAPPIST-1b

A new window opens to study the family of rocky planets and super-Earths with the launch of JWST. They are expected to have a wide range of properties ranging from no atmosphere to extended ones, hazes and clouds, and various compositions. The objective of my thesis is to focus on modelling the atmosphere of these planets, measuring the abundances of atmospheric molecules, temperature profiles, and identifying the presence and nature of clouds and hazes. In this talk, after briefly presenting the TRAPPIST-1 system, I will present my current investigation of the possibility of an atmosphere on TRAPPIST1b that would be compatible with the recent mesurement of its thermal emission[1] using the F1500W filter of the MIRI instrument on JWST.

Supervisors: Jean-Philippe Beaulieu, Pierre Drossard, Martin Turbet (LMD)

Back to timetable

[1] Greene, T.P., Bell, T.J., Ducrot, E. et al. Thermal Emission from the Earth-sized Exoplanet TRAPPIST-1 b using JWST. Nature (2023). `https://doi.org/10.1038/s41586-023-05951-7`

Stochastic Gravitational-Wave Background from compact binary mergers

Stochastic gravitational-wave backgrounds (SGWB) derive from the superposition of numerous individually unresolved gravitational-wave (GW) signals. In this talk, I will present a detailed modelization of the SGWB from compact binary mergers. I will discuss the use of population synthesis models to estimate the expected rate and properties of binary mergers for different types of compact objects such as neutron stars and black holes. I will also show how these predictions are used to calculate the resulting SGWB amplitude and spectral shape, taking into account the redshift evolution of the binary merger rate and the gravitational-wave strain from individual mergers. Finally I will discuss the prospects for detecting the SGWB with current and future gravitational-wave detectors.

Supervisors: Irina Dvorkin & Cyril Pitrou

Back to timetable

Particle content of inclined cosmic-ray air-showers for radio signal modeling

The origin of ultra-high-energy cosmic rays (UHECRs) is still unknown. They are likely produced in powerful cosmic accelerators but, because of their low flux and their deflections when they propagate across the magnetized Universe, it is difficult to collect them with large statistics and to infer their sources. When reaching the Earth, UHECRs penetrate the atmosphere and induce air-showers, which are cascades of secondary particles that emit a radio signal. The features of the radio signals emitted by very inclined air-showers are significantly different from those of vertical ones and the reconstruction of these air-showers is a new challenge for next-generation radio experiments such as GRAND, which focus on the detection of UHE particles. In this work, I'll present the electromagnetic particle content of very inclined air-showers, which has scarcely been studied so far and I'll explore the energy range that contribute the most to the radio emission. We will find that the distribution of the electromagnetic component in very inclined air-showers has characteristic features that could impact the reconstruction strategies of next-generation radio-detection experiments.

Supervisors: Kumiko Kotera & Olivier Martineau & Simon Prunet

Back to timetable

Fast realistic, differentiable halo generation for wide field galaxy surveys using physically constraint models

Accurately describing the relation between the dark matter over-density and the observable galaxy field is one of the significant obstacles to analyzing cosmic structures with next-generation galaxy surveys. Current galaxy bias models are either inaccurate or computationally too expensive to be used for efficient inference of small-scale information. To address this problem, in this talk, I will present a hybrid machine learning approach called the Neural Physical Engine (NPE) that was first developed and tested by Charnock et al. (2020). The network architecture exploits physical information of the galaxy bias problem and is suitable for zero-shot learning within field-level inference approaches. Furthermore, the model can efficiently generate mock halos catalogues consistent with full phase-space halo finders, including the 2-point correlation function.

Supervisors: Guilhem Lavaux & Jens Jasche (Stockholm University)

Back to timetable

Modelling of primeval galaxies at the JWST era

The James Webb Space Telescope is the largest and most powerful space telescope ever built. One of its main goals will be to study the birth of the first stars and galaxies of our Universe. Preparing for the exploitation of JWST data requires an improvement of the models currently used to interpret the light emitted by primeval galaxies. To reproduce the emission from such galaxies more realistically than possible today, it is necessary to examine the contribution from massive binary stars, which some recent studies suggest could play a significant role in the production of high-energy radiation in these young star-forming regions. Achieving this requires an extensive exploration of the spectral signatures of these stars and their dependence on galaxy physical parameters. It is also crucial to consider the contribution from several other physical processes, which had not yet been self-consistently included in stellar population synthesis models, such as accretion onto X-Ray binary systems, fast radiative shocks, or more realistic stellar formation histories.

