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T01

Some techniques to search for axions and axion-like particles

In the past years, axions and axion-like particles (ALPs) gained more popularity and slowly became one of the most appealing candidates that can form the total abundance of the cold dark matter (CDM) in the universe. In a short talk, I will try to give the flavor of using different methods to search for such a type of dark matter candidates and/or to constrain some of their properties.

T02

Binary system dynamics in the EFT approach

The recent detections of gravitational waves from coalescing binaries by the LIGO and Virgo interferometers not only opened a new window of observation into the Universe but also revived interest in the study of the relativistic two-body problem. Since then these detections have deeply impacted our current knowledge of processes of both astrophysical and cosmological nature. In particular, in the mid-2000s, the dynamics of binary systems gained a field-theoretical formulation, being then described as an Effective Field Theory (EFT). Within this framework, the different scales involved in the problem define different dynamical regions: on one side, the short-scale of potential modes describes the conservative interaction between the two bodies, while on the other, the long-distance scales account for gravitational-wave processes. These two regions define the so-called near and far zones, respectively. Although the computation of quantities in each of these two regions can be obtained independently at lower orders, at higher orders, the gravitational radiation starts to affect the conservative dynamics of the system through radiation-effect effects. In this talk, following the presentation of the general scope of this EFT and the role played by the different scales of the problem, we discuss the state-of-the-art progress towards the complete understanding of radiation-reaction effects on the two-body dynamics.

T03

Searching for spin-2 ULDM with gravitational waves interferometers

The detection of gravitational waves from merging binaries has ushered in the era of gravitational wave interferometer astronomy. Besides these strong, transient, calamitous events, much weaker signals can be detected if the oscillations are nearly monochromatic and "continuous", that is, coherent over a long time. In this work we show that ultra-light dark matter of spin two, owing to its universal coupling α to Standard Model fields, generates a signal that is akin to but distinct from a continuous gravitational wave. We show that this signal could be detected with current and planned gravitational wave interferometers. In the event of a null detection, current facilities could constrain the coupling to be below $\alpha\sim10-7$ for frequencies of tens of Hz, corresponding to dark matter masses around the 10−13 eV mark. Future facilities could further lower these upper limits and extend them to smaller masses down to 10−18 eV. These limits would be the most stringent bounds on the spin-2 Yukawa fifth force strength, parametrised by α, in the frequency ranges accessible by gravitational wave interferometers. The implementation of this type of searches for gravitational wave interferometers would therefore further our grasp of both dark matter and gravity.

T04

BAO scale inference from biased tracers using the EFT likelihood

The physical scale corresponding to baryon acoustic oscillations (BAO), the size of the sound horizon at recombination, is precisely determined by CMB experiments. Measuring the apparent size of the BAO scale imprinted in the clustering of galaxies gives us a direct estimate of the angular-diameter distance and the Hubble parameter as a function of redshift. The BAO feature is damped by non-linear structure formation, which reduces the precision with which we can infer the BAO scale from standard galaxy clustering analysis methods. Many methods to undo this damping via the so-called BAO reconstruction have so far been proposed; however, they all rely on backward modeling. In this talk, I will present the first results of BAO inference from rest-frame halo catalogs using forward modeling combined with the EFT likelihood, in the case where the initial phases of the density field are fixed.

T05

Baseline-Dependent Ionospheric Effects on Interferometer Calibration of LOFAR EoR Observations

The turbulent ionosphere causes phase shifts to incoming radio waves on a broad range of temporal and spatial scales. When an interferometer is not sufficiently calibrated for these direction-dependent effects, these time-varying phase shifts can cause the signal to decorrelate. Due to the multitude of spatial scales on which the ionosphere influences the signal, there is a baseline dependence in its effect on the interferometric array. We investigate the effects of this baseline-dependent decorrelation on the Epoch of Reionization observations with the LOw Frequency ARray (LOFAR). In this talk, we show how a simulated thin screen ionosphere influences the calibration of short, intermediate, and long baselines, as well as the effect of this ionosphere on power spectra produced with a model LOFAR-EoR pipeline. Furthermore, we show novel results on how the direction of the wind above LOFAR can directly influence the level of decorrelation experienced by its baselines. These results can shed light on the extent to which the ionosphere is currently a limiting factor in the detectability of the 21-cm hyperfine transition of neutral hydrogen using LOFAR.

