

## Reports of Sponsored Meetings

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SPRING 2025 MEETING OF THE EMS COMMITTEE FOR DEVELOPING COUNTRIES  
10–12 APRIL 2025, UCC

The Spring 2025 meeting of the European Mathematical Society Committee for Developing Countries (EMS-CDC) was hosted by University College Cork (UCC) over 10-12 April 2025. This event had a hybrid format, with 14 participants on-site and 20 more online. The local organisers were Cónall Kelly (currently vice-chair of the EMS-CDC) and Tom Carroll.



The EMS-CDC has a mandate to assist countries in the Global South in ways that include the development of mathematics curricula, libraries, and financial support. Recent major projects of the committee include the Emerging Regional Centres of Excellence (ERCE) programme, which recognises and supports centres of mathematics in the Global South that have achieved a substantial level of research activity and that play a key role in training students in their region.

The IMS President, Dr. Rachel Quinlan, gave welcoming remarks to open the meeting, which started with a session on academic publication practices and their implications for researchers in the Global South. The agenda also included reports from associate members of the committee representing organizations such as Centre International de Mathématiques Pures et Appliquées (CIMPA), the International Centre for Mathematical Sciences (ICMS), and the African Institute for Mathematical Sciences (AIMS).

Please see the committee's webpage for more about the work of the EMS-CDC.

The meeting received funding from the IMS; UCC College of Science, Engineering, and Food Science; and UCC School of Mathematical Sciences.

Report by Cónall Kelly, University College Cork  
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GROUPS IN GALWAY 2025  
15–16 MAY 2025, UNIVERSITY OF GALWAY

Groups in Galway 2025 took place at the University of Galway during 15–16 May 2025. The meeting was organised by Joshua Maglione and Rachel Quinlan. It was supported by the de Brún Centre for Mathematics, the Irish Mathematical Society, and Research Ireland. There were 7 invited speakers and nearly 40 participants. We also held a poster session with about 10 posters on display next to the University of Galway's *Women in Mathematics* poster exhibit.



The conference featured a total of seven invited talks covering a wide range of topics in contemporary group theory and related fields. The speakers were:

Anton Baykalov (University of Galway):

*Imprimitive partial linear spaces and groups of rank 3*

*Abstract:* A partial linear space (PLS) is a point-line incidence structure such that each line is incident with at least two points and each pair of points is incident with at most one line. We say that a PLS is proper if there exists at least one non-collinear point

pair, and at least one line incident with more than two points. The highest degree of symmetry for a proper PLS occurs when the automorphism group  $G$  is transitive on ordered pairs of collinear points, and on ordered pairs of non-collinear points. In this case,  $G$  is a transitive rank 3 group on the points. While the primitive rank 3 PLSs are essentially classified, we present the first substantial classification of a family of imprimitive rank 3 examples. We classify all imprimitive rank 3 proper partial linear spaces such that the rank 3 group is innately transitive (including quasiprimitive cases) or semiprimitive and induces an almost simple group on the unique nontrivial system of imprimitivity. We construct several infinite families of examples and ten individual examples. The examples admit a rank 3 action of a linear or unitary group, and to our knowledge most of our examples have not appeared before in the literature. This is a joint work with Alice Devillers and Cheryl Praeger.

Iker de las Heras (University of the Basque Country):

*Strong conciseness and equationally Noetherian groups*

*Abstract:* The notion of strong conciseness of a group-word extends the classical concept of conciseness from abstract groups to the profinite setting. A word  $w$  is said to be strongly concise in a class  $\mathcal{C}$  of profinite groups if, for any  $G \in \mathcal{C}$ , the cardinality of the set of values taken by  $w$  in  $G$  being strictly smaller than  $2^{\aleph_0}$  implies that the verbal subgroup of  $G$  is finite. In this talk we will study the relation between this notion and the notion of equationally Noetherian groups. These groups arise from the theory of algebraic geometry over groups, which we will develop throughout the talk. As a consequence, we will see that every word is strongly concise in the class of profinite linear groups, as well as in the class of profinite completions of virtually abelian-by-polycyclic groups. This is joint work with Andoni Zozaya.

Brita Nucinkis (Royal Holloway, University of London):

*Cohomological finiteness conditions for topological groups*

*Abstract:* I will give a quick introduction into the classical finiteness conditions  $FP_n$  and  $F_n$  for a discrete group and then explain how to extend these to certain topological groups. The search for discrete groups that are of type  $FP_n$  but not of type  $FP_{n+1}$  has a very interesting and rich history. In this talk will present a new family of discrete and topological groups with this property. This is joint work with I. Castellano, B. Marchionna, and Y. Santos-Rego.

Götz Pfeiffer (University of Galway):

*Reflection groups in the light of formal concept analysis*

*Abstract:* Formal Concept Analysis (FCA) is a branch of applied lattice theory, concerned with the study of concept hierarchies derived from collections of objects and their attributes. Introduced by R. Wille in the 1980s, FCA now has found applications in machine learning and related fields. An application of FCA to hyperplane arrangements yields a new Galois connection on the (conjugacy classes of) parabolic subgroups of a finite reflection group. Combined with methods from Serre's recent work on involution centralizers, we obtain a refinement of Howlett's description of the normalizers of parabolic subgroups of a finite Coxeter group. This is joint work G. Roehrl and J.M. Douglass.

