UNIVERSITY OF CAMBRIDGE

Summer Research Festival 2025

Monday 13 October 2025, Centre for Mathematical Sciences

	Meeting Room 2	Meeting Room 4
14:00	**p-adic Dynamics and the Failure of Newton's Method** *Ethan Sosin (supervisor: Holly Krieger)*	**Distinguishing Dynamical Quantum Resources** *Anirudh Khaitan (supervisors: Bjarne Bergh & Nilanjana Datta)*
14:20	**The Sequence of Totient Values on Short Intervals** *Alexia Ascott (supervisor: Joni Teräväinen)*	**Efficient Gibbs sampling of stabiliser code Hamiltonians** *Ivan Shum (supervisor: Ángela Capel Cuevas)*
14:40	**Correlations of Multiplicative Functions** *Lingde Yang (supervisor: Joni Teräväinen)*	**Loop-TNR (with generalized/categorical symmetry) algorithm to simulate spiral RG flows in complex conformal field theory** *Aryaman Mishra (supervisor: Frank Verstraete)*
	Tea & Coffee (Central Core), 15:00 - 15:30	
	Meeting Room 2	**Meeting Room 4**
15:30	**Hydrothermal circulation near mid-ocean ridges** *Rebecca Maver, Adam Michaels, and Reuben Price (supervisor: Duncan Hewitt)*	**Neutrino masses and mixings in the new Z' model** *Prabhoda Chandra Sarjapur (supervisor: Ben Allanach)*
15:50	**the above talk continues until 16:10**	**Simulation of Dust Particles in Accretion Disks** *Zac Owen (supervisor: Loren E. Held)*
16:10	**Flow Shear Transmission by Biological Membranes** *Erin Keeling (supervisor: Eric Lauga)*	**Metastable high-confinement states of a levitated-dipole fusion reactor** *Luca Swinnerton (supervisor: David Hosking)*
	Tea & Coffee (Central Core), 16:30 - 17:00	
	Meeting Room 2	**Meeting Room 4**
17:00	**How should we do linear regression?** *Sara El Khamlichi (supervisor: Richard J. Samworth & Elliot Young)*	**Rigorous Checkers for Neural Networks in PDEs** *Finley Gilder (supervisor: Anders C. Hansen)*
17:20	**Sample Complexity of Robust Hypothesis Testing** *Shankar Vallinayagam and Alston Xu (supervisor: Varun Jog)*	**Wintertime Polar Vortex Variability** *Isaac Simmonite (supervisor: Alison Ming)*
17:40		**Neural Networks for Modelling Gradients** *Moonis Haider (supervisor: Davide Murari)*

UNIVERSITY OF CAMBRIDGE

Summer Research Festival 2025

Monday 13 October 2025, Centre for Mathematical Sciences

	Meeting Room 3	Meeting Room 5
14:00	**Cubing the Cube** *Sida Li (supervisor: Imre Leader)*	
14:20	**Contructing Graphs of high Weisfeiler-Leman Dimension** *Joël Huber (supervisor: Anuj Dawar, Dept of Computer Science)*	
14:40	**Saturation Number for Posets** *Nandi Wang (supervisor: Maria-Romina Ivan)*	

Tea & Coffee (Central Core), 15:00 - 15:30

	Meeting Room 3	Meeting Room 5
15:30	**Maximal singularities on the Hilbert scheme of points** *Owen Mackenzie (supervisor: Fatemeh Rezaee)*	**Hilbert Distortion of the Stochastic Diamond Graph** *Ivan Vojvodić (supervisor: Jason Miller)*
15:50	**Generic Slice of the Moduli Space of Line Arrangements** *Leonardo Caiano Tavares (supervisor: Dhruv Ranganathan)*	**Mixing time of the random walk on the giant component of the random geometric graph** *Magnus H. Haaland (supervisors: Perla Sousi & Andjela Sarkovic)*
16:10	**Combinatorics of KP solitons** *Yuzhen (Chris) Yang (supervisor: Nicholas Williams)*	

