British Early Career Mathematicians' Colloquium 2021 Abstract Booklet

15th - 16th July 2021

Plenary Speakers

Pure Mathematics:

Shoham Letzter
University College London

Nóra Szakács
University of Szeged

Demi Allen
University of Bristol

Applied Mathematics:

Lorna Ayton
University of Cambridge

Sergey Dolgov
University of Bath

Ben Smith
University of Manchester

Contact:

Website: http://web.mat.bham.ac.uk/BYMC/BECMC21/
E-mail: becmc2021@contacts.bham.ac.uk

Organising Committee:

Ricky Hutchins, Amarja Kathapurkar, Bradly Deeley, Andrew Mitchell, Eoin O'Brien, Jordan Chellig.

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MAGIC

UNIVERSITY OF BIRMINGHAM

Thursday 15th July 2021

9:00-9:20	Welcome session and group photo (Zoom link 1)			
9:25-9:50	Dimensions and Deformation of elliptical polynomial spirals Stuart Burrell (Zoom link 1)	A class of increasing homeomorphism groups naturally isomorphic to diagram groups Liam Stott (Zoom link 2)	Colour-bias Hamilton cycles in dense graphs Andrea Freschi (Zoom link 3)	Mathematical analysis of feedback requirements for planar polarisation Eman Alwani (Zoom link 4)
9:55-10:20	Iterative periodic functions and their generalization Marc Homs Dones (Zoom link 1)	Generalized polygons and star graphs of cyclic presentations of groups Ihechukwu Chinyere (Zoom link 2)	On Hamilton Cycles in Kneser Graphs Namrata (Zoom link 3)	Mathematical Models and Uncertainty Quantification for Alzheimer's Disease Pavan Chaggar (Zoom link 4)
10:25-10:55	Research group networking session (Zoom link 1)			
11:00-11:55	Simplicity of Nekrashevych algebras of contracting self-similar groups Nóra Szakács (Plenary speaker) (Zoom link 1)		Deep Tensor Train Approximations of High-Dimensional Functions Sergey Dolgov (Plenary speaker) (Zoom link 4)	
Coffee break				
12:10-12:35	Stochastic Billiards with Markovian reflection in generalized parabolic domains Conrado da Costa (Zoom link 1)	Why are the p-adic integers like the Cantor set? Alberto Cobos (Zoom link 2)	Distances to Lattice Points in Rational Polyhedra Aled Williams (Zoom link 3)	Shape mode oscillation of bubbles near a rigid boundary Callan Corbett (Zoom link 4)
12:40-13:05	Longest Common Subsequence of Random Permutations Slim Kammoun (Zoom link 1)	Correlations of almost primes Natalie Evans (Zoom link 2)	T-duality: the Hypersimplex and the Amplituhedron Matteo Parisi (Zoom link 3)	Developing hybrid continuum-discrete methods to study chemical dynamics in bacterial biofilms Connah Johnson (Zoom link 4)
Lunch break				
14:20-14:45	Real forms of complexified dynamics Philip Arathoon (Zoom link 1)	Axial algebras Yunxi Shi (Zoom link 2)	The Ramsey number for 4-uniform tight cycles Vincent Pfenninger (Zoom link 3)	Numerical Solutions for the Skyrme Model Paul Leask (Zoom link 4)
14:50-15:15	The Muller-Schupp Theorem for special monoids Carl-Fredrik Nyberg Brodda (Zoom link 1)	A brief introduction to preprojective algebras Davide Morigi (Zoom link 2)	Matchings in k-partite k-graphs Candida Bowtell (Zoom link 3)	Genealogy and spatial distribution of the N-particle branching random walk with polynomial tails Zsófia Talyigás (Zoom link 4)
Coffee break				
15:30-16:25	Dyadic approximation in the middle-third Cantor set Demi Allen (Plenary speaker) (Zoom link 1)		Applications of matroids to auction theory Benjamin Smith (Plenary speaker) (Zoom link 4)	

Friday 16th July 2020				
9:25-9:50	Eigenvalue asymptotics for multi-variable Hankel operators Christos P: Tantalakis (Zoom link 1)	Picard groups of blocks and open conjectures Cesare Giulio Ardito (Zoom link 2)	Twin-free k-uniform hypergraphon Nawaf Alsowait (Zoom link 3)	Simultaneous evolution of host resistance and tolerance to parasitism Prerna Singh (Zoom link 4)
9:55-10:20	Dynamical Borel-Cantelli lemmas of interval maps Surabhi Desai (Zoom link 1)	Blocks of Ariki-Koike algebras Alice Dell'Arciprete (Zoom link 2)	Outerspatial 2-complexes: Extending the class of outerplanar graphs to three dimensions Tsvetomir Mihaylov (Zoom link 3)	Evolutionarily stable aposematic signalling in prey-predator systems Alan Scaramangas (Zoom link 4)
10:25-10:55	Networking shuffle (Zoom link 1)			
11:00-11:55	Tight cycles in hypergraphs Shoham Letzter (Plenary speaker) (Zoom link 1)		Bio-Inspired Turbulent Noise Control Lorna Ayton (Plenary speaker) (Zoom link 4)	
Coffee break				
12:10-12:35	Revivals for linear Schrödinger and Airy equations on a finite interval George Farmakis (Zoom link 1)	Modelling conflicting individual preference: target sequences and graph realizations Raneem Aizouk (Zoom link 2)	Holomorphic and Quasiregular dynamics Athanasios Tsantaris (Zoom link 3)	Data-driven discovery of physical laws with human-understandable deep learning Nicolas Boullé (Zoom link 4)
12:40-13:05	Iterated chromatic localization Nicola Bellumat (Zoom link 1)	Total positivity of the Eulerian triangle: A big generalisation of Brenti's conjecture Bishal Deb (Zoom link 2)	Polynomials with the same Mahler Measure Joshua Coyston (Zoom link 3)	Spatial networks and topological data analysis in blood vessels Sebastian Gilbert (Zoom link 4)
Lunch break				
14:20-14:45	The Applications of EDF's and SEDF's to AMD codes Laura Johnson (Zoom link 1)	sl2-triples in classical Lie algebras over fields of positive characteristic Rachel Pengelly (Zoom link 2)	Trees in tournaments Alistair Benford (Zoom link 3)	
14:50-15:15		Notes of the Tits Alternative for Cyclically Presented Groups of Positive Word Length Four Shaun Isherwood (Zoom link 2)	Path decompositions of tournaments Bertille Granet (Zoom link 3)	
Coffee break				
15:30-17:00	"Pursuing a career in academia" panel session and closing remarks (Zoom link 1)			

Networking Sessions

Thursday 15th July

Research group networking session

10:25-10:55 (Zoom link: 1)

Choose your group by your area of research and join fellow early career researchers within the same field for a great opportunity to network. Discuss common issues, share ideas, or just chat about anything for a chance to get to know one another. In each group, it is recommended that everyone introduces themselves and mentions what their research project is on.