Margherita Piccolo (University of Hagen):

*Representation zeta functions of subgroups and split extensions of  $SL_2^m(\mathcal{O})$*

*Abstract:* The representation growth of a group  $G$  measures the asymptotic distribution of its irreducible representations. Whenever the growth is polynomial, a suitable vehicle for studying it is a Dirichlet generating series called the representation zeta function of  $G$ . One of the key invariants in this context is the abscissa of convergence of the

representation zeta function. The spectrum of all abscissae arising across a given class of groups is of considerable interest and has been studied in some cases. In the realm of  $p$ -adic analytic groups (with perfect Lie algebra), the abscissae of convergence are explicitly known only for groups of small dimensions. But there are interesting asymptotic results for "simple"  $p$ -adic analytic groups of increasing dimension. In this talk, I will give an overview of the main tools and ingredients in this area and I will report on recent work joint with Moritz Petschick to enlarge the class of groups.

Anitha Thillaisundaram (Lund University):

*Normal subgroups of non-torsion multi-EGS groups*

*Abstract:* The family of multi-EGS groups form a natural generalisation of the Grigorchuk-Gupta-Sidki groups, which in turn are well-studied groups acting on rooted trees. Groups acting on rooted trees provided the first explicit examples of infinite finitely generated torsion groups, and since then have established themselves as important infinite groups, with numerous applications within group theory and beyond. Among these groups with the most interesting properties are the so-called regular branch groups. In this talk we investigate the normal subgroups in non-torsion regular branch multi-EGS groups, and we show that the congruence completion of these multi-EGS groups have bounded finite central width. In particular, we prove that the profinite completion of a Fabrykowski-Gupta group has width 2. This is joint work with Benjamin Klopsch.

Gareth Tracey (University of Warwick):

*How many subgroups are there in a finite group?*

*Abstract:* Counting the number of subgroups in a finite group has numerous applications, ranging from enumerating certain classes of finite graphs (up to isomorphism), to counting how many isomorphism classes of finite groups there are of a given order. In this talk, I will discuss the history behind the question; why it is important; and what we currently know.

The conference website contains abstracts of the talks and further information.

Report by Joshua Maglione and Rachel Quinlan, University of Galway  
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4TH IRISH LINEAR ALGEBRA AND MATRIX THEORY MEETING  
 29 APRIL 2025, MARY IMMACULATE COLLEGE

The 4<sup>th</sup> Irish Linear Algebra and Matrix Theory Meeting was organised by Cian O'Brien, and took place over one day in Mary Immaculate College. This meeting has previously taken place in University College Dublin, Maynooth University, and University of Galway, with the aim of bringing together and stimulating the community of linear algebra and matrix theory researchers in Ireland. More than 20 people registered to attend the meeting, and 18 actively participated on the day.

The conference featured nine invited talks, from colleagues across all career stages, covering a wide range of topics in linear algebra and matrix theory:

Patrick Browne (Technological University of the Shannon: Midwest):

*Chord Diagrams and Weight systems*

*Abstract:* In this talk, we explore weight systems in knot theory, i.e. linear functionals on chord diagrams. Chord diagrams, while motivated by singular knots, can be viewed as purely combinatorial objects with rich mathematical structure. The significance of weight systems stems from the fundamental result that every Vassiliev knot invariant

determines and is determined by a weight system. Moreover, Lie algebras provide a powerful framework for constructing these weight systems.

This presentation will introduce the connection between chord diagrams, weight systems, and Lie theory. We'll explore this interplay as preliminary research that may reveal new insights into both knot theory and combinatorial structures. The talk will be accessible to those without specialized background in knot theory or Lie algebras, focusing on the connections between these objects.



Niall Madden (University of Galway):

*Enriched FEMs: Stability and Fast Solvers*

*Abstract:* Finite Element Methods produce linear systems of equations which, when solved, yield numerical solutions to differential equations. The stability and efficiency of the FEMs depend on properties of the system matrix.

In this talk I'll outline a strategy for enriching the finite dimensional space on which the FEM is posed in order to improve accuracy, but the main focus will be on the surreptitious impact this has on the system matrix in terms of stability (in an  $M$ -matrix type way) and factorizability of the system matrix.

Arani Paul (University College Dublin):

*Code Equivalence and Conductors*

*Abstract:* Code Equivalence Problems (CEPs) have been discussed and studied for a long time not only for their importance in cryptography and cyber-security, but also because they connect to different areas of mathematics such as the Graph Isomorphism Problems and the Tensor Isomorphism Problems. This talk is particularly focused on the CEP for vector rank metric codes. Although rank metric codes have not been studied as extensively as Hamming metric codes, it has become an important topic of research in recent decades because of its applications in numerous sectors of modern-day digital technology.

Here we give a brief introduction to CEP in vector rank metric codes and discuss a way to classify all the equivalence classes of codes for given parameters. The key

concepts are classical objects from linear and abstract algebra, namely conductors and idealisers. We will discuss practical implementations of classification algorithms, and discuss possible future directions.

Rachel Quinlan (University of Galway):

*Idempotent Alternating Sign Matrices*

*Abstract:* An alternating sign matrix (ASM) is a square  $(0, 1, -1)$ -matrix in which the nonzero entries alternate between 1 and  $-1$  and sum to 1, within each row and column. Permutation matrices are examples of ASMs, and ASMs generalize permutation matrices in several apparently natural but unexpected ways. Every multiplicative group of nonsingular ASMs is a group of permutation matrices, but the set of all ASMs of size  $n \times n$  also contains multiplicative groups of singular matrices. The identity element  $E$  of such a group is an idempotent ASM, it is equal to its own square. In this talk we will discuss some methods for construction of idempotent ASMs, and identify the minimum rank of an idempotent ASM of specified size.

