The nature of Dark Matter and Large Scale Structure

Monday 10 June 2019 - Thursday 13 June 2019

University of Cyprus

Scientific Programme

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Abstracts

Chris Byrnes. *Cosmology with primordial black holes*

Primordial black holes (PBHs) could be part or all of the dark matter, but even if they don't exist, they constrain the initial conditions of the Universe and inflation. In this talk I discuss how the non-detection of PBHs constrains the primordial power spectrum over a wider range of scales than any other probe. I will discuss some of the subtleties associated with making these constraints, including their dependence on the shape of the primordial power spectrum (which cannot be steeper than k^4), the background equation-of-state parameter and the non-linear relation

between the curvature and density perturbations.
More optimistically, if LIGO and Virgo have detected even one PBH, I will show that the reduction in pressure during the QCD transition naturally leads to an exponentially enhanced number of solar mas PBHs. Being below the Chandrasekhar mass, the detection of such light black holes would be a smoking gun for a primordial black hole. Finally, I will show that a mixed dark matter model with WIMPs and PBHs is already observationally excluded, unless the PBHs are at least one million times lighter than the sun.

Eliza Chisari. *Cosmology with weak gravitational lensing: challenges and opportunities*

Weak gravitational lensing of galaxies is one of the key cosmological probes of the next decade. Dedicated campaigns, such as the Kilo-Degree Survey (KiDS), are measuring and modeling distortions of galaxy shapes to explore the nature of dark energy and dark matter. In the next decade, a dramatic increase of statistical power, driven by wider and deeper surveys, will result in opportunities to further constrain cosmological models, and this will also pose new challenges. The steep increase in constraining power will require more accurate models of the Universe. In particular, astrophysical effects such as the alignment of galaxies with the large-scale structure, or the impact of galaxy formation on the distribution of matter, will need to be taken into account for successful extraction of cosmological information. I will give an overview of the status of this generation of weak lensing experiments, highlighting recent results from the KiDS collaboration, and I will outline the challenges and opportunities that will be brought about by next generation experiments such as the Large Synoptic Survey Telescope.

Pier-Stefano Corasaniti. *Dark Matter Scenarios and the High-z Universe.*

Several scenarios of dark matter alternative to the Cold Dark Matter paradigm predict a suppression of the halo mass function at low halo masses. This has strong implications for the early abundance of faint galaxies as well as the process of cosmic reionisation. In this talk I will discuss constraints from recent observations of the high-z universe on a large class of DM models characterized by a small-scale cut-off in the linear power spectrum.

Anastasia Fialkov. *Effects of Dark Matter at Cosmic Dawn*

In hierarchical picture of structure formation, the first galaxies form in low mass dark matter halos of about 100000 solar masses. In some scenarios, dark matter might impact formation of first star-forming objects, affecting observable signals such as the 21-cm line of neutral hydrogen, while remaining consistent with the local Universe. I will talk about possible effects of dark matter on formation of first stars, galaxies and the 21-cm signal.

Ben Granett. *Mapping the Large-Scale Structure of the Universe with Spectroscopic Redshift Surveys*

I will review the power of spectroscopic redshift surveys to map the distribution of galaxies over cosmic time. Galaxy clustering statistics provide important constraints to track the growth of structure and the expansion history, and in combination with complementary experiments, will address fundamental questions about the nature of dark energy, gravity and the early Universe. I will highlight the role of simulations to forward model galaxy clustering observables for cosmological inference. The high statistical precision expected from upcoming surveys such as ESA Euclid will undoubtedly reveal new sources of systematic uncertainties in the observations and theoretical modelling. To overcome these challenges and fully realize the scientific potential of the data will call for the development of innovative analysis approaches.

Nico Hamaus. *Cosmic Voids as Cosmological Probes*

Redshift surveys measure the location of millions of galaxies in the observable Universe, thereby constructing a three-dimensional map of its large-scale structure. This structure is characterized by dense clusters of galaxies, connected by filaments and sheets of lower density. The remaining and dominant volume within this cosmic web is taken up by voids, vast regions of relatively empty space. I will highlight some recent advances in modeling average void density and velocity profiles, as well as their anisotropic shapes in redshift space on the basis of simulations and mock galaxy catalogs. While clusters, filaments and sheets have entered various stages of nonlinearity in the past, voids represent structures whose dynamic evolution can be described remarkably well by linear theory, suggesting them to be among the most pristine objects to consider for future studies on the nature of dark energy, dark matter and gravity. I will present first results in this context, obtained via the analysis of galaxy survey data from SDSS and DES.