Friday 16th July

Networking Shuffle

10:25-10:55 (Zoom link: 1)

Join us for this networking shuffle for a great opportunity to meet and discuss with researchers from a variety of mathematical disciplines. Everyone will be given 3 random numbers between 1 and 6 which allocates them to three different groups. Each group discussion will last 10 minutes.

Plenary Talks

Pure Mathematics

Thursday 15th July

Simplicity of Nekrashevych algebras of contracting self-similar groups

Nóra Szakács, University of Szeged
11:00-11:55 (Zoom link: 1)

A self-similar group is a group G acting on the infinite $|X|$-regular rooted tree by automorphisms in such a way that the self-similarity of the tree is reflected in the group. They first appeared in the eighties giving rise to exotic examples such as the famous Grigorchuk group, which was the first finitely generated group of intermediate growth. The most common examples, including the Grigorchuk group, can be constructed via finite, edge-labeled graphs.

Nekrashevych associated C^*-algebras and algebras with coefficients in a field to self-similar groups. In the case G is trivial, the algebra is the classical Leavitt algebra. A significant open problem about these algebras was a characterization of their simplicity. Nekrashevych showed that the algebra associated to the Grigorchuk group is not simple in characteristic 2, but Clark, Exel, Pardo, Sims and Starling showed its Nekrashevych algebra is simple over all other fields. Nekrashevych then showed that the Grigorchuk-Erschler group gives rise to non-simple algebras over any field, which was the first such example. The Grigorchuk and Grigorchuk-Erschler groups are both contracting self-similar groups. This important class of self-similar groups includes Gupta-Sidki p-groups and many iterated monodromy groups like the Basilica group.

In this talk we define self-similar groups and their Nekrashevych algebras and fully characterize the simplicity of Nekrashevych algebras of contracting groups. This work is joint with Benjamin Steinberg (City College of New York).

Dyadic approximation in the middle-third Cantor set

Demi Allen, University of Bristol
15:30-16:25 (Zoom link: 1)

In 1984, Mahler asked how well irrational numbers in the middle-third Cantor set can be approximated: (i) by rational numbers in the Cantor set, and (ii) by rational numbers not in the Cantor set. This question sparked great interest and nowadays the topic of Dio- phantine Approximation on Fractals is a hugely popular one. In this talk, I will discuss a recent contribution to this topic, and to Mahler's original question, obtained jointly with Sam Chow (Warwick) and Han Yu (Cambridge). In particular, I will discuss the problem of approximating points in the Cantor set by dyadic rationals (that is, rationals which have denominators which are powers of 2). I will endeavour to tell you what we expect to be true in this case, how far we have come towards establishing that truth, and hopefully convey to you why this is a difficult problem.

Friday 16th July

Tight cycles in hypergraphs

Shoham Letzter, University College London
11:00-11:55 (Zoom link: 1)

How many edges can an r-uniform hypergraph on n vertices with no tight cycles have? We determine the correct answer to this question up to a polylogarithmic factor, improving on a recent result by Sudakov and Tomon.

Applied Mathematics

Thursday 15th July

Deep Tensor Train Approximations of High-Dimensional Functions

Sergey Dolgov, University of Bath
11:00-11:55 (Zoom link: 4)

High-dimensional functions are notoriously difficult to integrate. This is one of the fundamental challenges in stochastic computation and Bayesian inverse problems, where one needs to compute statistics of intractable high-dimensional random variables, following a complicated joint probability density function. The recent surge of transport maps offers a mathematical foundation and new insights for tackling this challenge by coupling intractable random variables with tractable reference random variables.

In this talk I will present a nested variable transformation framework inspired by deep neural networks but driven by functional tensor-train (FTT) approximation of the inverse Rosenblatt transport instead. The resulting deep inverse Rosenblatt transport (DIRT) significantly expands the capability of tensor approximations and transport maps to random variables with complicated nonlinear interactions and concentrated density functions. We compare DIRT with random walk, kernel and neural network approximations of transport maps, and demonstrate the efficiency of the proposed approach on a range of applications in statistical learning and uncertainty quantification, including parameter estimation for dynamical systems and inverse problems constrained by partial differential equations. [https://arxiv.org/abs/2007:06968]

Applications of matroids to auction theory

Benjamin Smith, University of Manchester
15:30-16:25 (Zoom link: 4)

Linear independence is a fundamental property in both pure and applied mathematics. A matroid is a combinatorial object that encodes independence data, and therefore has applications to almost every aspect of mathematics. In particular, it gives us a combinatorial toolkit for problems far outside the range of combinatorics.

Auction theory is concerned with how bidders valuations of products informs their behaviour. A desirable situation is for bidders to have "gross substitutes valuations" - this essentially leads to an auction where both bidders and auctioneer are happy with the outcome. The issue with gross substitute valuations is they are complex to write down: n objects in an auction leads to 2^n values being required, one for each subset of items.

To overcome this, a key question is to find a simple class of valuations that generates all gross substitute valuations. One conjecture is to consider a class of valuations built from matroids. In this talk, we will refute this conjecture by introducing a more general class of valuations, and showing that even this is not sufficient.

This is joint work with Edin Husić, Georg Loho and László Végh.

Friday 16th July

Bio-Inspired Turbulent Noise Control

Lorna Ayton, University of Cambridge
11:00-11:55 (Zoom link: 4)

Noise is generated in an aerodynamic setting when flow turbulence encounters a structural edge, such as at the sharp trailing edge of an aerofoil. The generation of this noise is unavoidable, however this talk addresses various ways in which it may be mitigated through altering the design of the edge. The alterations are inspired by natural silent fliers: owls. A short review of how trailing-edge noise is modelled will be given, followed by a discussion of two independent adaptations; serrations, and porosity. The mathematical impacts of the adaptations to the basic trailing-edge model will be presented, along with the physical implications they have on noise generation and control.