Supervisor: Stéphane Charlot

Back to timetable

The Cosmological Flow

Inflation is a widely accepted paradigm explaining the origin of the observed spatial correlation in cosmological structures. However, the physics of inflation remains elusive, and a key challenge of primordial cosmology is to decipher it through the study of cosmological correlators, which notably encode high-energy physics effects during inflation. As we enter a precision physics era, it is vital to develop new computational methods to probe these fine features. In this short presentation, I will present the Cosmological Flow approach that enables one to compute inflationary correlators directly at the level of effective field theories of inflationary fluctuations, hence bypassing the intricacies of Feynman diagrams computations.

Supervisor: Sébastien Renaux-Petel

Back to timetable

Quantitative Comparison of Image Generation between Diffusion Model and GAN: Application in 21 cm Images

Generative adversarial networks (GANs) are frequently utilized in the field of astronomy to construct an emulator of numerical simulations. Nevertheless, training GANs can prove to be a precarious task, as they are prone to instability and often lead to mode collapse problems. Conversely, the denoising diffusion model also has the ability to generate high-quality data and has shown superiority over GANs with regard to numerous natural image datasets. In this study, we utilize simulated 21 cm images - an example of another non-trivial image dataset - and undertake a quantitative comparison between denoising diffusion models utilizing a non-Gaussian metric known as scattering transform. In particular, we utilize the two models to generate 21 cm images both unconditionally and conditionally based on astrophysical parameters. Using our new Frecher Scattering Distance score, we demonstrate that the diffusion model outperforms StyleGAN2 on all tasks. Through our fisher forecasting, we demonstrate that on our datasets, GANs exhibit mode collapses in varying ways, while the diffusion model yields more robust generation. Our findings suggest that the diffusion model may be a viable alternative to GANs for generating high-quality images, particularly in the realm of astrophysics.

Supervisor: Yi Mao (Tsinghua University, China)

Back to timetable

Thermal Sunyaev-Zeldovich power spectrum: analytical model and measures in simulations

The distribution of matter in the Universe is a powerful probe of cosmology. Measuring the efficiency with which gravity produces clusters against expanding Universe is the key to understanding, e.g. the equation of state of dark energy. Numerous projects aim at measuring the matter distribution across time in the Universe but no observable gives the perfect figure of this distribution (because of instrumental limitation, astrophysical limitation, or because they probe different redshifts). Cross-correlation of different probes is a powerful way to lift these limitations. My work focuses on the construction of a robust halo model for the thermal Sunyaev-Zeldovich power spectrum (one such tracer of the LSS) and to cross-correlate it with different probes of the distribution of matter (lensing, CMB lensing, galaxy count,…). To do so, I work with an analytical halo model of this power spectrum and I measure different profiles and power spectrums in the Horizon-AGN simulation to compare both and to test hypotheses of the model, such as the pressure profiles in halos and their link with feedback. In this talk I will thus present and comment my results on these comparisons.

Supervisors: Karim Benabed & Yohan Dubois

Back to timetable

Exploring the impact of recent episodes of star formation in the Milky Way disk

Star formation history (SFH) is a crucial but uncertain factor in studies of chemical evolution in the Milky Way. In recent years, large-scale surveys have provided detailed information on the properties of an enormous amount of stars covering a large volume of our Galaxy, allowing further insight into the recent SFH of the Milky Way disk. We study the recently reported episodes of recent star formation in the local Galactic disk, revealing the possibility of accretion events, or perturbations triggered by satellites. We simulate different types of star formation bursts (SFBs) induced by temporarily enhanced star formation efficiency based on a semi-analytical model of the MW evolution including stellar radial migration. Our model predicts the impact of these SFBs, which create distinct overdensities in various phase spaces of the stellar population properties (age-metallicity, abundance ratios, etc.).

Supervisor: Nikos Prantzos

Back to timetable

Loss of coherence and synchrotron emission for radio signals from inclined cosmic-ray air showers

Next-generation ultra-high-energy detectors such as GRAND, and AugerPrime target the radio emission from particle cascades induced by the interaction in air of ultra-high-energy cosmic-ray and neutrinos with energies beyond 100 PeV. Such showers arrive at the detector from very inclined trajectories and develop higher in the atmosphere than vertical showers. This enhances the magnetic deflection of the charged particles inside them and drastically affects their radio emission. I will show that in showers with zenith angles larger than 65°, and for an intense geomagnetic field, there can be significant synchrotron emission and loss of coherence in the shower as it develops.

