Quantum Fields and Fundamental Forces

Special Topics Lectures 2020

8 June to 20 June 2020

Prof. Toby Wiseman

Introduction to AdS/CFT

I will give a pedagogical review of the AdS/CFT conjecture. I will begin with a brief overview of the conjectured duality between certain quantum field theories and quantum theories of gravity (or strings) where spacetime is dynamical. I will emphasise that this gives new ways to discuss the problem of quantum gravity, and provides fascinating new tools to study certain strongly coupled field theories using geometry. I will then give a brief introduction into the relevant basics of conformal field theory (CFT) and then move on to discuss the Anti deSitter spacetime (AdS). Using these discussions I will state in some detail how the duality is realised as an equality between the CFT and gravity partition functions. I will discuss the example of a bulk scalar and its dual description in detail. I will end by discussing how the duality works for the bulk metric, and how to implement finite temperature in the duality, and the role that black holes play.

I will also distribute simple problems (and solutions) for students interested in performing some basic computations in this area.

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Dr Edoardo Vescovi

Wilson loops in (supersymmetric) gauge theories

Wilson loops are operators defined along closed paths in spacetime. Originally designed to explain quark confinement in QCD, they have become important observables to measure non-local properties of the gauge field. In these lectures we introduce Wilson loops from the notion of parallel transport in gauge theory and go through the textbook calculation of the potential energy of a pair of pointlike charges in Maxwell's theory. We then focus on a model endowed with supersymmetry and build the generalisation of the operator that is invariant under such symmetry. The Wilson loop over the circle is a quite rare example of observable that can be computed exactly by resumming the diagrammatical expansion.

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Dr Matthew Roberts

Quantum Hall Physics

When electrons are confined to a two-dimensional plane, subjected to a transverse magnetic field and cooled to low temperatures we discover fascinating macroscopic effects due to the quantum nature of the system - the quantum Hall effect. In this course I will discuss the quantum Hall problem, reviewing first the more familiar integer quantum Hall states before discussing the fascinating world of fractional quantum Hall plateaux, a field where the tools of condensed matter and high energy physics merge.

Dr Victor Lekeu

Introduction to higher spins

These lectures will introduce the basics of the theory of higher spins, which are fields describing elementary massless parAcles of arbitrary spin. The lectures will be divided into three parts. In the first, I will moAvate why they are interesAng; this will contain short reviews of the representaAons of the Poincaré group, and of the spectrum of string theory. The second part will deal with the formulaAon of free higher spin gauge fields, both in the ``metric-like'' and ``frame-like'' formalisms. In the third part, I will review the no-go theorems on higher-spin interacAons, and some of the ways around them such as Vasiliev's theory and three-dimensional topological models.

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Dr Antoine Bourget

Singularities in supersymmetric gauge theories and string theory

Geometric singularities play an important role in string theory, in particular in brane physics. I will briefly review how singular spaces are studied and resolved in algebraic geometry. Then I will then discuss two natural occurrences of singular spaces in string theory. One is singular space-time, which can be probed with strings and branes and yield interesting SQFTs. Another is the moduli space of vacua of some of these SQFTs, which form so-called symplectic singularities. The lecture will mainly be based on examples.

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Prof. Ulf Lindstrom

SUSY and Non-Linear Sigma Model Geometry

I will describe how nonlinear sigma models probe the target space geometry and how the requirement of supersymmetry constrains this geometry.
Depending on the number of supersymmetries and the dimension of the world sheet we will find that the geometry must be complex, e.g., Kähler or
hyperkähler, will carry torsion, be generalised complex et.c. A short introduction to 2d superspace will be included.