Short Talks

Pure Mathematics

Thursday 15th July

Dimensions and Deformation of elliptical polynomial spirals

Stuart Burrell, University of St Andrews
9:25-9:50 (Zoom link 1)

Spirals are exciting objects that spring up throughout nature and mathematics. For example, they arise in turbulent dynamical systems and play an important role in the theory of conformal welding. We introduce elliptical polynomial spirals, a flexible family of planar spirals with differing polynomial rates of decay in the two-axis directions. After setting the scene, we present the various dimensions of these spirals and probe the way they differ via the emerging field of dimension interpolation. Then, we consider the regularity of Hölder maps that deform one spiral into another. Dimension yields an initial bound on the Hölder exponent, which, surprisingly, may be improved upon by analysing the images of spirals under fractional Brownian motion.

This talk is based on joint work with Kenneth Falconer and Jonathan Fraser.

Iterative periodic functions and their generalization

Marc Homs Dones, University of Warwick
9:55-10:20 (Zoom link 2)

Can you find continuous functions that are iteratively periodic, i.e. $f^n := f \circ \cdots \circ f = \mathrm{id}$? It is easy to see that some rotations and symmetries are periodic but can you find any other examples? The classical Kerékjártó's theorem asserts that these are all the periodic functions in $\mathbb{R}^2$ (up to topological conjugacy). After covering the periodic case we will move on to study a generalization, namely $f^n = f^k$. We will show how with certain assumptions of regularity we can get similar results to Kerékjártó's theorem, and how without these assumptions, such classifications are impossible.

A class of increasing homeomorphism groups naturally isomorphic to diagram groups

Liam Stott
9:25-9:50 (Zoom link 2)

Deep connections between groups of increasing homeomorphisms and diagram groups are suggested when one considers properties and examples of groups from each class. For example, Brin showed that Thompson's group F embeds into a group of increasing piecewise linear homeomorphisms under a remarkably weak condition, while Guba and Sapir showed that F embeds into a diagram group under a similarly weak condition.

There have been limited results concerning direct connections; Guba and Sapir develop a procedure to find natural representations of any diagram group as a group of increasing homeomorphisms, though they are not always faithful. Thus, it is reasonable to ask: for which groups of increasing homeomorphisms does there exist a natural faithful representation as a diagram group? In this talk I will introduce a class of such groups which, among others, includes groups generated by geometrically fast sets of one orbital homeomorphisms.

Generalized polygons and star graphs of cyclic presentations of groups

Ihechukwu Chinyere
9:55-10:20 (Zoom link 2)

Groups defined by presentations for which each component of the corresponding star graph is the incidence graph of a generalized polygon are of interest as they are small cancellation groups that – via results of Edjvet and Vdovina – are fundamental groups of polyhedra with the generalized polygons as links and so act on buildings. A cyclic presentation of a group is a presentation with an equal number of generators and relators that admits a particular cyclic symmetry. We obtain a classification of the non-redundant cyclic presentations where the components of the corresponding star graph are generalized polygons. The classification reveals only generalized triangles and regular complete bipartite graphs arise as the components. In connection with a problem of Edjvet and Vdovina we show that many of the corresponding groups are large.

Colour-bias Hamilton cycles in dense graphs

Andrea Freschi, University of Birmingham
9:25-9:50 (Zoom link 3)

Balogh, Csaba, Jing and Pluhár determined the minimum degree threshold that ensures a 2-coloured graph G contains a Hamilton cycle of significant colour bias (i.e., a Hamilton cycle that contains significantly more than half of its edges in one colour). In this talk we present a generalisation of this result, determining the corresponding threshold for r-colourings.

On Hamilton Cycles in Kneser Graphs

Namrata, University of Warwick
9:55-10:20 (Zoom link 3)

For integers $k \geq 1$ and $n \geq 2k+1$, the *Kneser graph* $K(n,k)$ has as vertices all k-element subsets of $\{1,\ldots n\}$ and its edges connect pairs of subsets that are disjoint. It has long been conjectured that all Kneser graphs $K(n,k)$ have a Hamilton cycle, with one notable exception, namely the Petersen graph $K(5,2)$. To date, this conjecture has been verified in the dense case when $n \geq 2.62k+1$ and in the sparse case when $n = 2k+2^a$, $a \geq 0$.

We prove that $K(n,k)$ has a Hamilton cycle for all $n \geq 7$ that are a prime number or twice a prime number. These results are obtained from a new construction of a cycle factor via parenthesis matching approach. It turns out that these cycles can be described by a physical system of moving 'gliders' that participate in collisions and overtakings, while preserving kinetic energy.

This talk is based on joint work with Arturo Merino, Torsten Mütze and Pascal Su.

Stochastic Billiards with Markovian reflection in generalized parabolic domains

Conrado da Costa
12:10-12:35 (Zoom link 1)

In this talk, we consider a particle moving linearly inside generalized parabolic domain with Markovian reflection at the boundary. Our goal is to determine, with respect to the reflection law, when the process is recurrent or transient. The central idea, which applies a class of non-homogeneous random walks, is to find a Lyapunov function for the properly rescaled version of the problem. Next, we employ supermartingale methods to identify, given the reflection kernel, a phase transition, from recurrent to transient, as we change a single geometric parameter of the region for these stochastic billiards. The solution of this problem is done via a translation to a broad class of almost Markovian models, the half-strip models, and makes use of some tools from functional analysis. This is a joint work in progress with Mikhail Menshikov and Andrew Wade.

Longest Common Subsequence of Random Permutations

Slim Kammoun
12:40-13:05 (Zoom link 1)

Bukh and Zhou conjectured that the expectation of the length of the longest common subsequence (LCS) of two i.i.d random permutations of size n is greater than $\sqrt{n}$.

