Lecturers, Topics, Abstracts

CALIN LAZAROIU (IFIN-HH)

Title: Canonical quantum gravity and cosmological applications

Abstract: I briefly review the basics of the Wheeler-de Witt approach to canonical quantization of gravity and discuss some of the ideas and problems arising in the Hatle Hawking and loop quantum gravity proposals. I also sketch some of the applications and problems of these ideas to "quantum cosmology" in the context of multifield scalar models, which I described in the previous minischool.

Main References:

1. M. Bojowald, Canonical gravity and applications, Cambridge U.P., 2011
2. Cianfrani et al, Canonical Quantum Gravity, World Scientific, 2014
3. Bojowald, Foundations of Quantum Cosmology, IOP 2020
4. J.L. Lehners, Review of the no-boundary wave function, Phys. Rep. Vol. 1022 (2023) 1-82.

DRAGAN HUTERER (University of Michigan)

Title: Structure Formation in the Universe: from Dark Matter to Dark Energy

Abstract: The goal of these lectures is twofold: (1) to review how dark matter, dark energy, and fundamental physics are constrained by measurements of the large-scale structure, and (2) to introduce statistical techniques that are widely used in cosmology. I will first give an informal review of large-scale structure, and outline what aspects of its measurements can be connected to underlying theory. Then I will focus on some of the most useful statistical techniques in connecting cosmological data to theory, and provide a few practical "from scratch" exercises that the students will have an option to complete on their own.

JACKSON LEVI SAID (Univ. of Malta)

Title: Simulations in Cosmology: From fundamental physics to numerical simulations

Abstract: Recent observational cosmology has opened the possibility of new physics in our description of the Universe, which has led to a number of novel theoretical and numerical questions regarding these emerging physical theories. Moreover, any new candidate cosmological model must be assessed against observational data. In this lecture series, the relationship between fundamental physics and numerical simulations will be covered both at background and perturbative level. This will be done for the standard model of cosmology, LCDM, as well as some potentially realistic extensions of the concordance model. In all cases, the methods used to obtain constraints using the latest observational data will also be covered. This will include using Markov chain Monte Carlo approaches together with methods to assess the viability of different cosmological models. the principle aim of the series will be to learn how to turn fully developed theoretical models into numerical simulations and how to use observational data sets to confront these models with real-world measurements. The three lectures will be divided as follows:

1. General discussion on cosmic tensions

2. An example case of teleparallel cosmology - Theory and foundations
3. An example case of teleparallel cosmology - Observational constraints and current status

The tutorial will consist in a simple example of using MCMC to constrain some cosmological models based on arXiv:2108.03853.

References:
https://arxiv.org/abs/2504. https://arxiv.org/abs/2106. https://cosmoversetensions.eu/ - CosmoVerse training series

Tutorial (emcee):

https://emcee.readthedocs.io/

PAVEL PUTROV (ICTP)

Title: Chern-Simons theory and 3D Quantum Gravity

Abstract: In the first part of my lecture series, I will give a pedagogical review of 3D Chern-Simons Topological Quantum Field Theory (TQFT). I will then discuss its relation to 3D Quantum Gravity, giving particular attention to the so-called Teichmüller/Virasoro TQFT, which can be understood as a certain analytically continued version of the ordinary Chern-Simons TQFT.

Main references:

1. Quantum Field Theory and the Jones Polynomial, E. Witten, Commun.Math.Phys. 121 (1989), 351-399,
2. (2+1)-Dimensional Gravity as an Exactly Soluble System, E. Witten, Nucl.Phys.B 311 (1988), 46
3. Analytic Continuation Of Chern-Simons Theory, E. Witten, arXiv:1001.2933 [hep-th], AMS/IP Stud.Adv.Math. 50 (2011), 347-446
4. The Teichmüller TQFT, J.E. Andersen, R. Kashaev, arXiv: arXiv:1811.06853 [math.QA], Proceedings of the International Congress of Mathematicians 2018 (pp. 2541-2565).
5. Teichmüller TQFT vs. Chern-Simons theory, V. Mikhaylov, arXiv:1710.04354 [hep-th], JHEP 04 (2018), 085.

RAUL JIMENEZ (ICREA and Univ. of. Barcelona)

Title: The Quantum Universe: recent advances in theory and simulation

Abstract: If the Universe is quantum in Nature we should discover how. Further we should understand why and how quantum news is imprinted in Cosmological observables. Beyond this we should be able to reconstruct the full nature of the Universe quantum nature. I will describe how this is done in practice and what future observations might tell us.

Lecture 1: Quantum fluctuations, entanglement, bell experiments
Lecture 2: Inflation, perturbations and de Sitter
Lecture 3: Using machine learning in cosmology; introduction

Raul Jimenez will also give a lecture in the workshop **BWAM25:**
Title: Cosmology without models
Abstract: All we are doing in the LCDM model is to fit a model to observations. While

successful, fitting is very different from understanding. In this talk I will show how one can avoid fitting models to cosmology data and actually test theories.

and a lecture on zoom, on July 12, in the **BPU12** congress,
Title: How to understand the complexity of the Cosmos

Abstract: Observations of the sky are providing us with a wealth of data not only in the electromagnetic spectrum but also as gravitational waves. With these data sets we have managed to build an effective model of the Universe (LCDM) which describes all observations with just 6 free parameters. However, we are now in a position to advance one step farther and move from description to understanding. In this talk I will describe some efforts to understand the complexity of the cosmos in a fully model independent way by constructing theories rather than models to understand the laws of nature as seen in the Cosmos.