Quantum Fields and Fundamental Forces

Special Topics Lectures 2021

1 June to 11 June 2021

Dr David Tennyson

Generalities of Generalised Geometry

Generalised Geometry is a recently discovered tool in Differential Geometry (~ 20 years ago). Its development has been heavily influenced by String Theory, as it seems to provide the most natural framework for studying String /M- theory backgrounds / compactifications. We will cover basics on bundles, structure groups, etc.. I will then introduce what is called O(d,d) geometry, where we study objects on a combination of the tangent and cotangent bundles. After looking at some applications of this to String Theory, we will move on to an even newer construction known as "Exceptional Generalised Geometry".

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Dr Marcos Crichigno

Physics and Computation

Various aspects of the interplay between physics and the formal theory of computation will be covered. We will begin by describing the basics of computational complexity: classical Turing machines; the complexity classes P and NP; and the celebrated Cook-Levin theorem. We will discuss the relevance of these ideas in physics, in particular in the study of spin-glasses and other systems in statistical mechanics. We will then discuss quantum Turing machines, following the ideas of Feynman, Deutsch and others, and introduce the quantum complexity classes BQP and QMA, the quantum analogues of P and NP. We will briefly cover basic quantum algorithms and finally, time permitting, other areas of theoretical physics where computational complexity theory may offer new perspectives, including quantum field theory and string theory. The class is aimed mainly at physics graduate and advanced undergraduate students. No previous knowledge of the theory of computation is required.

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Dr Yasaman K. Yazdi

Introduction to Causal Set Theory

Causal set theory is an approach to quantum gravity where the deep structure of spacetime is fundamentally discrete and the causal relations among the discrete elements are important. These lectures will introduce causal set theory and review a selection of current research topics. The first lecture will cover the basics of causal sets and discuss how we can deduce concepts familiar from continuum spacetime from discreteness and causal order. The second lecture will give an overview of a free quantum scalar field theory on a fixed background causal set.

Dr Lasma Alberte

Hydrodynamic Modes in Holographic Models of Translational Symmetry Breaking

In this series of lectures I will show how long-distance, low-frequency fluctuations in asymptotically AdS spacetimes exhibit hydrodynamic behavior that can be described by the techniques of AdS/CFT correspondence. I will first briefly review the basic properties of linearised hydrodynamics and concepts like fluctuations of the densities of conserved charges, constitutive relations, linear response and correlation functions. I will then present the prescription for computing the correlation functions from AdS/CFT correspondence and show that the quasinormal modes of the field fluctuations in the asymptotically AdS background can be identified with the poles of the retarded Green's functions of the dual boundary CFT. In long-distance, low-frequency limit these coincide with the hydrodynamic modes. I will present the computation of the quasinormal modes in some simple examples. Finally I will extend the hydrodynamic description to holographic models with broken translational invariance in the boundary theory.

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Dr Antoine Bourget

Algebraic Singularities in Supersymmetric Gauge Theories and String Theory

Algebraic singularities play an important role in string theory. String theory / M-theory compactified on a singular variety can give rise to Superconformal Field Theories, and branes can be used to probe singularities. In this lecture, we will briefly review how singular spaces are studied and resolved in algebraic geometry. This is illustrated with the fundamental examples of orbifolds of the form C^2/G where G is a finite subgroup of SU(2), and toric geometry. We then explore how this allows to characterize the SCFTs in 5 dimensions after compactification.

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Dr Karapet Mkrtchyan

Hamiltonian Systems with Constraints

The course intends to introduce the Dirac's method for dealing with constrained Hamiltonian systems suitable for field theories with gauge symmetries. The idea is to introduce the basic notions of the algebra of the constraints, their classification as first and second class (also as primary and secondary, as viewed from Lagrangian perspective, while less relevant from the Hamiltonian perspective), gauge fixing and Dirac bracket. We will apply the method to some interesting examples