Tea & Coffee (Central Core), 16:30 - 17:00

	Meeting Room 3	Meeting Room 5
17:00	**Introducing Equality in a Visual Theorem Prover** *Thomas Thevenon (supervisor: Timothy Gowers)*	**On the word problem and Thompson's group** *Henry Jaspars (supervisor: Henry Wilton)*
17:20	**Covering $\mathbb{Z}_p$ by translates of a random subset** *Ihor Pylaiev (supervisor: Timothy Gowers)*	**Residual Finiteness of Graph Wreath Products** *Amy Needham (supervisor: Henry Bradford)*
17:40	**Homotopical Type Theory** *Eaton Liu (supervisor: Martin Hyland)*	

Meeting Room 2, 14:00 - 15:00

14:00

Ethan Sosin

p-adic Dynamics and the Failure of Newton's Method

DPMMS

Number Theory & Algebra

Newton’s method is a classical efficient method for locating the zeros of a polynomial. In this presentation, we will explore how the Newton map of a polynomial behaves p-adically. In particular, we will discuss the conditions under which Newton iterates converge p-adically for infinitely many primes p, and some computational evidence to describe the size of this infinite set.

14:20

Alexia Ascott

The Sequence of Totient Values on Short Intervals

DPMMS

Number Theory & Algebra

Although the behaviour of sequences with some "multiplicative structure" is well understood on long intervals (such as those of the form $[X,2X]$), their behaviour on short intervals is significantly more difficult to understand. Here, we investigate the sequence of totient values (numbers that are values of the Euler totient function) in short intervals of the form $[X, X + X^{1/2+\epsilon}]$ with $\epsilon > 0$ arbitrarily small, which resolves an open problem posed by Igor Shparlinski - that one can find totient values on significantly shorter intervals than on which one can unconditionally find primes (where the record is $[X, X + X^{0.525}]$ due to Baker, Harman and Pintz).

14:40

Lingde Yang

Correlations of Multiplicative Functions

DPMMS

Number Theory & Algebra

Of growing interest in analytic number theory is the study of multiplicative functions. In this talk I will motivate the study of multiplicative functions and their correlations. We shall then explore some problems regarding the correlations of these functions and the methods which can be used to tackle such problems.

Meeting Room 2, 15:30 - 16:30

15:30

Rebecca Maver, Adam Michaels, and Reuben Price

DAMTP

Fluid and Solid Mechanics

Hydrothermal circulation near mid-ocean ridges

A volume of water equivalent to the entire global ocean circulates through the ocean floor in around ten million years. This hydrothermal circulation is qualitatively understood, but the precise mechanics and dependence on key parameters are still largely unexplored. Through building and simulating a mathematical model informed by geophysical data, we aim to understand these crucial and complex dynamics.

15:50

The above talk continues until 16:10

16:10

Erin Keeling

DAMTP

Fluid and Solid Mechanics

Flow Shear Transmission by Biological Membranes

Lipid bilayers, the fundamental components of cell membranes, play a key role in mediating interactions between cells and their surrounding fluids. A recent experimental study (Amador, 2021) measured how hydrodynamic forces transmit through bilayers. Here we derive a mathematical model of these experiments, enabling us to infer their dependence on physical parameters and further explore their behaviour through numerical computations.

Meeting Room 2, 17:00 - 17:40

17:00

DPMMS

Statistics

Sara El Khamlichi

How should we do linear regression?

Ordinary least squares (OLS) prediction intervals are only valid under Gaussian errors. When this assumption fails, they can under-cover or grow arbitrarily wide. We develop a new framework for constructing prediction intervals in linear regression based on Antitonic Score Matching (ASM), an asymptotically optimal method of estimating the coefficient vector when the error density is unknown. By sampling from kernel density estimates of residuals, ASM prediction intervals are asymptotically valid under mild regularity conditions on the true error density, and both theoretical and empirical results show that they substantially improve both coverage and width compared to OLS.

17:20

DPMMS

Statistics

Shankar Vallinayagam and Alston Xu

Sample Complexity of Robust Hypothesis Testing

3 conjectures comparing the sample complexity of Huber and TV oblivious contamination of the binary hypothesis testing problem are introduced and disproved by counterexample. New conjectures motivated by this work, as well as potential extensions to the case of adaptive adversaries are discussed.