Supervisors: Kumiko Kotera & Olivier Martineau (LPNHE)

Back to timetable

A re-analysis of equilibrium chemistry in five hot Jupiters

Studying chemical composition is fundamental to model the formation history of planets and planetary systems. Before the leap forward expected with JWST and Ariel satellites, we propose here an analysis of five targets to improve the determination of their composition and the chemical mechanisms that take place in their atmospheres. Our five targets are: HAT-P-12b, HD 209458b, WASP-6b, WASP-17b and WASP-39b, which have temperatures ranging from 1000K to 1700K and radii ranging from 0.9 to 1.9 Jupiter radius. We use observations of the Wide Field Camera 3 and of the Space Telescope Imaging Spectrograph, two instruments on the Hubble Space Telescope, with a wavelength coverage from 0.4 to 1.7 microns. We analyze these data with the Iraclis pipeline (Tsiaras et al. 2018) and perform a Bayesian retrieval analysis with TauREx (Al-Refaie et al. 2019) using a nested sampling algorithm.

Supervisors: Jean-Philippe Beaulieu, Pierre Drossart & Olivia Venot (LISA)

Back to timetable

The gravitational wave phase at 4.5PN order

Since their detection, gravitational waves have been perfectly predicted by general relativity, in particular by the post-Newtonian approximation in the inspiral phase. With the prospect of third generation gravitational-wave detectors such as Einstein Telescope and LISA in the next decades, these predictions need to be improved in order to match detector sensitivity. To this effect, we are coming to the end of a six-year project aiming at computing the gravitational-wave phase at 4.5PN order. One of the last crucial steps was the computation of non-linear propagation effects, the tails of memory.

Supervisors: Luc Blanchet & Laura Bernard (LUTH)

Back to timetable

Does anisotropic AGN feedback hamper the migration of massive black hole binaries?

The hardening phase of Massive Black Hole (MBH) binaries in Circumbinary Discs (CBDs) is mainly driven by the gravitational torques exerted by the binary on the CBD. This mechanism is more efficient for massive and thick CBDs, whose viscous torque prevents the binary from carving a gap in the disc, leaving it embedded in the gas and hence leading to a rapid MBHs migration. A recent study has found that when AGN winds from the MBHs are taken into account, the ejection of gas makes the binary migration stall by the lack of gas to exchange torques with, in this way preventing the MBHs from reaching the gravitational waves emission regime. However, this work is limited to isotropic winds, but wind anisotropy could profoundly alter this picture by reducing the disc-wind coupling. In my presentation I will discuss preliminary results concerning the role of wind anisotropy in shaping the hardening phase of MBH binaries in CBDs.

Supervisors: F. Haardt (Università degli Studi dell'Insubria) & Marta Volonteri

Back to timetable

Multimessenger study of merging massive black holes in the Obelisk simulation: gravitational waves, electromagnetic counterparts, and their link to galaxy and black hole populations

Massive black hole (BH) mergers are predicted to be powerful sources of low-frequency gravitational waves (GWs). Coupling the detection of GWs with an electromagnetic (EM) detection can provide key information about merging BHs and their environments. Another important question is how the astrophysical information extracted from BH mergers can inform us about BH evolution. We analyse the high-resolution cosmological radiation-hydrodynamics simulation Obelisk, run to redshift z=3.5, to study the properties of the merging BH population, its differences with the underlying global BH population in terms of BH and galaxy properties, and its detectability in GW and EM domains, modelling spectral energy distribution and obscuration.

Supervisors: Marta Volonteri & Yohan Dubois

Back to timetable

Cosmological parameters with CMB primary anisotropies observed by the SPT-3G instrument

The South Pole Telescope (SPT) is observing the cosmic microwave background (CMB) anisotropies with arcminute resolution using its state-of-the-art camera (SPT-3G). Upcoming constraints on cosmological constraints from power spectrum analyses with the 2019/2020 data will be at least as tight as Planck's ones, while remaining independent from the satellite experiment, thus allowing to test the consistency of the two data sets and potentially discover evidence of new physics. In this talk, I will present improvements to the likelihood pipeline for the next data release.

