GR 3: Cosmology I

Zeit: Dienstag 11:00–12:45 Raum: HS 4

Hauptvortrag GR 3.1 Di 11:00 HS 4

An analytic approach to cosmic structure formation — •Matthias Bartelmann — Universität Heidelberg

The non-linear, late-time evolution of cosmic structures is notoriously hard to tackle with analytic methods. While numerical simulations are highly successful and lead to impressive results, there are fundamental as well as pragmatic reasons for an analytic understanding to be sought. Conventional methods based on the hydrodynamic equations are limited mainly by the shell-crossing problem. In this talk, I shall review a novel approach based on kinetic field theory. It structurally resembles a non-equilibrium statistical quantum field theory and avoids the shell-crossing problem by construction. Suitably approximating particle interactions allows the derivation of a closed, non-perturbative, parameter-free expression for the non-linear cosmic-density power spectrum which reproduces numerical results to better than 10% up wave numbers of k ~ 10 h/Mpc at redshift 0. The formalism can straightforwardly be generalised to mixtures of gas and dark matter, axionic dark matter, or modified gravity theories, for which I shall show first examples.

GR 3.2 Di 11:45 HS 4

A semiclassical path to cosmic large-scale structure — •Cora Uhlemann — Centre for Theoretical Cosmology, University of Cambridge, UK — Fitzwilliam College, University of Cambridge, UK

We chart a path towards solving for the nonlinear gravitational dynamics of cold dark matter by relying on a semiclassical description using the propagator. The evolution of the propagator is given by a Schroedinger equation, where the small parameter acts as a softening scale that regulates singularities at shell-crossing, where particle trajectories cross. The leading-order propagator, called free propagator, is the semiclassical equivalent of the Zeldovich approximation, where particles move along straight trajectories. At next-to-leading order, we solve for the propagator perturbatively and obtain the displacement and velocity fields in the classical limit. We show that our perturbative results respect the underlying Hamiltonian structure and complement our analysis with illustrative numerical examples showing that the propagator solutions closely resemble Lagrangian Perturbation Theory. Finally, we demonstrate the generation of vorticity, which is a non-trivial multi-stream phenomenon that arises naturally as a conserved topological charge in our propagator method.

GR 3.3 Di 12:00 HS 4

Structure formation with Kinetic Field Theory in the non-linear regime — •Elena Kozlikin and Matthias Bartelmann — Universität Heidelberg, Zentrum für Astronomie, Institut für Theoretische Astrophysik, Philosophenweg 12, 69120 Heidelberg

Thus far, the non-linear regime of structure formation is only accessible through expensive numerical N-body simulations since the conventional analytic treatment of cosmic density fluctuations via the hydrodynamical equations runs into severe problems even in a mildly non-linear regime. I will give an overview of a novel analytic approach to cosmic large-scale structure formation which provides a density fluctuation power spectrum that agrees well with state of the art N-body simulations up to $k = 10\mathrm{h\,Mpc}^{-1}$. I will point out how our Kinetic Field Theory avoids the difficulties of standard perturbation theory by construction and allows to proceed deeply into the non-linear regime of density fluctuations. My main focus will be on the opportunities this method provides to study the physics behind structure formation. I will show that a delicate balance between damping and the interaction potential is required to produce the large-scale structures we observe and how ignoring this balance in perturbation schemes can give misleading results. I will further discuss how the form of the interaction potential influences the formation of structure and the implication it bears on the density profile of dark matter haloes.

GR 3.4 Di 12:15 HS 4

Influence of baryonic matter on cosmic structure formation with Kinetic Field Theory — •Ivan Kostyuk[1], Robert Lilow[2], and Matthias Bartelmann[1] — [1]Universität Heidelberg, Zentrum für Astronomie, Institut für Theoretische Astrophysik, 69120 Heidelberg — [2]Department of Physics, Technion, Haifa 3200003, Israel

Baryonic matter with its non-gravitational interactions has profound influence on large-scale cosmic structure formation. To gain an understanding of structure growth it is therefore necessary to investigate how a mixture of dark and baryonic matter coevolves through the cosmic history. To describe this evolution Kinetic Field Theory is used whereby individual classical matter particles are evolved using their Hamiltonian dynamics. To average out frequent microscopic interactions between baryonic particles, they are encapsulated in effective mesoscopic particles which follow the hydrodynamic equations of motion. The main effects of baryons on large scale cosmic structures are of two kinds: firstly through baryon acoustic oscillations in the early Universe, and secondly through pressure and cooling effects in the late Universe. In the first case, we are able to reproduce features of baryon-acoustic oscillations in the spectrum. In the later case, taking into account pressure causes a suppression of power at small scales.

GR 3.5 Di 12:30 HS 4

Higher order statistics of cosmic density fluctuations with Kinetic Field Theory — •Sara Konrad and Matthias Bartelmann — Universität Heidelberg, Zentrum für Astronomie, Institut für theoretische Astrophysik

Computing third- and higher-order power spectra of the cosmic density fluctuations is of great interest for our understandig of cosmic structure formation, since polyspectra contain information about the non-gaussianity of the cosmic density field. Furthermore, in order to determine the likelihood of a cosmological model from measured n-point correlation functions, 2n-point correlation functions are necessary. However, up to now, no standard methods exist to compute non-linear polyspectra analytically for arbitrary scales, and obtaining them from simulations is computationally demanding. Our Kinetic Field Theory is a novel approach to describe non-linear structure formation analytically beyond shell crossing. In this talk I present an analytical closed expression for the non-linear free-streaming solution for polyspectra of arbitrary order, emerging from gaussian initial conditions. Furthermore, I show current approaches on how the non-linear evolution due to interactions can be incorporated and present first results for the cosmic bispectrum.