Padraig Ó Catháin (Dublin City University):

*Matrices with Specified Automorphisms*

*Abstract:* Combinatorial structures such as strongly regular graphs and projective planes are encoded as incidence matrices, which often have interesting linear algebraic properties. Non-existence results are obtained via algebraic arguments. E.g. the Bruck-Ryser-Chowla theorem gives non-obvious necessary conditions for existence of symmetric designs based on equivalence of quadratic forms, and many non-existence results for difference sets boil down to showing that the eigenvalues of an associated matrix must be norms in a suitable number field.

In this talk, I will discuss (constructive) existence of such matrices, under the assumption of a suitable group of automorphisms. This theory is well known for graphs (i.e. symmetric  $\{0, 1\}$ -matrices) but rather more subtle when the matrix contains  $k^{\text{th}}$  roots of unity. In fact, one can construct an explicit basis for the set of all matrices invariant under a given group representation, and construct the eigenvalues of a given invariant matrix in terms of character sums. Time permitting, I will show how to use these methods to build new complex Hadamard matrices.

Helena Šmigoc (University College Dublin):

*Arbitrarily Finely Divisible Stochastic Matrices*

*Abstract:* We will consider the class arbitrarily finely divisible stochastic matrices ( $AFD_+$ -matrices): stochastic matrices that have a stochastic  $c^{\text{th}}$  root for infinitely many natural numbers  $c$ . This notion generalises the class of embeddable stochastic matrices. In particular, if  $A$  is a transition matrix for a Markov process over some time period, then arbitrary finely divisibility of  $A$  inside the set of stochastic matrices is the necessary and sufficient condition for the existence of a transition matrix corresponding to this Markov process over infinitesimally short periods.

We will explore the connection between the spectral properties of an  $AFD_+$ -matrix  $A$  and the spectral properties of a limit point  $L$  of its stochastic roots. We will demonstrate a construction of a class of  $AFD_+$ -matrices with a given limit point  $L$  from embeddable matrices, and examine specific cases, including  $2 \times 2$  matrices,  $3 \times 3$  circulant matrices, and offer a complete characterisation of  $AFD_+$ -matrices of rank-two.

Badriah Safarji (University of Galway):

*Rank Distributions of Matrix Representations of Graphs Over  $F_2$*

*Abstract:* Over a finite field, the number of  $n \times n$  matrices of rank  $r$  typically increases as  $r$  increases,  $0 \leq r \leq n$ . However, over the field of two elements  $F$ , the most frequently occurring rank is not  $n$  but  $n - 1$ . The numbers of symmetric  $F$ -matrices of rank  $n$  and

$n - 1$  coincide if  $n$  is odd and differ marginally if  $n$  is even. This opens the door to a more thorough investigation of the distribution of the matrix ranks over the field of two elements.

Let  $\Gamma$  be a simple undirected graph. A symmetric matrix  $M$  with entries in a field represents  $\Gamma$  if the off-diagonal entries of  $M$  correspond to edges of  $\Gamma$  in the sense that the  $(i, j)$ -entry of  $M$  is non-zero if and only if vertex  $i$  and vertex  $j$  are adjacent in  $\Gamma$ . The diagonal entries of  $M$  are not subject to any constraints, and therefore there are many matrices representing  $\Gamma$  over the field. This project aims to identify and characterize simple connected graphs of order  $n$  with more  $F$ -matrix representations of rank  $n - 1$  than rank  $n$ , a property rare over other finite fields. We restrict our attention to graphs of order  $n \geq 3$  with an induced subgraph isomorphic to the path on  $n - 1$  vertices. This talk will present results on the rank distributions of matrix representations of such graphs over  $F$ .

Bernard Hanzon (University College Cork):

*Parametrization of Stable Multivariable Systems: Pivot Structures and Numbered Young Diagrams*

*Abstract:* In this presentation we show how stable linear multivariable systems can be parametrized using orthogonal  $m$ -upper  $(m + n) \times (m + n)$  Hessenberg matrices, where  $m$  stands for the number of inputs and  $n$  for the order of the system. To make sure all systems are covered by the parametrization certain column permutations of the Hessenberg matrix will be utilized. The lower part of the permuted ( $m$ -upper) Hessenberg matrix will give the pair  $[B; A]$ ; where  $(A; B)$  is the controllable pair of the system in state space form. Advantages of this approach to parametrization of stable linear systems will be discussed.

Cian O'Brien (Mary Immaculate College):

*The Bruhat Order for Latin Squares*

*Abstract:* Alternating sign matrices arise naturally as a generalisation of permutation matrices in a number of different contexts. For example, they are the unique minimal lattice extension of the permutation matrices under the Bruhat order. In 2018, Brualdi and Dahl defined alternating sign hypermatrices, a 3-dimensional analogue of alternating sign matrices. Latin squares can be thought of as the 3-dimensional analogue of permutation matrices, since the positions of each of the  $n$  symbols in an  $n \times n$  Latin square correspond to the non-zero entries in some  $n \times n$  permutation matrix.

We have extended this idea further, by defining the Bruhat order for Latin squares and studying the resulting poset. This talk presents current work relating to this poset, including 3-dimensional analogues of related combinatorial objects, and a lattice extension of the Latin square poset.

The conference website contains further information.