This problem is related to the Ulam-Hammersley problem; Ulam conjectured that the expectation of the length of the longest increasing subsection (LIS) for a uniform permutation behaves like $c\sqrt{n}$. The conjecture was solved in 1977, but few results are known for nonuniform permutations. The LIS and LCS are closely related, and solving the conjecture of Bukh and Zhou is equivalent to minimize the expected value of LIS for random permutations that can be written as $\rho_n \circ \sigma_n^{-1}$ where σ_n and ρ_n are i.i.d. random permutations.

We recall the classical results for the uniform case as well as partial answers for the conjugation invariant case.

Why are the p-adic integers like the Cantor set?

Alberto Cobos
12:10-12:35 (Zoom link 2)

The p-adic integers were introduced by Kurt Hensel in 1897. Even though they are not very familiar to most mathematicians, they play an important role in algebra, number theory and beyond. Topologically, a theorem of Brouwer shows that the p-adic integers are homeomorphic to the well-known Cantor set, but it is not clear how to construct one such homeomorphism in practice. This talk will be a journey through the fields of geometry, algebra, graph theory, order theory and topology ending with a way to construct such homeomorphisms.

Correlations of almost primes

Natalie Evans
12:40-13:05 (Zoom link 2)

The Hardy-Littlewood generalised twin prime conjecture states an asymptotic formula for the number of primes $p \leq X$ such that $p + h$ is prime for any non-zero even integer h. While this conjecture remains wide open, Matomäki, Radziwiłł and Tao proved that it holds on average over h, improving on a previous result of Mikawa. In this talk we will discuss an almost prime analogue of the Hardy-Littlewood conjecture for which we can go beyond what is known for primes. We will describe some recent work in which we prove an asymptotic formula for the number of almost primes $n = p_1 p_2 \leq X$ such that $n + h$ has exactly two prime factors which holds for a very short average over h.

Distances to Lattice Points in Rational Polyhedra

Aled Williams
12:10-12:35 (Zoom link 3)

During this talk we consider integer linear programs (ILPs) in standard form, namely $\min\left\{\boldsymbol{c}^T\boldsymbol{x} : A\boldsymbol{x} = \boldsymbol{b}, \boldsymbol{x} \in \mathbb{Z}^n_{\geq 0}\right\}$, where $A \in \mathbb{Z}^{m\times n}$ is an integral matrix with m rows and n columns, $\boldsymbol{b} \in \mathbb{Z}^m$ is an m-dimensional integral vector and $\boldsymbol{c} \in \mathbb{Q}^n$ is a n-dimensional linear objective function. It is well-known that solving the decision version of an ILP is in general $\mathcal{NP}$-complete and, therefore, when given such a problem one may instead attempt to find an approximate solution by solving some relaxed yet related problem. In this case, it is common to instead consider the polynomial solvable related linear program (LP), namely $\min\{\boldsymbol{c}^T\boldsymbol{x} : A\boldsymbol{x} = \boldsymbol{b}, \boldsymbol{x} \in \mathbb{R}^n_{\geq 0}\}$.

In light of this, a central problem within this research domain is to estimate the distance from an optimal solution to the LP to some feasible integer solution which solves the related ILP. Throughout the talk we firstly overview previously known worst-case upper bounds on this distance before providing some refined bounds upon making assumptions about the matrix A.

T-duality: the Hypersimplex and the Amplituhedron

Matteo Parisi
12:40-13:05 (Zoom link 3)

We discover a striking duality, *T-duality*, between two seemingly unrelated objects. The *hypersimplex* $\Delta_{k+1,n}$ is a polytope obtained as the image of the positive Grassmannian $\mathrm{Gr}^{\geq 0}_{k+1,n}$ under the well-known moment map. Meanwhile, the *amplituhedron* $\mathcal{A}_{n,k,2}$ is the projection from the positive Grassmannian $\mathrm{Gr}^{\geq 0}_{k+1,n}$ into the Grassmannian $\mathrm{Gr}_{k,k+2}$ under the amplituhedron map. Introduced in the context of the physics of *scattering amplitudes*, it is not a polytope and has full dimension inside $\mathrm{Gr}_{k,k+2}$. We draw novel connections between the two objects and prove many new properties of them. We exploit T-duality to relate their triangulations and *generalised triangles* (maximal cells in a triangulation). We subdivide $\mathcal{A}_{n,k,2}$ into chambers as $\Delta_{k+1,n}$ can be subdivided into simplices - both enumerated by Eulerian numbers. Moreover, we prove a main result about the hypersimplex and the *positive tropical Grassmannian* Trop$^+$ $\mathrm{Gr}_{k+1,n}$, several conjectures on the amplituhedron, and find novel cluster-algebraic structures.

This talk is based on the recent joint work with L. K. Williams and M. Sherman-Bennett and a previous work with L. K. Williams and T. Lukowski.

Real forms of complexified dynamics

Philip Arathoon
14:20-14:45 (Zoom link 1)

We consider what happens when we complexify a classical mechanical system. Such systems are expressed in the usual terms of Hamiltonian dynamics which take place in a symplectic manifold. If we now complexify everything the result is a little underwhelming and unsurprising: we simply obtain dynamics on what is now a complex symplectic manifold. However, it becomes more interesting when we ask what real systems complexify to a given complex one? This raises the prospect of defining a 'real form' of a complex Hamiltonian system analogous to the real forms of complex Lie algebras. Indeed, we shall show that many different real Hamiltonian systems can be seen as real forms of a single complex system, and show how this passage between the real and complex respects foundational concepts in mechanics such as reduction and integrability. Curiously, the details of this theory have substantial overlap with ideas from string theory and hyperkähler geometry, and we shall use these connections in an essential way to exhibit a compact 'real form' of the spherical pendulum.

The Muller-Schupp Theorem for special monoids

Carl-Fredrik Nyberg Brodda
14:50-15:15 (Zoom link 1)

The study of 'special' monoids goes back to S. I. Adian and his student G. S. Makanin, who reduced the word problem of such monoids to the same problem for their group of units. There are many ways in which special monoids behave like "generalised" groups, and studying them has many similarities with combinatorial group theory. I will give a brief overview of the main ideas involved in studying special monoids – including the definition! – and the role played by the group of units. I will then present some recent full generalisations of the celebrated Muller-Schupp theorem from virtually free groups to special monoids with virtually free groups of units.

