

CosmoFONDUE - Cosmological Fundamental Observables and Novel Discoveries in Universe Evolution



Tuesday 10 June 2025 - Friday 13 June 2025

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Scientific Programme

By combining observations, theoretical models, and advanced simulations, we aim to answer fundamental questions about the cosmos: What is the Universe made of? How did it begin, and how did it evolve over the past billions of years? During the last few decades, this field has made remarkable progress, for example with the discovery of the accelerated expansion of the Universe and the detection of the cosmic microwave background. And yet, for each solved puzzle, several new questions open up and add to the many unexplained mysteries about our cosmic history.

Now, recent observational advances are disclosing novel perspectives to address some of these main questions concretely, marking the start of a new exciting era for cosmology. For example, to investigate the nature of dark energy and the properties of dark matter, the latest generation of galaxy surveys is mapping out a large part of our Universe with unprecedented precision, while new cosmic microwave background observations are refining our understanding of the early Universe. Moreover, advances in gravitational wave observation offer a novel exciting window into our cosmos.

As young researchers with different backgrounds in cosmology, we are not only thrilled by the new insights that the different cosmological probes will provide, but we also believe that combining their outcomes represents an exquisite learning opportunity. For this, it is crucial to combine the expertise of the whole cosmological community, which is the main goal of the CosmoFONDUE conference. Therefore, a broad range of topics within cosmology will be covered. With generous time slots for discussions, we aim to foster the dialogue between the different generations of scientists, such that each participant can contribute while gaining new insights from the exchange with the community.

CMB

The Cosmic Microwave Background (CMB) radiation can be described as a picture of the Universe in its infancy, originating only 400 thousand years after the Big Bang. Remarkably, this is observable today, more than 14 billion years later. As such, it conserves various imprints of early-Universe physics, which makes it the target of various past, current, and future telescopes.

pre-CMB

The characteristics of the CMB temperature anisotropies opened up questions about the earliest moments: what is their origin? Which effects influenced the timed departure of the different particle species from equilibrium? Recent astrophysical and collider searches have made tremendous progress in answering these questions, while new explorations beyond the Standard Model of particle physics reveal many viable models.

GWs emitted before the CMB

Gravitational wave (GW) experiments offer a groundbreaking avenue to probe the cosmic history before the Universe became transparent to electromagnetic radiation. Indeed, theorists predict various possible sources for the earliest GWs emitted, which then propagate freely through space and time. Crucial now is thus the accurate estimate of their imprints in GW signals observable by both, currently operating and future detectors.

GWs emitted after the CMB

The strongest GW signals that we have observed to date have been emitted more recently in cosmic history. This includes mergers of black holes, the inspiralling of dense stars (called compact binaries), rotating neutron stars or supernovae explosions. By analyzing GW data, we can thus test

the evolution of astrophysical sources. This, in turn, is connected to the evolution of the Universe and the growth of structure, thus helping us to understand fundamental cosmological properties.

Neutrino and astroparticle cosmology

The imprints of neutrinos on cosmological observables might reveal information about their fundamental properties, such as their masses, providing insights that complement those gained from particle physics experiments. Unexplained observational features have also motivated the prediction of even more weakly interacting particles beyond the Standard Model, that constitute the so-called dark matter (DM) and are now searched for with novel experimental setups.

Large-scale structure

At the largest distances, the distribution of matter in our Universe is arranged into structures characterized by filaments of galaxies and voids in between. Mapping this distribution throughout different epochs provides information on the laws of gravity on cosmic scales and the onset of the Universe's accelerated expansion. The unprecedented precision of the data expected from the newest generation of galaxy surveys will challenge the analytical, numerical, and statistical methods underlying theoretical predictions.

Intensity mapping

Neutral hydrogen is a fundamental element in the Universe. Its late-time distribution traces the underlying matter field, making it an innovative key probe of the Universe's structure. The 21cm signal originating from atomic processes is detectable on Earth at radio frequencies. The measurement of the large-scale distribution of neutral hydrogen and its evolution over time can thus play an important role in the upcoming years, providing a complementary probe to traditional galaxy surveys.

Modified gravity

Cosmological observations are overall well described by the so-called Λ CDM model, which predicts a cosmological constant acting as a mysterious form of dark energy to explain the accelerated expansion observed in the late Universe. In this model, gravity is described by the theory of general relativity. However, motivated by the cosmological tensions among different data sets, recent research has focused on alternative models of gravity on the largest scales or new models of dark energy and dark matter.

Tensions

The theme of tensions in cosmology has become increasingly important in the past decade. Discrepancies between the values of key cosmological parameters, arising from measurements in the late and early universe, have raised concern about whether the standard model of cosmology is complete. It is of the utmost importance now to investigate if we are facing yet not understood systematic effects or new physics.