Report by Cian O'Brien, Mary Immaculate College  
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WORKSHOP ON NUMERICAL METHODS FOR PROBLEMS WITH LAYER PHENOMENA  
24–25 APRIL 2025, UNIVERSITY OF GALWAY

The *Workshop on Numerical Methods for Problems with Layer Phenomena* is an annual international workshop focusing on mathematical and numerical aspects of differential equations whose solutions feature boundary or interior layers, such as singularly perturbed problems. Though commonly called 'The Limerick Workshop', recent iterations have

been hosted in University of Cyprus (twice), Universidad de Sevilla, University of Limerick (online), Fern Universität in Hagen, and Charles University.

The 21<sup>st</sup> instance of the workshop was hosted at the University of Galway on 24–25 April 2025. It was organised by Niall Madden, Nanda Poddar, Jekaterina Mosalska, and Seán Tobin. There were twenty in-person participants, with another twenty joining for a special online session. Financial and organisational support was provided by the Irish Mathematical Society, and the School of Mathematical and Statistical Sciences, University of Galway.



The workshop featured fourteen research talks:

- Christos Xenophonos (Cyprus). *On the decomposition of the solution to reaction-diffusion two-point boundary value problems with data of finite regularity.*
- Alex Trenam (Heriot-Watt). *Nodally bound-preserving discontinuous Galerkin methods for charge transport.*
- Seán Kelly (Limerick). *Pointwise-in-time error bounds for a fractional-derivative parabolic problem on quasi-graded meshes.*
- Neofytos Neofytou (Cyprus). *rp-DG FEM for fourth order singularly perturbed problems with two small parameters.*
- Christos Pervolianakis (Jena). *A Stabilized Scheme for an Optimal Control Problem Governed by Convection-Diffusion-Reaction Equation.*
- Nanda Poddar (Galway). *Interplay of Dynamic Boundary Absorption and Layer-like Phenomena in Reactive Solute Transport: A Dual Numerical Approach.*
- Jenny Power (Bath). *Adaptive Regularisation for PDE-Constrained Optimal Control.*
- Niall Madden (Galway). *A tutorial on solving singularly perturbed problems in Firedrake.*
- Marwa Zainelabdeen (Berlin). *Gradient-robust finite element–finite volume scheme for the compressible Stokes equations.*
- Alan F. Hegarty (Limerick). *Novel meshes for the solution of a problem with interior parabolic layers.*
- Katherine MacKenzie (Strathclyde). *The Bound Preserving Method applied to the 2D Induction Heating Problem.*
- Natalia Kopteva (Limerick). *A posteriori error estimation for convection-diffusion equations.*
- Sebastian Franz (Dresden). *On a posteriori estimation in the energy norm for convection-diffusion problems.*

In addition, Martin Stynes (Beijing) gave a short talk, on Zoom, remembering Lutz Tobiska (Magdeburg), a major figure in the numerical analysis of singularly perturbed problems, who passed away a few weeks earlier.

The conference website contains abstracts of the talks and further information.

Report by Niall Madden, University of Galway  
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LMS HARMONIC ANALYSIS AND PDE NETWORK MEETING  
1 MAY 2025, UNIVERSITY COLLEGE CORK

The meeting was organised by Tom Carroll and Spyros Dendrinos (both from University College Cork). The meeting took place fully in person.

The meeting featured a total of four invited talks covering a range of topics in harmonic analysis, complex analysis and differential equations:

Joaquim Ortega-Cerdà (Universitat de Barcelona):

*The Hörmander-Bernhardsson extremal function*

*Abstract:* We characterize the function  $\varphi$  of minimal  $L^1$  norm among all functions  $f$  of exponential type at most  $\pi$  for which  $f(0) = 1$ . This function, studied by Hörmander and Bernhardsson in 1993, has only real zeros  $\pm\tau_n, n = 1, 2, \dots$ . We identify  $\varphi$  in the following way. We factor  $\varphi(z)$  as  $\Phi(z)\Phi(-z)$ , and show that  $\Phi$  satisfies a certain second order linear differential equation along with a functional equation, either of which characterizes  $\Phi$ . Furthermore, we use these facts to establish a series expansion for the zeros and a power series expansion of the Fourier transform of  $\varphi$ , as suggested by the numerical work of Hörmander and Bernhardsson. The dual characterization of  $\Phi$  arises from a commutation relation that holds more generally for a two-parameter family of differential operators, a fact that is used to perform high precision numerical computations.

This is joint work with Andriy Bondarenko, Danylo Radchenko and Kristian Seip.  
Link to arXiv

Stefan Buschenhenke (Universität zu Kiel):

*Maximal operators for two-dimensional surfaces of finite type and FIO-cone multipliers*

*Abstract:* We report on joint work with Spyros Dendrinos, Isroil Ikromov and Detlef Müller on a new class of ‘FIO-cone multipliers’. In previous work, we studied the boundedness range of the maximal average of any smooth compact hypersurface in three-dimensional space, up to a certain “exceptional class”, which is linked to the cone multiplier. We encounter a convolution operator, being the composition of two operators: the classic cone multiplier and additionally a certain translation invariant Fourier integral operator (FIO) with non-standard phase functions with singularities near the light cone. We develop a new theory for a class of these “FIO-cone multipliers”, that allows phase functions that are in a particular way adapted to the geometry of the cone. Our approach uses the recent breakthrough for the cone multiplier conjecture by Guth, Wang and Zhang.