Axial algebras

Yunxi Shi
14:20-14:45 (Zoom link 2)

Axial algebras are non-associative commutative algebras generated by some special axes satisfying a prescribed fusion law. In this talk, we introduce the basic concept of this class of algebras and investigate the properties of known examples. We also discuss the connectivity of the non-orthogonality graph in the flip subalgebras. Furthermore, we look into the notion of the baric algebras of Monster type.

A brief introduction to preprojective algebras

Davide Morigi
14:50-15:15 (Zoom link 2)

From a representation theory point of view, any associative algebra A can be seen as a quotient of the path algebra of a quiver Q by some admissible ideal I, i.e., $A \cong kQ/I$. One can organize the category rep$A$ of finite dimensional representations of A into another quiver Γ_A, called the Auslander-Reiten quiver of A. However, it is in general hard to get a full understanding of Γ_A. The preprojective algebra of A, that arises from the full subquiver of Γ_A whose vertices are the preprojective modules, provides a manageable, and yet very interesting, subclass of representations of A.

In this talk I will introduce the above mentioned concepts using examples, and I will present two equivalent definitions of preprojective algebra.

The Ramsey number for 4-uniform tight cycles

Vincent Pfenninger, University of Birmingham
14:20-14:45 (Zoom link 3)

The *Ramsey number* for a k-graph (k-uniform hypergraph) H is the least integer N such that any 2-edge-colouring of the complete k-graph on N vertices contains a monochromatic copy of H. A *k-uniform tight cycle* is a k-graph with a cyclic ordering of its vertices such that its edges are precisely the sets of k consecutive vertices in that ordering. We prove that the Ramsey number for the 4-uniform tight cycle on $4n$ vertices is $(5 + o(1))n$. Our result is asymptotically tight and confirms a special case of a conjecture of Haxell, Łuczak, Peng, Rödl, Ruciński and Skokan.

This talk is based on joint work with Allan Lo.

Matchings in k-partite k-graphs

Candida Bowtell, University of Oxford
14:50-15:15 (Zoom link 3)

Let H be a k-partite k-graph with parts $V_1, \dots, V_k$ each of size n, such that, for every $i \in [k]$, every $(k-1)$-set in $\prod_{j\in[k]\setminus\{i\}} V_j$ lies in at least a_i edges. Suppose further that $a_1 \geq \dots \geq a_k$. Han, Zang and Zhao showed that for every $\epsilon > 0$ and sufficiently large n, with $a_1, a_2 \geq \epsilon n$, H contains a matching of size at least $\min\{n-1, \sum_{i\in[k]} a_i\}$, answering and generalising a question of Rödl and Ruciński. Their arguments use complex absorbing methods which fail when all of $a_2, \dots, a_k$ are small. We consider the remaining cases and, in particular, show that when $\sum_{i=2}^{k} a_i \leq \sqrt{\frac{n}{k+1}}$, H in fact contains a matching of size at least $\min\{n, \sum_{i\in[k]} a_i\}$. Our proof uses a novel approach, making use of Aharoni and Haxell's 'Hall's Theorem for Hypergraphs' and rainbow matchings.

Friday 16th July

Eigenvalue asymptotics for multi-variable Hankel operators

Christos P. Tantalakis, Kings College London
9:25-9:50 (Zoom link 1)

A Hankel operator is an infinite matrix $\{a_{j+k}\}_{j,k\geq 0}$, considered as an operator on $\ell^2(\mathbb{N}_0)$, $\mathbb{N}_0 = \mathbb{N}\cup\{0\}$. The spectral theory of Hankel operators is a well studied branch of mathematics at the overlap of complex analysis and operator theory. In this talk, we shall discuss a multi-variable (d-variable) analogue of Hankel operators, defined as infinite matrices $\{a_{j+k}\}_{j,k\in\mathbb{N}_0^d}$, where $d > 1$. For a class of compact d-variable Hankel operators, we will explicitly determine the asymptotics of eigenvalues, extending earlier 1-variable results by Pushnitski and Yafaev.

Dynamical Borel-Cantelli lemmas of interval maps

Surabhi Desai, University of Exeter
9:55-10:20 (Zoom link 1)

In probability theory, the Borel-Cantelli lemma can be used to determine the infinitely often occurrence of a sequence of events. We are interested in establishing analogous recurrence properties in order to describe the long term behaviour of a dynamical system. In this talk, we focus on a class of interval maps and characterise sequences for which these properties hold. This talk is based on joint work with M. Holland.

Picard groups of blocks and open conjectures

Cesare Giulio Ardito
9:25-9:50 (Zoom link 2)

In this talk I will define Picard groups of a block and briefly describe some of the newest results concerning these objects, with a focus on how studying these invariants could help solving solve long-standing open conjectures in modular representation theory. In particular, I will describe the relation between Picard groups and Morita equivalence classes of blocks in a chain of normal subgroups, and then I will talk about endopermutation-source Morita equivalences (also called *basic* Morita equivalences) and how an “upgrade” to these equivalences could massively simplify the study of blocks of finite groups.

Blocks of Ariki-Koike algebras

Alice Dell'Arciprete
9:55-10:20 (Zoom link 2)

We consider representations of the Ariki–Koike algebra, a q-deformation of the group algebra of the complex reflection group $Cr \wr Sn$. The representations of this algebra are naturally indexed by multipartitions of n. We examine blocks of the Ariki–Koike algebra, in an attempt to generalise the combinatorial representation theory of the Iwahori–Hecke algebra.

In particular, we prove a sufficient condition such that restriction of modules leads to a natural correspondence between the multipartitions of n whose Specht modules belong to a block B and those of $n - \delta_i(B)$ whose Specht modules belong to the block B', obtained from B applying a Scopes' equivalence.

Twin-free k-uniform hypergraphon

Nawaf Alsowait, University of East Anglia
9:25-9:50 (Zoom link 3)

We give a new definition of the k-uniform hypergraphon and describe what we mean by a twin-free hypergraphon. Following the work of Borge, Chayes and Lovász with graphons, we describe how we may reduce every k-uniform hypergraphon to a twin-free separable k-uniform hypergraphon. Furthermore, we show that every k-uniform hypergraphon is weakly isomorphic to a twin-free separable k-uniform hypergraphon.

