Field Theory in Cosmology (L24)

Enrico Pajer and Tobias Baldauf

This course discusses applications of classical, statistical and quantum field theory to cosmology. The course comprises three interconnected topics:

- Cosmological inflation and primordial quantum perturbations (QFT in curved spacetime)

- The matter and galaxy distribution in the Large Scale Structure of the Universe (statistical field theory)

- The physics of the Cosmic Microwave Background (classical and statistical field theory)

The goals of the course are: to discuss open problems in cosmology and describe their intimate relation to fundamental high energy physics; to provide the basic knowledge to understand modern research literature in cosmology; to explore how field theory provides a unifying formalism to describe disparate physical processes from the birth of the Universe to the highly non-linear cosmic web.

More specifically, after a general introduction to open current research and open problems in cosmology, we review inflation and introduce the Effective Field Theory of cosmological perturbations and its connection to field theories with non-canonical interactions. Then we present the so-called "in-in" or Schwinger-Keldysh formalism to compute cosmological correlators and discuss some simple examples, focusing on the leading non-Gaussian statistic, the bispectrum. After showing that cosmological perturbations become classical, we review some basic properties of stochastic fields and correlation functions. The equations determining the dynamics of Large Scale Structure are then introduced together with the concept of renormalization. As an application, we derive a prediction for the matter and galaxy power spectrum at next-to-leading order. Finally, we introduce the Boltzmann equations for the coupled photon-baryon "fluid" and use them to compute the observed temperature anisotropies in the Cosmic Microwave Background.

Pre-requisites

Some familiarity with introductory Quantum Field Theory and General Relativity, as for example provided by the respective Michaelmas courses, is highly recommended. Basic knowledge of introductory Cosmology is essential. Students who did not attend the Michaelmas course on Cosmology may still follow this course after reviewing the relevant course notes.

Literature

Lecture notes including references will be provided by the lecturers.

Additional support

Four example sheets will be provided and four associated example classes will be given. There will be a one-hour revision class in Easter Term.