Myrto Manolaki (University College Dublin):

*Boundary behaviour of holomorphic and harmonic functions*

*Abstract:* The study of the boundary behaviour of holomorphic and harmonic functions is of significant importance in many areas in Analysis. In this talk I will present an overview of my research on this topic, focusing on two theorems which complement and strengthen some classical results. The first one concerns Abel’s Limit Theorem, which

connects the behaviour of a Taylor series as we approach the boundary from the interior with its behaviour on the boundary itself. The second one strengthens Plessner's and Spencer's theorems about the angular behaviour of holomorphic functions on the unit disc. Moreover, its harmonic analogue in higher dimensions improves classical results of Stein and Carleson. As we will see, these two theorems, which are based on a variety of tools from potential theory, find applications to certain classes of holomorphic functions with wild boundary behaviour. (Based on joint works with Stephen Gardiner, Stéphane Charpentier and Konstantinos Maronikolakis.)

Itamar Oliveira (University of Birmingham):

*A phase-space approach to weighted Fourier extension inequalities*

*Abstract:* The goal of the talk is to present a certain ray bundle representation of the Fourier extension operator in terms of the Wigner transform to investigate weighted estimates in restriction theory and their connections to time-frequency analysis and geometric combinatorics.

In joint work with Bennett, Gutierrez and Nakamura, we show how Sobolev estimates for the Wigner transform can be converted into certain tomographic bounds for the Fourier extension operator, which implies a variant of the (recently shown by H. Cairo to be false) Mizohata-Takeuchi conjecture. Together with Bez and the previous three authors, we employed our phase-space approach in the context of Strichartz inequalities for orthonormal systems in the spirit of the work of Frank and Sabin. If time allows, we will make a further connection between our results and Flandrin's conjecture in signal processing through the study of certain singular integral operators similar to those studied by Lacey, Lie, Muscalu, Tao and Thiele.

The meeting website contains further information. The meeting was also funded by Scheme 3 of the London Mathematical Society and the School of Mathematical Sciences (UCC).

Report by Spyros Dendrinos, University College Cork  
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IMS & IRISH SIAM STUDENT CHAPTER CONFERENCE 2025  
9 MAY 2025, UNIVERSITY OF LIMERICK

On 9<sup>th</sup> May, the University of Limerick hosted the IMS & Irish SIAM Student Chapter Conference, welcoming over 40 applied mathematicians from industry and academia alike. Originally scheduled to take place in January 2025, the 10<sup>th</sup> edition of the conference had to be postponed on account of Storm Éowyn. Thankfully, the delay did not dampen the enthusiasm of the participants, who filled the large lecture hall in the Analog Devices Building to listen to two keynote lectures and 11 contributed presentations. A poster session also took place, providing students with an opportunity to present their research to an audience of their peers in a friendly, relaxed atmosphere.

The day opened with remarks from Dr. Doireann O'Kiely, followed by a keynote lecture by Dr. Niall Madden. In his presentation, Dr. Madden described the use of numerical methods in disparate fields such as tidal modelling and preventing aortic aneurysms. The variety of his work drew several thought-provoking questions from a rapt audience. After lunch, the second keynote lecture was delivered by Orla Fitzmaurice, a recent Mathematical Sciences graduate of UL, now working with Analog Devices. Her presentation gave an insight into the various ways large language models were being implemented into Analog Devices' engineering workflows. In addition to outlining the various advantages of large language models, Orla also gave an overview of the challenges in benchmarking the performance of these models.



Following a full conference programme, the organising committee had the difficult decision of choosing the best speaker. After much deliberation, the award was presented to Emmet Lawless for his presentation “A variational approach to portfolio choice”, applying methods in control theory to a financial planning problem. Once the conference was brought to a close, a dinner was held in the Pavilion on the UL North Campus. Here, the conference participants had a chance to mix and mingle, forging connections and fostering collaborations among a promising group of early-career researchers.

The conference was a resounding success from start to finish, showcasing the impressive breadth and depth of applied mathematics research taking place at Irish universities. The organising committee are very grateful to SIAM, Analog Devices, the Irish Mathematical Society and also the UL Department of Mathematics and Statistics for their generous financial support. Going forward, the conference will hopefully continue to be a mainstay of the Irish mathematical calendar as an event run by students, for students.

The following speakers contributed talks to the conference programme:

- (1) Dr. Anthony Bonfils (University of Limerick)
- (2) Lorenzo Pisani (Dublin City University)
- (3) Lyudmila Ivanova (Technological University Dublin)
- (4) Daire O’Donovan (University College Dublin)
- (5) TJ O’Brien (University College Dublin)
- (6) Evan Murphy (Dublin City University)
- (7) Emmet Lawless (Dublin City University)
- (8) Jack Cromwell (Dublin City University)
- (9) Ole Cañadas (Dublin City University)
- (10) Julius Busse (University College Dublin)
- (11) Daniel Devine (Trinity College Dublin)

Titles and abstracts of keynote lectures and contributed talks:

Dr. Niall Madden:

*Numerical modelling of solute transport in oscillatory flow, and other things*

*Abstract:* In this talk I'll discuss some recent work on numerical modelling of solute transport in an oscillatory flow. The physical system features particles that are released at a point in a channel bounded above and below by plates. Particles encountering the plates may be either reflected or absorbed. The main focus on the talk will be on how the scenario can be modelled numerically, including

- comparison between numerical models based on classical finite differences and Brownian Dynamic Simulation;
- a discussion on how numerical results might be validated;
- how the numerical modelling process can inform the mathematical model.