T06

Augmenting redshift information in large cosmological surveys

Exploiting next generation cosmological surveys will require estimating redshift for large samples of galaxies, beyond the available spectroscopic measurements. For example, the accuracy of cosmological constraints as those from weak lensing tomography will depend on the knowledge of the underlying redshift distributions based on photometric redshift calibrations. I will discuss two ways to augment broad-band photometric data using ancillary spectroscopic information. In the first method, we stack low signal-to-noise simulated Euclid spectra for homogeneous colour groups identified in the multi-band photometry using Self-Organising Maps (SOMs). The high spectral resolution available in the stacked spectra complements the photometry and helps to break the colour-redshift degeneracy and constrain the redshift distribution of galaxy samples. We demonstrate the method on simulated Vera C. Rubin Observatory and Euclid mock survey data sets based on the Euclid Flagship mock galaxy catalogue (Cagliari+ 2022, A&A, 660, A9). In a second approach, I will show preliminary results on the application of Graph Neural Networks to combine photometric multi-band information with known redshifts from neighbouring objects, exploiting the intrinsic spatial correlation of galaxies.

T07

The covariance of the halo bispectrum

Predictions from single-field inflation are consistent with CMB observations. Large scale structure observations will greatly improve our knowledge of the early universe. In particular, we can learn much about the inflationary era by testing for primordial non-Gaussianity (PNG). The upcoming galaxy surveys promise to improve such constraints by mapping the 3-dimensional distribution of matter and galaxies in the universe to scales of the order of the Hubble horizon. Then, to extract information about the early universe, we need to compute observables with the same precision as the observations, for example, the galaxy Power Spectrum and Bispectrum. One important ingredient to determining the information content of an observable is a precise estimation of the covariance. The main goal of the talk is to present how the modelling of the power spectrum-bispectrum covariance is improved by including non-Gaussian terms that agree with N-body simulations at a 20% level. Non-Gaussian terms in the covariance are significant for observables evaluated at the squeezed limit, as in the case of the local PNG factor. Then, by doing a Fisher analysis on the constraining power of PNG it is confirmed that non-Gaussian terms have to be taken into account, as they degrade the constraint by more than a factor of 2.

T08

Imprint of the Seesaw Mechanism on Feebly Interacting Dark Matter and the Baryon Asymmetry

We show that the type-I seesaw, responsible for generating the light neutrino mass, itself is capable of accommodating one of the three right-handed neutrinos as a freeze-in type of dark matter (DM) where the required smallness of the associated coupling is connected to the lightness of the (smallest) active neutrino mass. It turns out that (a) the non-thermal production of DM having mass $\lesssim \mathcal{O}(1)$ MeV (via decays of W, Z bosons and SM Higgs) consistent with relic density as well as (b) its stability determine this smallest active neutrino mass uniquely $\sim {\mathcal{O}}(10^{-12})$ eV. On the other hand, study of flavor leptogenesis in this scenario (taking into account the latest neutrino data and Higgs vacuum stability issue) fixes the scale of two other right-handed neutrinos.