Meeting Room 4, 14:00 - 15:00

14:00

Anirudh Khaitan

Distinguishing Dynamical Quantum Resources

DAMTP

Quantum Information

In quantum information theory, dynamical resources are a fundamental class of objects that describe how information can be transmitted between two systems. In this talk, we will investigate the hypothesis testing problem of distinguishing between two different dynamical resources, and explore how the error incurred in this task behaves asymptotically. Then, we will connect this to the broad framework of quantum resource theories, establishing that such dynamical resources can be transformed asymptotically back and forth without loss.

14:20

Ivan Shum

Efficient Gibbs sampling of stabiliser code Hamiltonians

DAMTP

Quantum Information

We present algorithms for diagonalising stabiliser Hamiltonians, providing an alternative view of quantum topological order, and discuss their application in quantum Gibbs sampling.

14:40

Aryaman Mishra

Loop-TNR (with generalized/categorical symmetry) algorithm to simulate spiral RG flows in complex conformal field theory

DAMTP

Quantum Information

High Energy Physics

Meeting Room 4, 15:30 - 16:30

15:30

Prabhoda Chandra Sarjapur

Neutrino masses and mixings in the new Z' model

DAMTP

High Energy Physics

The Standard Model (SM) is our most successful theory of particle physics, yet it leaves open puzzles such as dark matter, matter–antimatter asymmetry, and the origin of neutrino masses. Neutrinos, predicted massless in the SM, are now known to oscillate.

In this talk, I will present a model that in conjunction with explaining slightly anomolous B meson decays, attempts to explain the neutrino masses, and how they lead to neutrino oscillations.

15:50

Zac Owen

Simulation of Dust Particles in Accretion Disks

DAMTP

Astrophysics

Accretion disks are large astrophysical disks made up of gas and dust, that orbit a central object like a star. Some disks (protoplanetary disks) have a significant dust component and are believed to be sites of planet formation, but the behaviour of dust particles in such disks is not fully understood. This talk aims to shed some light on this via computer simulations.

16:10

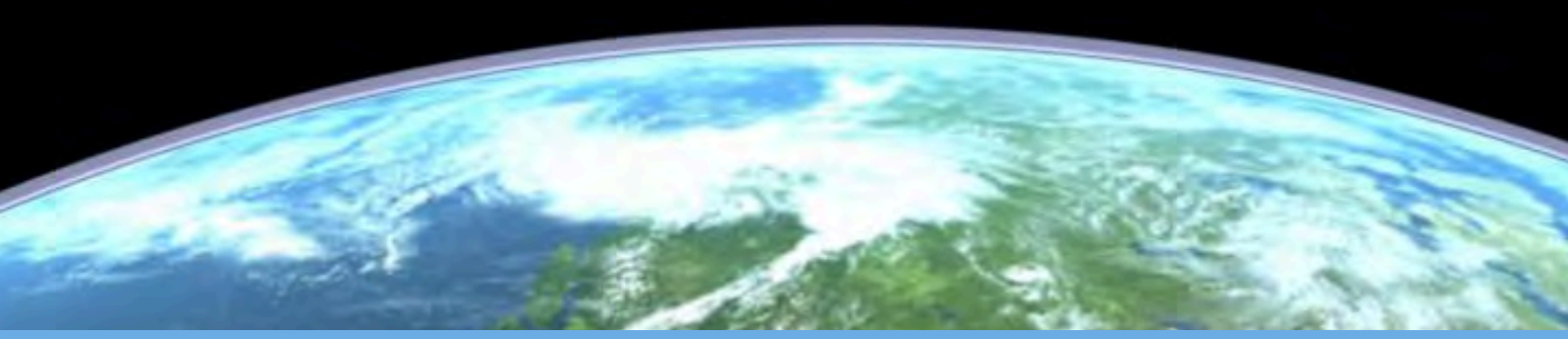
Luca Swinnerton

Metastable high-confinement states of a levitated-dipole fusion reactor

DAMTP

Astrophysics

The tokamak fusion reactor exhibits a high-confinement mode in which an edge transport barrier forms, accompanied by a steep pressure gradient. This regime can trigger explosive magnetohydrodynamic instabilities, the edge-localised mode (ELM). I will explore the possibility of analogous high-confinement metastable states and ELM-like eruptions in an alternative reactor design, the levitated dipole.



