UNIVERSITY OF CAMBRIDGE

PART III SEMINAR SERIES

LENT 2019

ABSTRACTS

Thursday March 14th 2019
Friday March 15th 2019

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Part III Seminar Series Directors

Contents

1 (Applied) Analysis

1.1 Alexander (Bob) Cliffe: Strichartz Estimates and Nonlinear Schrödinger Equations

Thursday, March 14th, 15:30 - 16:15 (MR 2)
Chair: Samuel Alperin

Nonlinear Schrödinger equations exhibit a wide range of interesting behaviours which make them particularly useful as models for physical processes, including the formation and propagation of 'rogue waves? at sea. A key tool in understanding the nonlinear problem are the Strichartz estimates, which provide control over the size and decay of solutions to the linear problem. This talk will cover the linear theory, and give some general background on the nonlinear problem. Detailed knowledge of PDE is not required, some knowledge of functional analysis will be useful.

1.2 Linden Disney-Hogg: Swinging Atwood's Machine

Thursday, March 14th, 16:30 - 17:15 (MR 2)
Chair: Samuel Alperin

Integrability is a powerful property of a dynamical system, allowing its solution to be expressed very simply in a certain coordinate system. We will see a method for showing that a system is integrable, and then apply this method to a very interesting dynamical system, the Swinging Atwood's Machine (SAM). We will finish up with a discussion of the proof of non integrability of certain Hamiltonian systems, and its application to the SAM.

1.3 Mathias Hockmann: Krylov subspaces applied to an inverse problem in imaging

Thursday, March 14th, 17:15 - 18:00 (MR 2)
Chair: Samuel Alperin

In the context of deblurring and denoising of an image we are often confronted with large-scale linear systems, which we would like to invert. Due to the presence of noise and the singularity of the linear operator, we can't do this directly but we have to use efficient regularisation strategies. This talk introduces such a regularisation method based on so called Krylov subspaces. We will study the regularising properties of these methods and emphasize their advantages compared to other common techniques for regularisation. Finally, we will apply our ideas to an image processing problem.

2 Number Theory

2.1 Eve Pound: (Extended) Affine Weyl Groups

Thursday, March 14th, 14:45 - 15:30 (MR 3)
Chair: Marius Leonhardt

A Weyl group is a finite group (arising in the study of Lie algebras and root systems) which acts simply transitively on a nice geometric set - the set of Weyl chambers. The affine Weyl group is an infinite group with a simply transitive action on an analogous set, the set of alcoves, which can be thought of as polytopes tessellating Euclidean space. I will give a concise presentation for this group, and use it to explain the structure of the extended affine Weyl group. Understanding this larger group is a key step to understanding the Chevalley group of adjoint type of a Lie algebra over an arbitrary field, and enables a sort of Bruhat decomposition over a local field.

2.2 Rodrigo Duarte: Bounded gaps between primes

Thursday, March 14th, 15:30 - 16:15 (MR 3)
Chair: Marius Leonhardt

The Prime Number Theorem predicts that the average of the first n gaps between consecutive primes is asymptotically log(n). However, how small can the gaps be? Famously, the twin prime conjecture asserts that there are infinitely many gaps of size two. In recent years there has been great progress in the study of small gaps between the primes. In 2013, Yitang Zhang showed that there are bounded gaps between primes, in fact showing there are infinitely many gaps of size at most 70 million. Later in the same year James Maynard improved this result to gaps of at most 600. In this talk we will explore the main ideas of the methods used to show these results, focusing on the new ideas of Maynard's work.

3 Geometry and Topology

3.1 Andreas Stavrou: Characteristic Classes of Surface Bundles

Thursday, March 14th, 16:30 - 17:15 (MR 3)
Chair: Michal Buran

Characteristic classes of surface bundles are useful in understanding the Mapping Class of a surface and consequently the Moduli Space of Riemann Surfaces of fixed genus. In this talk, we will define the Mumford-Morita-Miller classes and will discuss some key points of the proof of their non-triviality. Some background in algebraic topology will be assumed.