T09

Self-similar solutions for Fuzzy Dark Matter

Fuzzy Dark Matter (FDM) models admit self-similar solutions which are very different from their Cold Dark Matter (CDM) counterparts and do not converge to the latter in the semiclassical limit. In contrast with the familiar CDM hierarchical collapse, they correspond to an inverse-hierarchy blow-up. Constant-mass shells start in the nonlinear regime, at early times, with small radii and high densities, and expand to reach at late times the Hubble flow, up to small linear perturbations. Thus, larger masses become linear first. This blow-up approximately follows the Hubble expansion, so that the central density contrast remains constant with time, although the width of the self-similar profile shrinks in comoving coordinates. As in a gravitational cooling process, matter is ejected from the central peaks through successive clumps. As in wave systems, the velocities of the geometrical structures and of the matter do not coincide, and matter slowly moves from one clump to the next, with intermittent velocity bursts at the transitions. These features are best observed using the density-velocity representation of the nonrelativistic scalar field, or the mass-shell trajectories, than with the Husimi phase-space distribution, where an analogue of the Heisenberg uncertainty principle blurs the resolution in the position or velocity direction. These behaviours are due to the quantum pressure and the wavelike properties of the Schrödinger equation. Although the latter has been used as an alternative to N-body simulations for CDM, these self-similar solutions show that the semiclassical limit needs to be handled with care

T10

E and B modes from secondary polarisation of CMB

Detection of primordial B modes will be a primary goal for upcoming CMB related experiments. If detected, it will have important consequences for inflationary theory and will also act as a probe for testing different physics at very early times. A major hindrance in detecting these B modes will be the various foreground sources which can also create polarisation signal. These secondary anisotropies can be as strong as the primordial B modes. Hence it is important that we look at the different sources of later times and predict their signal, in order to correctly estimate the strength of primordial B modes. Our work involves looking at the polarisation signal which gets generated due to the kinetic Sunyaev Zel'dovich (kSZ) effect. This signal has a spectral signature which is different from Planckian, due to which it may be more easily detected by the sensitive future experiments. This signal is generated at higher orders in perturbation theory, so we expect to get both E and B mode polarisation, even if the velocity fields are assumed to be sourced by scalar perturbations. We do a full sky numerical estimation of the power spectrum of both E and B modes.

T11

Gravitational Reheating

Our present understanding of reheating phase is incomplete due to a lack of observations. Apart from its cosmological implications, reheating should play a vital role in particle physics and inflation model building. No systematic studies on reheating have been done so far, keeping such broader implications in mind. Conventionally reheating dynamics are modeled by invoking arbitrary coupling among the inflaton and daughter fields. Such an approach lacks robust cosmological predictions and is difficult to verify through observation. In this letter, we propose a reheating scenario where the inflaton is coupled with all the daughter fields only gravitationally. Besides being successful in reheating the universe, the scenario offers a robust cosmological prediction of the primordial gravitational wave spectrum and discards a large number of possible models of dark matter and inflation that are otherwise consistent with PLANCK. Reference: e-Print: 2201.02348.

T12

Rare events are non-perturbative.

In recent years, it has been noted that perturbative treatment of large fluctuations fails to make correct predictions, e.g., for the formation of primordial black holes. Some non-perturbative methods like stochastic formalism were introduced to explore the tail of distributions, resulting in exponential tails for probability distributions in some models when quantum kicks dominate the classical trajectory. We advocate that the \delta N formalism can be applied to non-perturbatively calculate the tail of the distribution of fluctuations. We study a model of single-field inflation in which the tail of the PDF decays more slowly than exponential. This may significantly enhance the probability of the formation of PBHs. Furthermore, we employ the nonlinear \delta N formalism in a model of two-field ultra-slow-roll (USR) inflation. We show that the geometry of the surface of the end of USR phase in the field space plays a crucial role in the PDF of fluctuations. In particular, we illustrate how the geometrical properties of the boundary may lift the tail of PDF for curvature perturbation. References: arxiv/2112.04520 arxiv/2201.07258

T13

Pairwise Hot Spot detections through deep neural network

Heavy particles with masses much bigger than the inflationary Hubble scale can be pair produced through their couplings to the inflaton. The previous work on the model, arXiv:2107.09061, describes that these pair produced particles can directly affect primordial curvature perturbation. Then, the perturbation, preserved in superhorizon scale, propagates and creates distinct pairwise hot spot like signatures on CMB map. We present the possibility of convolutional neural network's performance on capturing such pairwise hot spot signatures in simulated CMB map.