Supervisors: Silvia Galli, Karim Benabed & Eric Hivon

Back to timetable

Building the COSMOS-Web galaxy catalog: A key resource for tracing galaxy evolution with JWST observations

Since the beginning of the observations in 2022, JWST has revealed the faintest and furthest galaxies ever observed. However, to push forward our understanding of early mass assembly and processes driving star formation efficiency, there is a need for wider extragalactic surveys, large enough to eliminate cosmic variance, and probe the early filamentary large-scale structures. COSMOS-Web is the largest imaging program in the JWST's first cycle of observations, with a contiguous coverage of 0.54 deg^2 in the COSMOS field. Thanks to its deep and high-resolution photometry in five infrared filters and the combination of multiwavelength data available in COSMOS, it will provide an valuable resource for the study of the formation and evolution of galaxies and their environments back to the universe's earliest epochs. In this talk, I will present an overview of this survey and discuss the creation process of the COSMOS-Web catalog, from the detection of sources in the images to the determination of galaxy properties such as their magnitude, redshift or stellar mass. I will highlight the catalog's first results, including remarkable depth, redshift coverage and precision, surpassing those obtained by previous wide deep field surveys. Furthermore, I will demonstrate how this key resource can be used to investigate galaxy evolution, such as the study of galaxy clustering across the cosmic web.

Supervisors: Henry Joy McCracken & Clotilde Laigle

Back to timetable

Long-term relaxation of self-gravitating systems

The master equation describing the long-term evolution of isolated discrete self-gravitating systems is the so-called inhomogeneous Balescu-Lenard equation. Such a formalism is particularly valuable because it analytically captures some of the key non-linear processes involved in these systems' orbit reshuffling when driven by Poisson shot noise. Yet, this kinetic framework relies on specific sets of asymptotic assumption, (e.g., integrability, timescale separation…) which may not be strictly fulfilled in practice. In this presentation, I will outline these different processes involved in the long-term evolution of self-gravitating systems by highlighting their respective contributions depending on the considered geometry and regime.

Supervisors: Christophe Pichon & Jean-Baptiste Fouvry

Back to timetable

Observing z>9 galaxy candidates through lensing cluster Abell 2744 with JWST

The new era of observation has begun with JWST. The first series of observations has already revealed surprising results regarding high-redshift galaxies. In particular, the number density and stellar mass of these sources defy current theoretical predictions of galaxy formation. While these galaxies might be a particular case of rare enhancement of star formation due to the limited survey area, these exciting findings highlight the potential for JWST to probe the early stages of galaxy formation.

In this presentation I will talk about the results of our new search for high-redshift galaxies at z>9 using ultra-deep NIRCam observations of the lensing cluster Abell 2744 as part of our JWST Cycle 1 program UNCOVER. We used two independent codes BEAGLE and Eazy to identify high-redshift galaxies through photometric redshifts , in combination with dropout selection. We found 15 candidates at $9 < z < 12$ and 3 candidates at $12 < z < 13$, some of those galaxies show not only the Lyman break, but also a Balmer break. Finally, I will discuss the implications of our results regarding recent JWST observations and theoretical predictions.

Supervisors: Hakim Atek & Stéphane Charlot

Back to timetable

What drives the corpulence of galaxies? The formation of compact and diffuse dwarf galaxies in TNG50

By their fragility, dwarf galaxies are excellent laboratories for understanding how physical processes act on the evolution of galaxies. Despite their limitations, cosmological hydrodynamical simulations are useful tools for modeling these processes, allowing us to verify our understanding (or lack thereof) of galaxy evolution. In this work, we study the evolution of dwarf galaxies in IllustrisTNG50, trying to understand why some of them became very compact while others become very diffuse. For this, we split our z = 0 sample of dwarf galaxies ($\log M_\star$ between 8.3 and 9.3) between *Normal*, *Compact* and *Diffuse* objects (according to the size of the galaxy). While their most massive progenitors are similar in size at the early time, there subsequent evolution follows different trends, with *Diffuse* galaxies growing continuously from z $\sim$ 2 while *Compact* galaxies decreasing in size from z $\sim$ 1.

In my presentation, in addition to describing the *Diffuse* and *Compact* dwarf galaxies present in TNG50, I will describe what is happening during the evolution of these different objects in terms of different parameters and mechanisms analyzed such as: gas content and the velocity fields; star formation rates; halo spin magnitude and direction; global and local environment; merger history; black holes and AGN. I will conclude by presenting our favorite scenario that distinguishes the corpulence of dwarf galaxies in TNG50, and whether or not this is related to the simulation sub-grid physics.

Supervisor: Gastão B. Lima Neto (Instituto de Astronomia, Geofísica e Ciências Atmosféricas, São Paulo, Brasil)
Supervisor of this projet: Gary Mamon

Back to timetable