4 Relativity and Gravitation

4.1 Frank Qu: Gravitational Waves from inflation

Thursday, March 14th, 13:00 - 13:45 (MR 2)
Chair: Amelia Drew

One of the key predictions from inflation is the generation of gravitational waves. Their detection will provide invaluable information about the energy scale of inflation, a window to test quantum gravity and last but not least serve as a strong validation for the inflationary theory. In this talk I will explain the generation of gravitational waves by inflation, the imprints they will leave in the CMB polarization pattern and some of the main implications of their detection as well as the challenges along the way to detect the B-mode polarization.

4.2 Charlie Prior: Transient Hunting with ZTF

Thursday, March 14th, 13:45 - 14:30 (MR 2)
Chair: Amelia Drew

4.3 Ian Lim: Quasinormal modes in the eikonal limit

Thursday, March 14th, 14:45 - 15:30 (MR 2)
Chair: Amelia Drew

As solutions to a modified wave equation in curved spacetime, quasinormal modes are a key tool for studying perturbations of black hole spacetimes. They are especially useful in understanding the stability of horizons and the formation of singularities after perturbation. In this talk, I will describe the geometric optics ("eikonal") limit for the calculation of quasinormal mode frequencies, and discuss the use of quasinormal modes in addressing one of the major outstanding problems of mathematical relativity, the strong cosmic censorship conjecture.

5 Probability

5.1 Zheneng Xie: Exploration Processes

Friday, March 15th, 13:00 - 13:45 (MR 21)
Chair: Kasia Wyczesany

Graphs are an immensely powerful tool in mathematics. They allow for the abstraction of many complex problems, but that same abstractness can hinder the understanding of how a limit of graphs might work. Exploration processes realise random graphs as concrete stochastic processes. This then allows us to apply powerful convergence theorems from stochastic calculus. This talks aims to give an example of how this can be used to analyse cluster sizes in $G(n, p)$.

6 Combinatorics

6.1 Vojtech Dvorak: Application of tensor power trick to Sidorenko's Conjecture

Friday, March 15th, 13:45 - 14:30 (MR 21)
Chair: Kasia Wyczesany

Sidorenko's Cojecture is an open problem in combinatorics concerning graph homomorphisms. In this talk, I will show how applying a tool known as 'tensor power trick' helps us prove many cases of the conjecture.

6.2 Huy Pham: Sparse and robust basis of integers

Friday, March 15th, 14:45 - 15:30 (MR 21)
Chair: Kasia Wyczesany

We all know that the powers of two form an additive basis of the natural numbers, i.e., every natural number can be written as a sum of distinct powers of two. This basis is quite sparse, in that it only contains log n elements in the interval $[1, n]$, however, it is very sensitive to partition or removal of elements. Burr and Erdos asked if there exist a sparse additive basis that is robust, in the sense that under an arbitrary partition of the basis into r sets, each integer can still be written as a sum of distinct elements, all of which come from one part of the partition. We will discuss several recent developments around this question, and other Ramsey type questions relating to subset sums.

6.3 Tim Graute: Singularity of random Bernoulli matrix

Friday, March 15th, 15:30 - 16:15 (MR 21)
Chair: Kasia Wyczesany

Given a set of real numbers with modulus not below one, the Littlewood-Offord problem asks for the number of subsets whose elements add up to a value within a neighbourhood of diameter surrounding a fixed number. While this problem can be solved explicitly, the subject can be generalized if every integer in the set is randomly weighted with -1, 0 or 1, now investigating the probability that this weighted sum lies within a fixed neighbourhood of diameter 1. In 1995, a related inequality by Halász applied to the question whether a random Bernoulli matrix is singular, partially to be hinted during this talk.

7 Algebra

7.1 James Timmins: Cohomology of Groups and Group Algebras

Friday, March 15th, 16:30 - 17:15 (MR 21)
Chair: Liam Jolliffe

Homological algebra was born in the 1940s by abstracting ideas from algebraic topology. As well as becoming a major subject in its own right, over the last 70 years it has permeated almost all areas of mathematics involving algebraic objects. In this talk, I explain what it is, how to use it, and why we should care: with particular reference to groups and representation theory.
The talk will be accessible to anyone with some basic knowledge of algebraic topology and/or representation theory.

7.2 Theodoros Stylianos Papazachariou: Logarithmic Geometry

Friday, March 15th, 17:15 - 18:00 (MR 21)
Chair: Liam Jolliffe

This talk will aim to make an account of the theory of Logarithmic Geometry developed by Fontaine, Illusie and K. Kato, while making some ties with toric geometry and mirror symmetry.