T14

Helical magnetic field lead to baryogenesis

The origin of primordial magnetic fields and baryon asymmetry of the Universe are still unresolved issues and require physics beyond the standard models of cosmology and particle physics. Since both require physics beyond the standard model, there is a possibility that the same new physics can solve both. In our recent works we have proposed a model, where non-minimal coupling to the Riemann tensor generates sufficient primordial helical magnetic fields at all observable scales during inflation. Interestingly, the generation of helical magnetic fields leads to baryogenesis and the model predicts the observed amount of baryon asymmetry of the Universe for a range of reheating temperatures consistent with the observations. Refs: Phys. Rev. D 102, 103528 (arXiv: 2008.10825); Phys. Rev. D 104, 063502 (arXiv: 2103.05339)

T15

The importance of clustering analysis in future gravitational wave surveys

The question underneath this talk is: can future gravitational wave surveys be an effective tool to constrain cosmology and astrophysics? Long story short, the answer is: yes, they will. One of the most interesting aspects in this field is the analysis of the clustering properties of black hole binary mergers, that will be mapped by future detectors in the full sky and up to very high distances. I will discuss how hydrodynamical simulations can help modelling the clustering of such sources and, provided that the redshift cannot be directly measured from gravitational wave signals, how the use of luminosity distance space can constitute a valid alternative to build a self-consistent analysis avoiding the need of external datasets or assumptions. Finally, I will show how the tomographic analysis of binary mergers' angular power spectra can be used both to constrain cosmology and to disentangle the astrophysical or primordial origin of their progenitors.

T16

The Effective field Theory of Large-Scale Structure and Multi-Tracer

The fluid equations describing the large-scale structure of the universe are complex, which requires a perturbative approach. In this talk, I will summarize the work done in Thiago Mergulhão et al JCAP04(2022)021: I will review the main ideas of the Effective Field theory of Large-Scale Structure (EFTofLSS) and show how it leads to a description of the galaxy clustering occurring in small-scales. After having introduced all the relevant tools and results for the single-tracer case, I will show how to extend it to include the concept of multiple tracers within perturbation theory. Although the analysis with many tracers has a higher dimensional parameter space, the constraints on both cosmological and bias parameters when performing a full-shape power spectrum analysis are improved. It indicates that splitting the tracer field into subgroups includes new information in the modelling, from both linear and non-linear scales, that is not present in the single-tracer case. I explain where this information comes from and give a brief overview of the follow-up paper I am working on at the present moment.

T17

Evolution of Primordial Magnetic Fields from the Moment of Generation till Today

Magnetic fields are ubiquitous on all cosmic scales probed so far, from planets and stars to large scale, coherent (up to kpc scales and with the strengths of microGauss) fields found in galaxies and galaxy clusters. The origin of these fields still remains unknown. A leading possible explanation is that the observed fields are amplified remnants of significantly weaker, primordial seed magnetic fields generated in the early Universe. An intriguing possibility of having very weak magnetic fields in cosmic voids, as hinted at by observations of distant blazars, is strengthening the view of the relic magnetisation of the Universe. The major questions in the studies of primordial magnetic fields (PMFs) include: what are the generation scenarios of primordial seed fields and how do they evolve in the early Universe and later, during structure formation? In our work, we study inflation-generated PMFs which might have unlimited correlation length scales and causally, phase-transition generated fields with correlation lengths limited by the Hubble length scale (at the moment of generation). We use the cosmological magnetohydrodynamical (MHD) code ENZO to evolve these PMFs during large scale structure formation. We account for the magnetic field dynamics prior to recombination. In this talk, I will discuss the evolution of PMFs from the early Universe till the current epoch. I will present our findings which include the distinctive evolution of different seed fields retaining the information of magnetic initial conditions on the largest scales of the Universe. Finally, I will talk about the observational perspective of our