Along the way, there will be discussion of how numerical computing (and numerical analysis) can be of value in projects as diverse as modelling Galway Bay, predicting aortic aneurysms, and reducing the reliance on animal testing in testing therapies in ICU settings.

Orla Fitzmaurice:

*Generative AI in Practice: Retrieval Augmented Generation and Evaluation Challenges*

*Abstract:* Orla Fitzmaurice graduated from the University of Limerick with a Bachelor of Science in Mathematical Sciences with Statistics in August 2024 and works at Analog Devices in Limerick as a graduate Machine Learning Engineer. Her current work focuses on evaluating application specific Generative AI systems being developed by her team.

Generative AI has revolutionized numerous domains, enabling applications ranging from creative writing to technical problem-solving. Large Language Models (LLMs), a subset of generative AI, are designed to produce natural language output by learning patterns and structures from massive datasets of unlabelled text. Generative Pre-trained Transformers (GPTs) power widely used systems like OpenAI's ChatGPT and Microsoft's Copilot. However, retraining these models to incorporate up-to-date information is time and resource intensive. Retrieval-Augmented Generation (RAG) offers an innovative solution by integrating LLMs with external, domain-specific datasets. RAG can be used as a question-answering based system, it employs prompt engineering and vector search to deliver tailored answers, grounded in truth, without exhaustive retraining.

Despite significant progress in LLM capabilities, the field suffers from notable deficiencies in standardised model evaluation and reporting practices. Ragas is one example of a framework designed to evaluate RAG systems. Ragas employs an evaluation LLM to assess a target model's performance against a dataset of human-verified ground truths. Ragas provides several metrics that allow the user to determine areas where the LLM is not performing as expected. Model evaluation is often conducted without leveraging robust experimental methodologies that have been well established in other scientific disciplines. Current literature frequently reports with a "highest number is best" approach rather than testing for significant results. This presentation will explore the foundational technologies of LLMs and RAG, while examining limitations in LLM evaluation practices.

Dr. Anthony Bonfils:

*Finite length and boundary effects in the mode selection of a floating elastic sheet*

*Abstract:* Leave me free, I buckle.

Give me a support, I wrinkle.

Pinned, I am trigonometric.

Clamped, I am eclectic.

My asymptotic analysis will make you tumble.

Lorenzo Pisani:

*Quantum effects in black holes*

*Abstract:* The search for a quantum gravity theory is widely regarded as one of the most significant challenges in fundamental physics. While several candidate theories have been proposed, there is no consensus amongst theorists. There are, however, robust and uncontroversial approximations to quantum gravity. One such approximation is semiclassical gravity, which describes the interaction of quantum fields with a classical spacetime metric.

In this framework, the stress-energy tensor, which accounts for the presence of matter in the classical equations, is replaced by its quantum equivalent: a (formally) divergent operator known as the expectation value of the stress-energy tensor of a quantum field in a quantum state. The process of renormalization involves systematically removing the divergence to isolate the physical state-dependent component, which is known as the renormalized stress-energy tensor (RSET). The renormalization procedure is very complicated in black holes spacetimes and practical schemes were only developed in recent years.

We present a mode-sum prescription to directly compute the RSET for scalar fields in the Boulware vacuum state. The method generalizes the recently developed extended coordinate method which was previously only applicable to Hartle-Hawking states and enables the study of semiclassical effects in spacetimes without such states, including extremal black holes and stellar spacetimes.

We demonstrate the accuracy and efficiency of the method by calculating the RSET in both sub-extremal and extremal Reissner-Nordström spacetimes, finding numerical evidence for the regularity of the RSET at the extremal horizon regardless of the field mass or coupling. In addition, we compute the semiclassical backreaction on the background metric by employing the numerical results obtained for the RSET to source the static semiclassical Einstein equations. Our results indicate that extremal horizons are unstable under quantum perturbations: if the RSET is considered as a static perturbation, it will either de-extremalize the black hole or convert it into a horizonless object.

The development of this methodology opens a window to computing semiclassical backreaction in previously unexplored scenarios, particularly in stellar spacetimes.

This talk is based on:

J. Arrechea et al., PhysRevD.111.085009

Lyudmila Ivanova:

*Nonlinear Hamiltonian Models for Propagation of Intermediate Internal Ocean Waves in the Presence of Currents*

*Abstract:* A two-dimensional water wave system is examined with two layers separated by a free common interface. The fluids are incompressible and inviscid. The system consists of a lower medium, bounded below by a flatbed, and an upper medium with a free surface, where wind-generated surface waves occur. However, we consider the flat surface approximation, based on the assumption that surface waves have negligible amplitude. In a geophysical context, this represents a model of an internal wave formed within a pycnocline or thermocline in the ocean. In addition, a current profile with depth-dependent currents in each domain is considered. An example of the physical situation described above is clearly illustrated by the equatorial internal waves in the presence of the Equatorial Undercurrent (EUC). We consider wave propagation in the so-called intermediate long wave approximation, where the wavelength is comparable to the depth of the lower layer, which in turn is much shallower than the upper layer. The study is based on the Hamiltonian approach. The equations of motion are formulated as a Hamiltonian system, and the Hamiltonian is determined and expressed in terms of

canonical wave-related variables. A specific scaling is chosen, which leads to the integrable Intermediate Long Wave Equation (ILWE). The limiting behavior is investigated, and connections with other known models are established.