Meeting Room 4, 17:00 - 18:00

17:00

Finley Gilder

Rigorous Checkers for Neural Networks in PDEs

DAMTP

Applied and Computational Analysis

Physics Informed Neural Networks (PINNs) are a way of solving partial differential equations (PDEs) using machine learning methods. Whilst PINNs can be effective, they do not always come with guarantees about the accuracy of the solutions they find. So this project is about assessing the accuracy of solutions produced by PINNs.

17:20

Isaac Simmonite

Wintertime Polar Vortex Variability

DAMTP

Applied and Computational Analysis

Fluid and Solid Mechanics

Geophysics

An introduction to the winter polar vortex and a look at some results that were found. Defining strong years of the winter polar vortex, explaining what happens in the southern hemisphere winter polar vortex, and then focusing on strong years of the northern hemisphere winter polar vortex.

17:40

Moonis Haider

Neural networks for modelling gradients

DAMTP

Applied and Computational Analysis

Fluid and Solid Mechanics

There are many (broadly ML) problems where one aims to use a neural network to parametise a function R^d -> R^d, that is a gradient. Three examples are 1. Gradient step denoisers used in "Plug and play" methods. 2. Score-based generative models and 3. Approximation of optimal transport maps. Our research considers how best to do this.

Meeting Room 3, 14:00 - 15:00

14:00

Sida Li

Cubing the Cube

DPMMS

Combinatorics

What is the minimum number of translates of {0,1}^n needed to cover all points in (Z/3Z)^n? The best known bounds are on the order of (3/2)^n vs. n(3/2)^n. We study related sub-problems involving linear subspaces, partitions and digit-balanced points. To attack the upper bound, we consider both probabilistic techniques and deterministic constructions.

14:20

Joël Huber

Contructing Graphs of high Weisfeiler-Leman Dimension

Computer Science

Combinatorics

The Weisfeiler Leman dimension of a graph measures how "logically unstructured" it is. Recently, a new upper bound has been proven, and the goal of the project was to find constructions which get closer to this bound. I will talk about various graph parameters, known constructions based on expander graphs, and why we ended up doing complex analysis to estimate distributions in a Combinatorics problem.

14:40

Nandi Wang

Saturation Number for Posets

DPMMS

Combinatorics

Given a finite poset P, how small can a maximal P-free family of subsets of [n] be? Such families are called P-saturated, and the size of the smallest is the (induced) saturation number. Focusing on a specific poset, we prove its saturation number grows at least linearly by studying substructures within saturated families and using a key graph theory argument.

Meeting Room 3, 15:30 - 16:30

15:30

DPMMS
Algebraic Geometry
Combinatorics

Owen Mackenzie

Maximal singularities on the Hilbert scheme of points

In this talk, I will introduce the Hilbert Scheme of points in a specific case and describe what is meant by the problem of finding the points of maximal tangent space on this Scheme. I will then vaguely discuss how this was translated to a problem in combinatorics and the techniques that we used to partially solve it.

15:50

DPMMS
Algebraic Geometry

Leonardo Caiano Tavares

Generic Slice of the Moduli Space of Line Arrangements

I will start with an overview of the Moduli Space of n-Pointed Lines and simple computational results. After that I will introduce an obvious generalisation of this space that allows no simple computations, namely that of Line Arrangements. I will then finally present an intermediate space that occurs naturally as a Generic Slice of this Moduli Space and allows to bridge this gap.

16:10

DPMMS
Combinatorics
Differential Geometry & Topology

Yuzhen (Chris) Yang

Combinatorics of KP solitons

The Kadomtsev-Petviashvili equation describes shallow water waves. It has rich mathematical structure, and despite being nonlinear, admits a large class of exact solutions called solitons. The "discrete" nature of solitons opens them up to combinatorial study. In this project, we apply ideas from combinatorial and tropical geometry to understand and classify solitons.

Meeting Room 3, 17:00 - 18:00

17:00

Thomas Thevenon

Introducing Equality in a Visual Theorem Prover

DPMMS

Logic

This talk introduces a new graph-based representation of equality and explores problems encoded with this representation. Rather than just treating equality as another axiom, this representation embeds the properties of equivalence relations and the indiscernibility of identicals. This work is part of an interactive theorem proving study platform, used to analyse the methods by which participants prove theorems.

