Quantum Fields and Fundamental Forces

Special Topics Lectures 2018

4 June to 15 June 2018

Prof. Carl Bender
Asymptotics

Problems in theoretical physics cannot solved exactly. Therefore, it is necessary to learn powerful analytical tools that reveal the nature of solutions to hard problems. This course provides a lightning survey of some
of these tools. We will discuss perturbation theory, divergent series, summation theory, asymptotics beyond all orders, and related topics.

****

Dr Louise Anderson

Localisation and Matrix Models

The tool of supersymmetric localisation enables us to, under favourable conditions, to compute observables in (supersymmetric) quantum field theories exactly. In this course, we will review the basics of localisation, what these "favourable conditions" mean, and how we can approach the resulting matrix models.

****

Dr Hagen Triendl

Supergravity and Flux Compactifications

Ten-dimensional superstring theory can be related to four-dimensional theories at low energies by compactification. The question which four-dimensional theories can emerge from string theory has been a major topic of research for several decades now.

I will give an introduction to the topic of compactifications and fluxes in string theory and the relation to effective four-dimensional supergravity descriptions. Knowledge of the material from the courses on supersymmetry and on string theory will be advantageous.

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.

****

Dr Andrew Tolley

Effective Field theories for Cosmology

The theories we use to describe the universe, such as inflation, dark energy are all non-renromalizable since at the very least they necessarily include gravity. Nevertheless they can be consistently quantized as low energy effective field theories. We will discuss how to deal with non-renormalizable interactions in practice, and how to construct effective field theories in situations were time dependence is spontaneously broken. In connection with this we will review the `in-in' or Schwinger-Keldysh formalism. These techniques will then be applied to effective field theories of inflation, dark energy and modifications of gravity. Given time we may discuss constraints on low energy effective field theories such that they have a UV completion.

****

Dr Tim Adamo

Twistor Theory

Twistor theory is a formalism, developed 50 years ago by Roger Penrose, which gives an intrinsically geometric approach to the study of physics. Broadly speaking, this is a framework for encoding physical information on space-time as geometric data on a complex projective space, known as twistor space. The relationship between space-time and twistor space is non-local and has some surprising consequences, which we will explore in these lectures. Starting with a review of the 2-spinor methods and the twistor correspondence for Minkowski space, we will learn about some of twistor theory's historic successes (e.g., describing free fields and integrable systems) as well as some of its historic shortcomings. We will then learn how in recent years many of these problems have been overcome, with a view to understanding how twistory theory is used today in the study of perturbative QFT.