Daire O’Donovan:

*Achieving Optimal Locomotion using Self-Generated Waves*

*Abstract:* Horizontal locomotion of a body on the fluid surface can be achieved by interacting with self-generated waves via a vertical bobbing motion. Mathematically, this can be interpreted as a pressure source acting on the surface. To study the conditions for maximal thrust in a chosen direction, an optimal control problem can be posed, where the pressure source is the control and the thrust force is the objective. A bound is then applied to the control to regularise the problem. The work is split into two parts given two different bounds, firstly the norm of the control function, and secondly the power, which is derived from the rate of change of the energy. To begin this work, the problem is reduced to the shallow limit. Given the assumption that the pressure source is periodic, an analytical approach can be taken with variational calculus. Numerical optimisation can be carried out to calculate the optimal pressure given a constraint and can be shown to match the analytical solution, which corresponds with emitting a wave purely in the direction opposite to movement.

TJ O’Brien:

*Shell Spacing in GOY-Like Shell Models of Turbulence*

*Abstract:* The Gledzer-Ohkitani-Yamada (GOY) model and its improvement by L’vov et al., the Sabra model, have proved useful in modelling energy cascades in two and three dimensional turbulence. These models are widely used in the literature. However, they are not the only model equations that can be constructed as “improvements” of the GOY model.

First, by revisiting the derivation of the Sabra model, we propose two new model equations based on the GOY and Sabra modelling paradigm. Two heuristic approaches to generate the new equations are presented. These new equations satisfy the same properties of conservation of two quadratic invariants and of phase symmetries, with only slight variations in structure and behaviour. Collectively, these four model equations form what could be considered the class of ‘GOY-Like’ shell models.

$$\frac{d}{dt} \sum_n |u_n|^2 \propto \begin{cases} \sum_n k_n \Im(\overline{u_{n-1} u_n u_{n-2}}) \\ \sum_n k_n \Im(\overline{u_{n-1} u_n u_{n-2}}) \\ \sum_n k_n \Im(\overline{u_{n-1} u_n \overline{u_{n-2}}}) \\ \sum_n k_n \Im(u_{n-1} \overline{u_n u_{n-2}}) \end{cases}$$

Second, we explore the differences within the class under the assumptions of three dimensional helicity-preserving turbulence. We begin with a review of the phase symmetries and their implication. Next, a general form for the flux formula is analysed. Then, recalling that the shell wavenumber is given in terms of the shell spacing  $\lambda$  by  $k_n = k_0 \lambda^n$ , we compare the models with  $\lambda = \mu$  and  $\lambda = 1/\mu$ , with  $\mu > 1$  fixed. This leads to mappings between our GOY-Like models. Certain mappings go from one model to another in the class with reciprocal spacing, indicating that a projection from the typical spacing regime used in literature  $\lambda \in (1, \infty)$  to the bounded interval  $\lambda \in (0, 1)$  is possible. This amounts to ‘flipping’ the shell index, where the model then starts with a defined smallest spatial scale at index 0 and grows to large scales as index increases.

Finally, an exploration of the class’ behaviour under various shell spacings is conducted. Due to the role of the triangle inequality with respect to a shell model’s relation to Navier-Stokes turbulence we focus on the Golden Ratio  $\Phi \approx 1.618$  and its reciprocal

$\Phi^{-1} \approx 0.618$ . Discussion of other spacings, such as the literature standard ratio  $\lambda = 2$ , is done in comparison to the former. Additionally, the behaviour of the equations in the limit  $\lambda \rightarrow 1$  is briefly explored.

Evan Murphy:

*A Stochastic Birth-and-Death Approach for Street Furniture Detection in Urban Environments*

*Abstract:* Urban environments are evolving rapidly, and efficient city planning requires accurate and up-to-date information about public spaces. Comprehensive mapping of street assets role in shaping the urban landscape, and enhancing quality-of-life and accessibility in cities. This work aims to contribute to the problem of autonomously maintaining up-to-date data regarding the location, condition, and distribution of these assets.

Existing segmentation modules (such as those discussed in [1]) have proven effective for the extraction of objects from street-view imagery, and providing estimates for camera-to-object distance, bearing, and a measure of confidence. This new work builds upon the model described in [1], wherein pairwise intersections between rays originating from camera positions are considered as favourable candidates for object positions, and form the solution space for a boolean optimisation problem (OP). The solution of the OP is subject to clustering, giving a good prediction for the ground truth object locations.

The alternative strategy considered in this work is to build a configuration of objects by considering a stochastic birth and death (SBD) process [2] led by an energy function that will be constructed from static data terms, and an interaction term. This process models objects as a 2D-coordinate, with a radius  $r$ , defining an area of exclusivity. To each pixel in a rendering of the target area, a data energy is assigned, comprising of four terms. The first two terms relate to the detection confidence and depth consistency of nearby pairwise intersections, while the third term penalises clashes with existing infrastructure. The final data energy term is proportional to the radius of the point, penalising “greedy” objects. The data energy of a spawned object is then the sum of all pixels covered by a disc of radius  $r$  around the chosen coordinate. An object interaction term is also included, introducing a penalty proportional to the area of overlap between two generated objects. The goal of this approach is to find a configuration of minimal energy, representing the most favourable object locations. Joint work with Vladimir Krylov and Marco Viola.

### References

- (1) Krylov, V.A., Kenny, E. and Dahyot, R., 2018. Automatic discovery and geotagging of objects from street view imagery. *Remote Sensing*, 10(5), p. 661.
- (2) Descombes, X., Minlos, R. and Zhizhina, E., 2009. Object extraction using a stochastic birth-and-death dynamics in continuum. *Journal of Mathematical Imaging and Vision*, 33 (3), pp.347-359.