17:20

Ihor Pyalev

Covering $\mathbb{Z}_p$ by translates of a random subset

DPMMS

Combinatorics

I will discuss the problem of covering the group Z/pZ by translates of a random k-element subset. Specifically, given such a subset, we ask for the smallest number t of translates needed to cover all of Z/pZ. I will give an overview of what is known about how the typical value of t grows with p, for various choices of k.

17:40

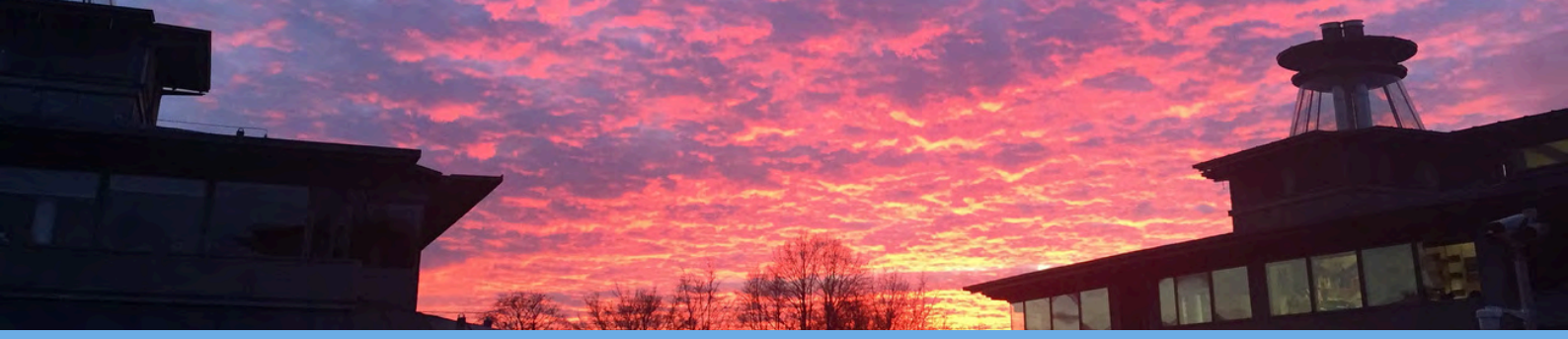
Eaton Liu

Homotopical Type Theory

DPMMS

Foundations

Homotopy Type Theory (HoTT) is a modern framework at the intersection of homotopy theory (topology) and type theory (logic). In this talk, we will focus on the homotopical perspective of HoTT: interpreting types as spaces and equalities as paths. Along the way, we will encounter striking results applicable to classical topology, including the idea that "every function is continuous", and the fundamental principle of "path induction".



Meeting Room 5, 15:30 - 16:10

15:30

DPMMS

Probability, Applied Probability, & Mathematical Finance

Ivan Vojvodić

Hilbert Distortion of the Stochastic Diamond Graph

The diamond graph is a recursively defined graph which starts with an edge, and then iteratively replaces each edge with a diamond. It attains the planar graph distortion upper bound of O(sqrt(log n)). We investigate a stochastic version where each subdivision occurs with a fixed probability p<1. An interesting phenomenon occurs: distortion grows as sqrt(log n) above a certain threshold probability, and sqrt(log log n) below it.

15:50

DPMMS

Probability, Applied Probability, & Mathematical Finance

Magnus H. Haaland

Mixing time of the random walk on the giant component of the random geometric graph

A random geometric graph is formed by placing Poisson(n) vertices in a torus of volume n, connecting vertices of distance less than r. For r bounded and not too small, G has a giant component w.h.p.. We establish the order of the mixing time (first time distribution is always close to invariant) of the lazy simple random walk on this giant.

Meeting Room 5, 17:00 - 17:40

17:00

DPMMS

Geometric Group Theory

Henry Jaspars

On the word problem and Thompson's group

In this talk, I will supply a brief historical overview into the word problem, an area of study with connections to group theory, computation and geometry.

17:20

DPMMS

Differential Geometry & Topology

Analysis & Partial Differential Equations

Amy Needham

Residual Finiteness of Graph Wreath Products

Graph wreath products simultaneously generalise many types of products common in group theory. In this talk I will discuss the extent to which the graph wreath products of groups which can be approximated by their finite quotients are similarly approximable, culminating in necessary and sufficient conditions for when graph wreath products are residually finite.