Outerspatial 2-complexes: Extending the class of outer-planar graphs to three dimensions

Tsvetomir Mihaylov, University of Birmingham
9:55-10:20 (Zoom like 3)

We introduce the class of outerspatial 2-complexes as the natural generalisation of the class of outerplanar graphs to three dimensions. Answering a question of O-joung Kwon, we prove that a locally 2-connected 2-complex is outerspatial if and only if it does not contain a surface of positive genus as a subcomplex and does not have a space minor that is a generalised cone over K_4 or $K_{2,3}$.

Revivals for linear Schrödinger and Airy equations on a finite interval

George Farmakis
12:10-12:35 (Zoom link 1)

The linear Schrödinger and Airy equations under periodic boundary conditions incorporate the phenomenon of revivals, meaning that their solution at certain times called "rational" can be expressed as a finite linear combination of translated copies of the initial function. In particular, for an initial condition with a jump discontinuity, the solution also exhibits jump discontinuities at each rational time, although at other generic times the solution is known to be continuous. Moving beyond the periodic case, in this talk, by considering non-periodic boundary conditions we will describe their influence on the revival property for both equations.

This talk is based on joint work with Lyonell Boulton and Beatrice Pelloni.

Iterated chromatic localization

Nicola Bellumat
12:40-13:05 (Zoom link 1)

The work of Ravenel, Devinatz, Hopkins and Smith in the 80s provided the basis of chromatic homotopy theory: its protagonists are the Morava theories $E(n)$ and $K(n)$, whose associated Bousfield localizations give us optimal means to decompose the stable homotopy category in pieces easier to understand. It comes naturally to wonder how the compositions of such localizations behave: there are classical results regarding the relationship of the Bousfield classes of wedges of the above spectra which lead us to expect some kind of regularity. In this talk I will present a positive result in this direction: we show that, fixed an upper bound n for the chromatic height, the compositions of localizations with respect to spectra which are wedges of $K(i)$'s, for i integers between 0 and n, are only finitely many up to isomorphism. The crucial point of the proof is that we can reduce the composition of such iterated localizations to a combinatorial operation on a finite poset.

Modelling conflicting individual preference: target sequences and graph realizations

Raneem Aizouk
12:10-12:35 (Zoom link 2)

In this presentation, we will consider a group of individuals, who each have a target number of contacts they would like to have with other group members. We are interested in how close this can come to being realized, and consider the long term outcome for the group under a reasonable dynamics on the number of contacts. We formulate this as a graph realization problem for undirected graphs, with the individuals as vertices, and the number of contacts as the vertex degree. It is well known that not all degree sequences can be realized as undirected graphs and the Havel-Hakimi algorithm characterizes those that can. When we ask how close the degree sequences can be to realization, we ask for graphs that minimize the total deviation between what is desired and what is possible. The set of all such graphs and the set of all such associated sequences are termed the minimal sets. This problem has previously been considered by Broom and Cannings in a series of papers, and it is a hard problem to tackle for general target sequences. In this talk, we consider the n-element arithmetic sequence (n-1, n-2, ... 1,0) for general n, including obtaining a formula that generates the size of the minimal set for a given arithmetic sequence. We also consider a strategic version of the model where the individuals are involved in a multiplayer game, with each trying to achieve their target.

This is based on joint work with Mark Broom.

Total positivity of the Eulerian triangle: A big generalisation of Brenti's conjecture

Bishal Deb

12:40-13:05 (Zoom link 2)

A matrix is called totally positive if all its minors (that is, all the determinants of its square submatrices) are non-negative. In 1996, Brenti conjectured that the Eulerian triangle, namely, the infinite lower-triangular matrix whose (n, k) entry is the number of permutations of $\{1, \ldots, n+1\}$ with k descents, is totally positive. In this talk, we will introduce a 4-variable polynomial generalisation of the Eulerian triangle that we conjecture to be coefficientwise totally positive in all four variables. (We have checked this up to 13x13, taking 109 days CPU time.) We look at some specialisations of this matrix, including a three-variable case that we have proven to be totally positive. The proofs use both algebraic and combinatorial/graphical methods.

This talk is based on ongoing work with Xi Chen, Alexander Dyachenko, Tomack Gilmore and Alan D. Sokal.

Holomorphic and Quasiregular dynamics

Athanasios Tsantaris, University of Nottingham

12:10-12:35 (Zoom link 3)

Complex dynamics is the study of dynamical systems defined by iterations of holomorphic maps. In this talk we are going to first discuss how we can study such dynamical systems. Then we are going to talk about quasiregular maps, which are a higher dimensional generalization of holomorphic maps, and discuss how we can also develop an iteration theory for such maps.

Polynomials with the same Mahler Measure

Joshua Coyston, Royal Holloway, University of London
12:40-13:05 (Zoom link 3)

The Mahler measure is used to show how far away a polynomial's roots are from being in the unit circle. We explore under what conditions two integer polynomials can have the same Mahler measure. From here, we look at a conjecture which argues that Mahler measure values are, up to a set of conditions, unique to certain polynomials. We end with a brief look at my attempts to prove this conjecture, and what the future holds.

The Applications of EDF's and SEDF's to AMD codes

Laura Johnson
14:20-14:45 (Zoom link 1)

Many classic cryptographical schemes prevent against attacks from passive adversaries; in other words, a third party who is trying to intercept and decrypt messages sent between two participants within a cryptographical scheme. The goal of a passive adversary is simply to gain access to information that they are not privy too, but this is not the only aim an adversary may have. Some adversaries, know as active adversaries, wish to alter messages sent between participants in a cryptographical scheme in order to cause miscommunication between two parties. AMD codes are a type of cryptographical tool that may be deployed alongside cryptographical schemes to reduce the success probabilty of an attack from an active adversary.

In this talk, I will fully introduce AMD codes and then go on to explain how combinatorial objects such as external difference families and their generalisations may be used to represent and analyse AMD codes. Specifically; an external difference family (or EDF) is, in essence, a collection of subsets of a particular group G, whose pairwise differences yield each non-zero group element of a group G precisely λ times and a strong external difference family (or SEDF) is an EDF with extra constraints on how many times an element may occur as a pairwise difference between a fixed subset D of G and all other subsets of G.