8 Philosophy of Physics/History of Maths

8.1 Linden Disney-Hogg: Pioneering Mathematicians

Friday, March 15th, 16:30 - 17:15 (MR 13)
Chair: Nina Gottschling

For much of history, women have been discouraged and turned away from mathematics. Indeed, Sophie Germain?s parents believed the subject was harmful to young women. This talk will then be a celebration of pioneering women in mathematics, the work they have done, and the impact they have had on the future. Special attention will be paid to the role of some of these women in progressing maths at the University of Cambridge. The talk will be very non-technical, focusing more on the pioneering ideas than the maths itself, but in a few places I will elaborate on the details.

8.2 Viktoria Kabel: Philosophy of Science 101

Friday, March 15th, 17:15 - 18:00 (MR 13)
Chair: Nina Gottschling

Introduction to philosophy of science for theoretical physicists.

9 Quantum computation/Quantum Information

9.1 Marcel Hinsche: Stabilizer formalism and the Gottesman-Knill theorem

Friday, March 15th, 13:00 - 13:45 (MR 5)
Chair: Kasia Warburton

Even though not ultimately proved, it is generally believed that quantum computers provide a speed up over classical algorithms for a specific class of problems. The lack of proof for this so called quantum supremacy can be traced back to the difficulty of proving what cannot be done with classical computing but also our still limited understanding of how the speed up is achieved and what makes it possible. A major step forward was made by Gottesman and Knill in 1998 when they showed that a set of very common operations in QC called Clifford operations can be efficiently simulated on a classical computer. In my talk, I will introduce the stabilizer formalism and how it naturally leads to the findings of Knill and Gottesman. I hope to make the talk as accessible as possible though a basic understanding of quantum computing is certainly a plus.

9.2 Charles Stahl: Quantum Dynamics and Random Unitary Circuits

Friday, March 15th, 13:45 - 14:30 (MR 5)
Chair: Kasia Warburton

This talk will aim to explain two broad classes of quantum dynamics (thermalization and localization) and show how random unitary circuits can be used to explore these possiblities.

9.3 Vu Phan Thanh: Network Coding of Quantum Information

Friday, March 15th, 14:45 - 15:30 (MR 5)
Chair: Kasia Warburton

The routing problem of commodities (e.g. vehicles or goods) in a flow network can be easily solved by the Ford?Fulkerson algorithm. Commodity flow also exhibits a basic duality principle through the fundamental "max-flow min-cut" theorem. However, information flow through such a network might work differently: That is certainly the case for a flow of classical/digital information - as exemplified through Network Coding on the Butterfly Network. Hence, through network coding, "information flow" does not necessarily follows the rules of commodities as well as their underlying duality principles. Nonetheless, network coding relies on taking linear combinations of inputs from ingoing edges to "broadcast" that result on the outgoing edges of a vertex - which involves copying of information. On the other hand, as the interesting bit of this talk, quantum information cannot be copied by the familiar No Cloning theorem - that leads to the question whether and how Network Coding might possible or achievable in the quantum setting, actually.

9.4 Lukas König: Quantum Markov Chains

Friday, March 15th, 17:15 - 18:00 (MR 3)
Chair: Jakub Supeł

Classical Markov chains have become useful tools in modelling various memoryless processes in a wide range of fields. From an information theoretic point of view they are very well understood and well-behaved. In quantum information theory, analogous *quantum Markov chains* are similarly useful in e.g. measuring entanglement and characterising specific communication rates. This talk will focus on some of the difficulties that are special to the quantum theory and, time permitting, touch on the practical applications. Some familiarity with Markov chains and entropies will be assumed.

10 Theoretical Physics

10.1 Graham Van Goffrier: Confinement

Friday, March 15th, 16:30 - 17:15 (MR 14)
Chair: George Fortune

I will discuss confinement in the nonperturbative sector of QCD, with an account of the dual superconductor model for flux tubes between quarks. I intend to maintain a healthy ecosystem of example derivations and qualitative exploration of this approach to what remains an analytically open question of modern physics.