T18

Dissipative effects during inflation

Dissipative effects during inflation can be introduced by coupling the inflaton field to light degrees of freedom. Assuming thermalization and a temporarily non-negligible radiation density during inflation, a localized enhancement of the primordial power spectrum can appear due to stochastic dynamics. This enhancement may lead to primordial black hole production as well as a stochastic background of gravitational waves. If these black holes constitute a significant fraction of the dark matter, the associated gravitational wave signal would be potentially observable by LISA. The calculation of the primordial power spectrum in this setup differs from the usual one in standard single-field inflation, mainly due to the stochastic nature of the radiation source of fluctuations. I will present three different (and mutually consistent) approaches to solve the problem. This work is in progress in collaboration with my PhD supervisor at IFT UAM-CSIC, Dr. Guillermo Ballesteros Martínez, as well as Dr. Marcos Alejandro García García (Universidad Nacional Autónoma de México), Dr. Mathias Pierre (DESY) and Julián Leonardo Rey Idler (IFT UAM-CSIC).

T19

Removing extragalactic foregrounds in CMB lensing reconstruction

Extragalactic foregrounds in temperature maps of the Cosmic Microwave Background (CMB) severely limit the ability of standard estimators to reconstruct the weak lensing potential. These foregrounds are not fully removable by multi-frequency cleaning or masking and can lead to large biases if not properly accounted for. We explore both geometric and multi-frequency methods to mitigate these foregrounds, and use simulations to quantify the effectiveness of these methods. In particular, we find that a simple bias-hardening technique - which approximates the foregrounds as a collection of sources with identical profiles - combined with a partial "deprojection" of the foregrounds using multi-frequency information, is capable of dramatically reducing the biases induced by these foregrounds, at a minimal cost in noise.

T20

Analytical growth functions for cosmic structures in a ΛCDM Universe

The cosmological fluid equations describe the early gravitational dynamics of cold dark matter (CDM), exposed to a uniform component of dark energy, the cosmological constant Λ. Perturbative predictions for the fluid equations typically assume that the impact of Λ on CDM can be encapsulated by a refined growing mode D of linear density fluctuations. Here we solve, to arbitrary high perturbative orders, the nonlinear fluid equations with an {\it Ansatz} for the fluid variables in increasing powers of D. We show that Λ begins to populate the solutions starting at the fifth order in this strict D-expansion. By applying suitable resummation techniques, we recast these solutions to a standard perturbative series where not D, but essentially the initial gravitational potential serves as the bookkeeping parameter within the expansion. Then, by using the refined growth functions at second and third order in standard perturbation theory, we determine the matter power spectrum to one-loop accuracy as well as the leading-order contribution to the matter bispectrum. We find that employing our refined growth functions impacts the total power- and bispectra at a precision that is below one percent at late times. However, for the power spectrum, we find a characteristic scale-dependent suppression that is fairly similar to what is observed in massive neutrino cosmologies. Therefore, we recommend employing our refined growth functions in order to reduce theoretical uncertainties for analysing data in related pipelines.

T21

Optimum frequency range required for component separation in CMB-Bharat

The Indian Consortium of cosmologists have proposed a space mission, Exploring Cosmic History and Origins (ECHO), popularly known as ‘CMB-Bharat’ to the ISRO. Detecting the primordial CMB B-mode signal is among the key scientific goals of ECHO[*]. ECHO will be a fourth-generation space mission, equipped with thousands of detectors spread over a wide frequency range of 28 -850 GHz. The B-mode signal is much fainter than the temperature anisotropy and is buried under galactic foregrounds at least by two orders of magnitude. The detection of the primordial signal will require highly sensitive instruments, efficient removal of the foregrounds and excellent control of the systematics. In my talk, I will focus on the performance of component separation methods in the presence of complex foreground models of synchrotron and dust emissions. I will specifically focus on various complexities in thermal dust modelling. First, I will talk about the efficiency that can be achieved in removing the foreground and noise given the instrument specifications of ECHO. Next, I will talk about the optimum range of frequency channels that should be utilised to extract the CMB B-mode. I will demonstrate that it is beneficial to use fewer number dust dominated frequency channels for certain forms of dust complexities.

