GR 10: Cosmo II

Time: Thursday 13:30–15:35 Location: ZHG008

Invited Talk GR 10.1 Thu 13:30 ZHG008

Probing the cosmic large-scale structure beyond the average — •Cora Uhlemann — Bielefeld University, Germany

The cosmic web of structure arises from the delicate interplay between the gravitational pull of dark matter and the accelerated expansion driven by dark energy. Galaxies form within this intricate skeleton of dark matter, making galaxy surveys powerful laboratories for exploring fundamental physics. The Euclid space telescope will map the distribution of galaxies across most of the sky, spanning over 10 billion years of cosmic history. Analysing billions of galaxies across vast cosmic volumes poses a significant big-data challenge, involving complex nonlinear physics and non-Gaussian statistics often simplified by relying on averages. I will describe how we can squeeze out more information by probing the cosmic large-scale structure beyond the average of standard forward models and statistical analyses. I will illustrate how ultralight dark matter creates quantum wave effects that dress the cosmic web and explain how it can help us to go beyond the average of standard forward models. Additionally, I will highlight the power of one-point statistics, which provide unique and complementary information to the commonly used two-point statistics, and show how these can be accurately predicted and utilised.

GR 10.2 Thu 14:15 ZHG008

Betti Functionals as Probes for Cosmic Topology — Ralf Aurich and •Frank Steiner — Institute for Theoretical Physics, Ulm University, Albert-Einstein-Alle 11,89060 Ulm

The question of the global topology of the Universe (cosmic topology) is still open. In the LCDM concordance model,it is assumed that the space of the Universe possesses the trivial topology of R^3, and thus that the Universe has an infinite volume. We study one of the simplest non-trivial topologies given by a cubic 3-torus describing a universe with a finite volume. To probe cosmic topology, we analyze certain structures in the cosmic microwave background (CMB) using Betti functionals and the Euler characteristic evaluated on excursion sets, which possess a simple geometrical interpretation. Since the CMB temperature fluctuations are observed on the sphere S^2 surrounding the observer, there are only 3 Betti functionals, beta_k(nu), k=0,1,2 (nu is the temperature threshold). Analytic approximations of the Gaussian expectations for the Betti functionals and an exact formula for the Euler characteristic are given. It is shown that beta_0 and beta_1 decrease with an increasing volume of the cubic 3-torus universe. Comparing with 4 Planck 2018 sky maps, it is found that the betas of the Planck maps lie between those of the torus universes with side-lengths L=2.0 and L=3.0 in units of the Hubble length. These results give a further hint that the Universe has a non-trivial topology. Ref.: Universe 2024, 10, 190

GR 10.3 Thu 14:35 ZHG008

Connecting Field-level and Summary Statistics — •Ivana Nikolac, Fabian Schmidt, and Beatriz Tucci — Max Planck Institut fur Astrophysik, Karl Schwarzschild Straße 1, 85748 Garching, Germany

Current methods for extracting cosmological information from galaxy distributions typically involve modelling and analysing the power spectrum or the 2-point correlation function. Expanding beyond the power spectrum can unveil significantly more information, including better constraints on dark energy and inflation models. Employing a Lagrangian EFT-based forward model, LEFTfield, other summary statistics can be investigated. These can then be used to obtain the posterior of the cosmological and bias parameters through simulation-based inference (SBI). A primary goal is to assess how the cosmological constraints obtained through SBI compare with those derived from field-level inference.

GR 10.4 Thu 14:55 ZHG008

Simulation-based inference has its own Dodelson-Schneider effect (but it knows that it does) — •Jed Homer[1,2], Oliver Friedrich[1,2,3], and Daniel Gruen[1,2,3] — [1]University Observatory, Faculty of Physics, Ludwig-Maximilians-Universität, Scheinerstr. 1, 81677 Munich, Germany — [2]Munich Center for Machine Learning (MCML) — [3]Excellence Cluster ORIGINS, Boltzmannstr. 2, 85748 Garching, Deutschland.

Making inferences about physical properties of the Universe requires knowledge of the data likelihood. A Gaussian distribution is commonly assumed with a covariance matrix estimated from a set of simulations. The noise in such estimates causes two problems: it distorts the parameter contours, and it adds scatter to the location of those contours. For non-Gaussian likelihoods, an approximation may be derived via Simulation-Based Inference (SBI). It is often implicitly assumed that parameter constraints from SBI analyses are not affected by the same problems as parameter estimation, with a covariance matrix estimated from simulations. We investigate whether SBI suffers from effects similar to those of covariance estimation in Gaussian likelihoods. SBI suffers an inflation of posterior variance that is equal or greater than the analytical result in covariance estimation for Gaussian likelihoods for the same number of simulations. The assumption that SBI requires a smaller number of simulations than covariance estimation for a Gaussian likelihood analysis is inaccurate. Despite these issues, we show that SBI correctly draws the true posterior contour given enough simulations.

GR 10.5 Thu 15:15 ZHG008

Constraining Mixed Dark Matter Scenarios in the Framework of Perturbation Theory — •Safak Celik and Fabian Schmidt — Max Planck Institute for Astrophysics, Garching bei München, Germany

In this study, we explore the dynamics of mixed dark matter scenarios, focusing on the interplay between cold dark matter (CDM) and warm dark matter (WDM) components. Utilizing perturbation theory techniques, we analyze the evolution of perturbations in a cosmological context where CDM constitutes the primary dark matter component, while WDM, characterized by a weakly interacting, thermally produced mass in the eV-keV range, serves as a secondary component. While the effects of WDM on the linear power spectrum, governed by its mass and abundance, are well-documented, our research delves into the non-linear evolution of these systems. We particularly investigate the role of isocurvature perturbations between the two dark matter components and their impact on the evolution process. Employing a 1-loop galaxy power spectrum, we conduct a Fisher forecast analysis to constrain key parameters, including the fraction and mass of the WDM component and galaxy bias parameters, while examining the degeneracies among them. Our findings enhance the understanding of mixed dark matter models and their implications for cosmological observations.