Stephane Ilic. *Challenging the CDM paradigm: constraining DM properties with CMB data*

To date, all evidence for Cold Dark Matter (CDM) is still purely gravitational and thus the CDM paradigm remains to be thoroughly tested. In calculations of the Cosmic Microwave Background (CMB) anisotropies, CDM is usually modelled as pressureless perfect fluid. In the present work, we test the CDM paradigm by replacing the pressureless perfect fluid description by an imperfect fluid called Generalised Dark Matter (GDM). The standard CDM is nested in this new model which possesses more degrees of freedom and parameters. The GDM is indeed able to model natural deviations from a pressurless perfect fluid, with non-zero equation of state, sound speed, and viscosity. Using the Planck CMB data (and various other datasets), we present here the best constraints on the GDM model to date. This includes cases where all its parameters are allowed to vary independently in time in a non-parametric way, and cases where we model nonlinear effects using a GDM halo model, which allowed us to robustly include datasets from galaxy surveys to significantly tighten the constraints on GDM parameters.

Raul Jimenez. *Model Independent Cosmology*

Inference in cosmology is traditionally done via Bayesian model parameter estimation. However, this depends on the chosen model. I will show that it is possible to make model-independent-inference and in particular I will describe new findings about dark energy; the local and the very early Universe.

Michael Kopp. *The Schrödinger method: a unifying dynamical description for dark matter and massive neutrinos.*

This talk presents an introduction to the "Schrödinger method", a method to solve the Vlasov equation via the Schrödinger-Poisson equation. The Vlasov equation describes the collisionless dynamics of self-gravitating systems, in particular cold dark matter (CDM) and hot/warm DM to which non-relativistic massive neutrinos belong. For the first time, we implemented the Schrödinger method in two spatial dimensions in CUDA, extending the previous one-dimensional studies. We present a quantitive comparison of our code and the Vlasov solver ColDICE, finding excellent agreement. Similar excellent agreement is also found for hot initial conditions. This establishes that the Schrödinger method can be used as a unifying framework to accurately describe large scale structure formation in CDM + massive neutrino cosmologies both in simulations, as well as semi-analytical calculations. This is because all higher cumulants, like vorticity and velocity dispersion, are described by a spatially local field theory with only 2 degrees of freedom.

Lorenzo Reverberi. *fRevolution – Relativistic Cosmological Simulations in f(R) Gravity*

We present the new relativistic cosmological particle-mesh code fRevolution, based on gevolution, aimed at simulating non-linear structure formation in f(R) gravity. We introduce the general framework and approximation scheme, and the set of equations used to solve for the full set of gravitational perturbations. We show results for a point mass field and for cosmological simulations in the Hu-Sawicki model, and compare them to those of existing Newtonian codes.

Leonardo Senatore. *The Effective Field Theory of Large-Scale Structure applied to SDSS/BOSS data*

The Effective Field Theory of Large-Scale Structure is a formalism that allows us to predict the clustering of Cosmological Large-Scale Structure in the mildly non-linear regime in an accurate and reliable way. After validating our technique against several sets of numerical simulations, we perform the analysis for the cosmological parameters of the DR12 BOSS CMASS NGC data sample. We assume ΛCDM, a fixed value of the baryon/dark-matter matter ratio, Ω_b/Ω_c, and of the tilt of the primordial power spectrum, n_s, and no input from numerical simulations. By using the one-loop power spectrum multipoles and the tree-level bispectrum monopole, we preliminarly measure the primordial amplitude of the power spectrum, A_s, the abundance of matter, Ω_m, and the Hubble parameter, H_0 to several-percent level. These preliminary results, if confirmed, appear to be a substantial qualitative and quantitative improvement with respect to former analyses, and suggest that the Large-Scale Structure of the universe might contain much more cosmological information than previously believed. I will review the main aspects of the formalism and explain the details and the preliminary results of its application to the BOSS data.

Kyriakos Vattis. *Dark matter decaying in the late Universe can relieve the H0 tension*

We study the cosmological effects of two-body dark matter decays in which the products of the decay include a massless and a massive particle. We show that if the massive daughter particle is slightly warm it is possible to relieve the tension between distance ladder measurements of the present-day Hubble parameter with measurements from the cosmic microwave background.

Jesus Zavala. *Is gravity the only dark matter interaction that matters in the physics of galaxies?*

The standard model of cosmic structure formation is based on the Cold Dark Matter (CDM) hypothesis where non-gravitational dark matter interactions are irrelevant for the formation and evolution of galaxies. Surprisingly, current observations allow for significant departures from the CDM hypothesis, which could potentially leave signatures of the dark matter particle nature in the properties of galaxies. In this talk, I will describe some of these 'alternative' dark matter hypotheses and their connection to particle physics models from the perspective of a generalized theory of structure formation.