T22

Improved early warning efforts of compact binary mergers using higher modes of gravitational radiation

The pre-merger (early-warning) gravitational-wave (GW) detection and localization of a compact binary merger would enable astronomers to capture potential electromagnetic (EM) emissions around the time of the merger, thus shedding light on the complex physics of the merger. While early detection and sky localization are of primary importance to the multimessenger follow-up of the GW event, improved estimates of luminosity distance and orbital inclination could also provide insights on the observability of the EM emission. We demonstrate that the inclusion of higher modes of gravitational radiation, which vibrate at higher multiples of the orbital frequency than the dominant mode, would significantly improve the early-warning estimates of the sky-localization, luminosity distance, and orbital inclination of the binary. This will help astronomers to better determine their follow-up strategy.

T23

Interacting Dark Energy with the Power Spectrum and Bispectrum Multipoles

Interacting dark energy models have been proposed as attractive alternatives to the standard cosmological model. In the next few years, Stage-IV galaxy clustering surveys are promising to provide highly accurate measurements, which would allow us to constrain these models. In my talk I will discuss how the state-of-the-art Effective Field Theory for Large Scale Structure permits us to model mildly non-linear scales of the galaxy power spectrum and bispectrum multipoles, while including the effects of the dark sector coupling. Using measurements from a large set of simulations and a likelihood pipeline, I will demonstrate the interplay between models, scales of interest and the interfered parameters. Finally, I will present a forecast of uncertainties on the dark energy equation of state and on the interaction parameter from the joint multipoles analysis.

T24

The spin bias of dark-matter halos

To this day we have neither a complete analytical understanding nor a established observational evidence for secondary halo bias, i.e., the fact that dark-matter halo bias depends on properties other than mass. In this talk, I will focus on spin bias, the secondary dependence of halo clustering on spin. This phenomenon displays a non-trivial mass-dependence, where higher-spin halos have a higher bias at the high-mass end, while the trend inverts for low-mass halos. I will show how we can disentangle this complicated effect and easily understand the physical origins of low-mass spin bias by investigating a very specific population of halos, the splashback halos. I will also discuss how halo spin bias can be detected in observations using the kinetic Sunyaev-Zel'dovich effect and how it is manifested in the galaxy population. Finally, I will go over some of our new findings related to spin bias.

T25

Hunting for ultra-light axion dark matter in the Dark Ages

21cm intensity mapping can potentially provide us with an unprecedented window on high redshifts, thus shedding light on the Dark Ages of the Universe. We can use it to probe the nature of dark matter: in particular, if the dark matter is made of ultra-light axion-like particles around the 10^-19/-21 eV mass scale, the 21cm angular power-spectrum will exhibit suppressions at certain scales and enhancement at other ones, with respect to the CDM case. This effect is intertwined with the imprint of baryon-dark matter relative velocity at recombination. The interplay of the two can be used to put constraints on the mass of the axion with future experiments.

T26

Impact of galaxy formation on the evolution of dark matter halo in the cosmic web

Dark matter haloes have been extensively studied using gravity-only simulations, but to compare with actual observations, the role of galaxy formation must also be incorporated. However, predicting the response of dark matter halo to galaxy formation remains an unsolved problem. I will discuss our recent work, where we have studied this halo response statistically as a function of various halo properties using hydrodynamical simulations, IllustrisTNG and EAGLE. It is usually expected that the relaxation of the dark halo is given by the amount of baryons condensed. However, we find that the relaxation explicitly depends on the location from the centre of the halo. While this halo response behaves differently at different mass scales, a simple quasi-adiabatic relaxation relation works reasonably well among haloes of similar mass and at any specific radius. We use this result to build a comprehensive model that has direct application in baryonification procedures and rotation curve studies.