10.2 Gabriel Bliard: Instantons

Friday, March 15th, 17:15 - 18:00 (MR 14)
Chair: George Fortune

Have you ever been bored of perturbative QFT? Have you ever been yearning for topological information about your theory?

Some solutions to the equations of motion don't have a pertubative expansion and yet contribute to the partition function of your quantum field theory, these solutions are called instantons. Despite their contribution being negligeable at all orders in expansion, these solutions are ubiquitous in quantum field theories. Not only this, but they are also very beautiful mathematical structures in their own right. They link into tunnelling, spontaneous vacuum decay, results in the standard model, string theory, quaternions, supersymmetry, AdS/CFT, Borel resummation, and the list goes on. I'm surprised they haven't included it in the shark courses in Easter.
In special supersymmetric cases, the instanton contribution is important and the β-function can be found non perturbatively (Such as in $N = 2$ SYM/Seiberg-Witten theory)
In this short seminar, I will only cover the double well and yang mills instanton to give you a taste of the subject so that you can hop on the instanton hype train and explore these other results on your own.

10.3 Zechen Zhang: Dynamical Phase Transition

Friday, March 15th, 15:30 - 16:15 (MR 3)
Chair: Jakub Supeł

Most physical processes happen far from equilibrium (eg. biological processes), yet we know suprisingly little about the physics that describes them. This talk serves an introduction to non-equilibrium phase transitions. I will talk about the directed perculation (DP)–the Ising Model of non-equilibrium phase transition, and the universality classes related to it.

10.4 Jason Joykutty: Non-Commutative Geometry and the Standard Model

Friday, March 15th, 16:30 - 17:15 (MR 3)
Chair: Jakub Supeł

It can be shown that the properties of a differentiable manifold can be encoded by the commutative algebra of smooth functions on it. Non-commutative geometry proposes a generalisation of this for non-commutative algebras. This has applications in a few areas of mathematics and physics, but one of its primary motivations was applications to quantum field theory, with an eye toward the Standard Model. In the 1990s, Alain Connes used this theory to derive an extension of the Standard Model which included a modified form of general relativity in one of its greatest successes (with some incorrect predictions). Naturally the time permitted for this talk is not sufficient for a proper treatment of such a deep result, but I aim to give a brief review of it.

10.5 Andrea Russo: The second law of quantum complexity

Friday, March 15th, 15:30 - 16:15 (MR 5)
Chair: Sam Collingbourne

Quantum complexity arises as an alternative measure to the Fubini metric of the distance between two quantum states. Given two states and a set of allowed gates, it is defined as the least complex unitary operator capable of transforming one state into the other. It is possible to define a Second law of Quantum Complexity. The law states that, if it is not already saturated, the quantum complexity of a system will increase with overwhelming probability towards its maximum value.

10.6 Campbell McLauchlan: Dimensional Reduction

Friday, March 15th, 16:30 - 17:15 (MR 5)
Chair: Sam Collingbourne

Some of our most promising candidates for a theory of everything require more spacetime dimensions than our familiar four. Dimensional reduction describes the attempt to squish these extra dimensions onto small, compact manifolds so that we end up with only four large dimensions remaining. Remarkably, this process results in the appearance of different types of fields not present in the higher dimensional theory! In my talk I will motivate this topic with brief mention of supergravity theories, and then elaborate on the dimensional reduction procedure. I will focus initially on the original Kaluza-Klein proposal of 5-dimensional gravity, and then discuss extensions to higher dimensions and more exotic compactifications.

10.7 James Moore: Grand Unified Theories

Friday, March 15th, 17:15 - 18:00 (MR 5)
Chair: Sam Collingbourne

Symmetry is fundamental in our description of the physical world. But in day to day life, the symmetries of Nature are broken - for example, the translational invariance of the Universe is broken by the discrete lattice of atoms making up the page you're reading this on. With this motivation, *grand unified theories* posit that the gauge symmetry group of our Universe, $SU(3) \times SU(2) \times U(1)$, has been spontaneously broken from some larger symmetry group. In this talk, we'll discuss the $SU(5)$ grand unified theory which explains features of the Standard Model which are seemingly arbitrary otherwise.
This talk will be accessible to all; the only mathematics I'll assume is a little group representation theory, and I won't assume you know any physics.