$\mathfrak{sl}_2$-triples in classical Lie algebras over fields of positive characteristic

Rachel Pengelly
14:20-14:45 (Zoom link 2)

Let K be an algebraically closed field of arbitrary characteristic. Given three elements of some Lie algebra over K, we say that these elements form an $\mathfrak{sl}_2$-triple if they generate a subalgebra which is a homomorphic image of $\mathfrak{sl}_2$. In this talk we introduce Lie algebras and $\mathfrak{sl}_2$-triples before discussing the Jacobson-Morozov theorem in characteristic 0, and the progress made in extending this result to fields of characteristic p. In particular, we focus on the results in classical Lie algebras, which can be found as subsets of $\mathfrak{gl}_n(K)$.

Notes of the Tits Alternative for Cyclically Presented Groups of Positive Word Length Four

Shaun Isherwood
14:50-15:15 (Zoom link 2)

Bogley and Parker obtained a classification of the finiteness of cyclically presented groups with positive length four relators. This was with the help of congruence conditions on specific parameters. A natural question to ask, then, is whether the Tits alternative holds for such groups. This has been the focus of my research for the last few years, with all but one set of truth values of the congruence conditions being resolved. I will give a short summary of the work so far.

Trees in tournaments Alistair Benford

Alistair Benford
14:20-14:45 (Zoom link 3)

Given an n-vertex oriented tree T, what is the smallest size a tournament G must be, in order to guarantee G contains a copy of T? A strengthening of Sumner's conjecture poses that it is enough for G to have $(n + k - 1)$ vertices, where k is the number of leaves of T. Recently, Dross and Havet used a method of median orders to prove that this is true for arborescences – i.e. trees with edges oriented outwards from a specified root vertex. We show that median orders can make further progress towards $(n+k-1)$, by proving that there exists a constant C such that $|G| = (n+Ck)$ is enough, as well as confirming a separate conjecture that $|G| = (n+k-2)$ is enough, provided we allow n to grow large with k fixed. In this talk we shall discuss these results and further progress that could be made.

This talk is based on joint work with Richard Montgomery.

Path decompositions of tournaments

Bertille Granet
14:50-15:15 (Zoom link 3)

In 1976, Alspach, Mason, and Pullman conjectured that any tournament T of even order can be decomposed into exactly $\mathrm{ex}(T)$ paths, where $\mathrm{ex}(T) \coloneqq \frac{1}{2}\sum_{v\in V(T)} |d_T^+(v) - d_T^-(v)|$ ($d_T^+(v)$ and $d_T^-(v)$ denote the out and indegree of v in T, respectively). We prove this conjecture for all sufficiently large tournaments. We also prove an asymptotically optimal result for tournaments of odd order.

This talk is based on joint work with António Girão, Daniela Kühn, Allan Lo, and Deryk Osthus.

Applied Mathematics

Thursday 15th July

Mathematical analysis of feedback requirements for planar polarisation

Eman Alwani
9:25-9:50 (Zoom link 4)

During animal development, oriented cell behaviours are required to ensure appropriate growth and structure. Planar polarity, which describes polarisation within the plane of a cell sheet, is an important example of such behaviours. Disruption of planar polarity is associated with cancer progression and a range of congenital defects. In the fly wing, experimental analysis suggests that intercellular complex formation and feedback interactions result in the asymmetric distribution of planar polarity proteins at opposite cell junctions, leading to oriented hair outgrowths. However, the nature and source of these feedback interactions remain unclear. We investigate this theoretically by constructing and analysing an ordinary differential equation model that abstracts the process of planar polarisation in the fly wing. Our aim is to gain a qualitative understanding of the requirements for different feedback interactions to establish planar polarisation. Our approach is to examine a minimal mass conservative model of planar polarity protein complex formation in a ring of cells, where nonlinear feedback interactions may act on the kinetics of protein complex formation and/or diffusion. We also examine a non-conservative model, in which feedback interactions may act on the kinetics of protein endocytosis from the plasma membrane. Through steady-state, linear stability and bifurcation analysis, we compare the mathematical requirements for planar polarisation to occur as a result of these different mechanisms, and relate our results to a more detailed description of core planar pathway polarisation in the fly wing.

Mathematical Models and Uncertainty Quantification for Alzheimer's Disease

Pavan Chaggar
9:55-10:20 (Zoom link 4)

Alzheimer's disease (AD) is a debilitating neurodegenerative disorder that brings a significant personal, social and financial cost to society. At present, clinical interventions remain limited, in part due to the complex and multifaceted aetiology of AD. In the first section of this talk, I will overview how applications of dynamical systems modelling have elucidated the mechanistic underpinnings of AD, namely the importance of interactions between toxic proteins, structural brain connections and waste clearance pathways. Secondly, I will discuss recent work connecting mathematical models to patient data using a Bayesian framework. The framework combines sophisticated numerical solvers and Hamiltonian Monte Carlo methods for performing hierarchical inference on high dimensional ODE systems against very sparse patient data. Our results quantify sources of uncertainty in the modelling process that will inform future modelling, disease prediction and clinical research.

Shape mode oscillation of bubbles near a rigid boundary

Callan Corbett
12:10-12:35 (Zoom link 4)

The dynamics of bubbles have been extensively studied and have numerous applications such as ultrasonic cleaning and targeted drug delivery. Despite the rich history of the topic, certain important aspects remain unknown. One example of this is the features of shape mode oscillations when a bubble is near to a rigid boundary. This is of particular interest to ultrasonic cleaning, as the shape modes, and the amount of shear stress they generate, can greatly affect the efficiency when removing substances from a boundary.

In this talk I will discuss the aspect of shape mode oscillations of a bubble in a viscous compressible fluid near a wall. I will present an axisymmetric model used to simulate the behaviour, based on the boundary integral method, which allows for high accuracy modelling of multiple cycles of oscillation. Finally, I will detail the calculation of shear stress on the wall and compare results for several different shape modes of oscillation.

Developing hybrid continuum-discrete methods to study chemical dynamics in bacterial biofilms

Connah Johnson
12:40-13:05 (Zoom link 4)

Biofilms are ubiquitous in medical settings. Biofilms can contain multiple distinct bacterial strains which complicate the task of tackling infections. It has been shown that within biofilms cross feeding between different cell types or species can support strains who would otherwise starve under substrate removal. We seek to understand biofilm systems through mathematical modelling using our hybrid modelling platform. Biofilms are modelled through coupling multiple reaction-diffusion systems to a population of individual cell agents. The cells each have their own metabolic models encoding different cell types. They can interact through the excretion and uptake of chemicals in the shared film environment. The spatial distribution of these cells and their behaviours is investigated under a range of metabolic processes and phenomena. Therein providing insights into the complex dynamics that may suggest clinical applications.

Numerical Solutions for the Skyrme Model

Paul Leask
14:20-14:45 (Zoom link 4)

In the Skyrme model of nuclear physics, baryons are modelled as topological solitons in a non-linear theory of pions. A Skyrmion may be regarded as a topologically non-trivial map from one Riemannian manifold to another, which minimizes the static energy functional within its homotopy class. They have an associated topological charge that is identified with the conserved baryon number, preventing them from being continuously deformed to the vacuum field configuration.

In this talk, we show how to construct the $B = 1$ Skyrmion using the spherical hedgehog ansatz and obtain the radial profile function using a shooting method. To build higher charge Skyrmions, we introduce a rational map ansatz that yields approximate Skyrmions. However, further numerical relaxation is required to find true Skyrmions. We then introduce an accelerated gradient descent algorithm to find (local) static energy minima. Finally, we construct chunks of the Skyrme crystal using a multi-shell rational map ansatz.

Genealogy and spatial distribution of the N-particle branching random walk with polynomial tails

Zsófia Talyigás
14:50-15:15 (Zoom link 4)

É. Brunet and B. Derrida's work in the physics literature inspired significant research on branching processes with selection. In recent years the N-particle branching random walk (N-BRW) has been studied as an important model in this area. In my talk I will state and explain the ideas behind a result about the genealogies of the N-BRW model under conditions which have previously been studied by J. Bérard and P. Maillard.

In the N-BRW we have N particles located on the real line at all times. At every time step each particle is replaced by two offspring, each of which makes a jump from its parent's location, independently from the other jumps, according to a given jump distribution. Then among the $2N$ offspring particles only the N rightmost survive; the other particles are removed from the system. The result says that if the jump distribution is heavy-tailed, then at a typical large time almost the whole population descends from a single particle which performed an extremely large jump.

This talk is based on joint work with Sarah Penington and Matthew Roberts.

Friday 16th July

Simultaneous evolution of host resistance and tolerance to parasitism

Prerna Singh
9:25-9:50 (Zoom link 4)

Tolerance and resistance are two modes of defense mechanisms used by hosts when faced with parasites. Here we assume tolerance reduces infection-induced mortality rate and resistance reduces the susceptibility of getting infected. Importantly, a negative association between these two strategies has often been found experimentally. We study the simultaneous evolution of resistance and tolerance in a host population where they are related by such a trade-off. Using evolutionary invasion theory, we examine the patterns of optimal investment in each defense strategy, under different ecological scenarios. Our focus is on predicting which of the two strategies is favored under various epidemiological and ecological conditions. Our key findings surround the impact of recovery and sterility of infected hosts. When infected hosts are sterile, investment in tolerance increases (resistance decreases), but this pattern reverses when infected hosts can reproduce. These results emphasize the role of fecundity in driving the evolutionary dynamics of a host. We also found that the crowding factor affects investments in tolerance and resistance only when infected hosts can reproduce.

Evolutionarily stable aposematic signalling in prey- predator systems

Alan Scaramangas
9:55-10:20 (Zoom link 4)

Aposematism is the signalling of a defence for the deterrence of predators. Our research focuses on aposematic organisms that exhibit chemical defences, which are usually signalled by bright skin pigmentation; although our treatment is likely transferable to other forms of secondary defence. This setup is a natural one to consider and opens up the possibility for robust mathematical modelling: the strength of aposematic traits (signalling and defence) can be unambiguously realised using variables that are continuously quantifiable, independent from one another and which together define a two-dimensional strategy space. We develop a mathematical model and explore the joint co-evolution of aposematic traits within the context of evolutionary stability. Even though empirical and model-based studies are conflicting regarding how aposematic traits are related to one another in nature, most allude to a positive correlation. We suggest that both positively and negatively correlated combinations of traits can achieve evolutionarily stable outcomes and further, that for a given level of signal strength there can be more than one optimal level of defence. Our findings are novel and relevant to a sizeable body of physical evidence, much of which could, until presently, not be addressed in terms of a single, well-understood mechanism.

Data-driven discovery of physical laws with human- understandable deep learning

Nicolas Boullé
12:10-12:35 (Zoom link 4)

Scientific computing and machine learning have recently successfully converged on partial differential equation (PDE) discovery, PDE learning, and symbolic regression as promising means for applying machine learning to scientific investigations. These PDE learning techniques attempt to discover the coefficients of a PDE model or learn the operator that maps excitations to system responses. In this talk, we will introduce a novel data-driven and theoretically rigorous approach for learning Green's functions, and deriving mechanistic understanding, of unknown governing PDEs from observation data. First, physical system responses, under carefully selected excitations, are collected to train rational neural networks and learn Green's functions of hidden partial differential equations. Then, we analyze the learned Green's functions to reveal human-understandable properties and features, such as linear conservation laws, and symmetries, along with shock and singularity locations, boundary effects, and dominant modes. We illustrate this technique on several examples and capture a range of physics, including advection-diffusion, viscous shocks, and Stokes flow in a lid-driven cavity.

Spatial networks and topological data analysis in blood vessels

Sebastian Gilbert
12:40-13:05 (Zoom link 4)

Tissue engineered by self-assembly (TESA) allows the development of a tissue's own extracellular matrix, resulting in tissue that better recapitulates biochemical and biomechanical properties of native tissue. More complex networks of blood vessel depend on these properties, alongside environmental factors, to allow growth and stability at multiple scales. The automated image processing techniques to distinguish the functional blood vessels from three dimensional stacks imaged by confocal microscopy comes with its own challenges. The image processing techniques provide insight on the assumptions that can be made about the final segmented vessel network. After resolving this, we proceed to automate the previous manually measured geometry by experimentalist followed by our own analysis of Graph Theory-based metrics. We can consider a blood vessel network as a series of nodes and edges, where each vessel is an edge and the junction of two or more vessels are the nodes. Finally, we look to topological data analysis and other methods to combine all geometric and topological measurements in a single multi-dimensional analysis.