Emmet Lawless:

*A variational approach to portfolio choice*

*Abstract:* In this talk we propose a calculus of variations approach to a popular stochastic control problem in finance. Stochastic control can be summarised as a field wherein one tries to solve an optimisation problem that depends on an underlying stochastic process which you can partially control. We focus on the financial planning problem which consists of a single economic agent who has to choose an investment and consumption policy which maximises her expected utility from consumption subject to certain risk preferences. The agent may choose to invest in risky assets (for example the stock market) or a safe asset (for instance a government bond or a bank account) and simultaneously choose a consumption policy which covers required spending. This is the classical

problem faced by pension schemes and financial planners to ensure future financial security for their policy holders.

The main tool used to solve this problem is the so called dynamic programming approach which reduces the infinite dimensional stochastic problem to the study of a (in general) non linear differential equation (DE). This approach although very useful can often times be unsatisfactory as the resulting DE is difficult to analyse. We propose a novel approach to this problem by proving it can be solved by considering a deterministic calculus of variations problem. This circumvents the need to analytically (or numerically) solve the associated DE. This method provides a new set of mathematical tools to analyse such problems and highlights how certain stationary stochastic control problems can be solved via deterministic methods.

This work is part of a joint project with Paolo Guasoni and Ho Man Tai.

Jack Cromwell:

*Central Limit Theorem for Random Variables Under Constraints*

*Abstract:* We study sequences of random variables whose joint distribution is supported on constrained surfaces defined by relations  $\sum_{j=1}^n V_j(X_j) = na$ , with general functions  $V_j$ . These include hard constraints, such as confining vectors to spheres or ellipsoids. These constraints induce dependency among the random variables and cause them to be non-identically distributed. We develop Central Limit Theorem results on these random variables under Lindeberg conditions tailored to the geometry of the constraint.

Ole Cañadas:

*A Class of Mathematical Models for Highly Fluctuating and Random Real World Phenomena*

*Abstract:* Modelling real-world phenomena using mathematical methods and addressing related questions, such as optimal strategies or asymptotic behaviour, has been the focus of mathematicians for decades. Examples include population growth/decline, the optimal route for a salesman, and the efficient distribution of goods in containers. Additionally, the mathematical community has agreed that certain events, like stock prices or weather patterns, should be modelled using methods that incorporate randomness. This is typically done using Itô's classical stochastic calculus, a tool that is nowadays well understood.

However, recent empirical studies of financial and commodity market data suggest that volatility (i.e., price fluctuations) varies more than can be captured by Itô's stochastic calculus. As a result, there has been growing interest in tools that go beyond this classical machinery, such as the theory of rough paths and stochastic Volterra processes. Unfortunately, these tools are thus far not fully understood, leaving many theoretical questions unanswered, such as those regarding monotonicity and long-term behaviour which are essential for developing a robust statistical framework. In this talk, we focus on particular dynamics given in terms of stochastic Volterra processes and present recent results such as comparison principles, limiting distributions, law-of-large numbers, central limit theorem and cut-off phenomena.

This talk is based on joint works in progress with Mohamed Ben Alaya (Rouen University), Luigi Amedeo Bianchi, Stefano Bonaccorsi (both Trento University) and Martin Friesen (DCU).

Julius Busse:

*Modelling the spread of particulate pollution in the ocean*

*Abstract:* We explore the influence of the Stokes number, the Stokes drift, and noise (diffusion) on the advection of particles advected by irrotational water waves. We follow a Lagrangian model of particle dynamics, describing the positions of individual particles as governed by a randomly perturbed advection equation.

We ask if adding small-scale turbulence in the finite depth water column increases the transport distance of particles and quantify it. We consider multiple models for turbulence in order to quantify the distance travelled from the initial position where a particle is released to the point where it settles on the seabed.

Simulating the stochastic differential equation (SDE)

$$\begin{aligned}\frac{\partial \mathbf{v}}{\partial t} &= \frac{1}{t_p}(\mathbf{u} - \mathbf{v} - \nu_T \mathbf{e}_z), \\ \frac{\partial \mathbf{x}}{\partial t} &= \mathbf{v} + \sigma W'(t), \text{ where} \\ \mathbf{u} &= \frac{a\omega}{\sinh(kh)} \begin{pmatrix} \cosh(k(z+h)) \cos(kx - \omega t) \\ \sinh(k(z+h)) \sin(kx - \omega t) \end{pmatrix},\end{aligned}$$

with  $\mathbf{x}(t=0) = \mathbf{v}(t=0) = \mathbf{0}$  shows that with increased diffusion (realised as an increased noise coefficient  $a$ ), the mean advection of the particles increases. We seek to quantify this relationship and provide an analytical framework for it by transforming it into a deterministic advection-diffusion like equation using the Fokker–Planck equation. This allows considering diffusion coefficients that depend on the concentration.

Daniel Devine:

*Existence and Convergence Results for a System of PDEs*

*Abstract:* In this talk, we will discuss a nonlinear elliptic system of PDEs which has its origins in the study of the dynamics of viscous, heat-conducting fluids. To model viscous heating effects, the system of interest contains source terms with a nonlinear gradient dependence, which presents considerable theoretical challenges. By restricting our attention to solutions which are radially symmetric, the problem becomes far more mathematically tractable. To begin, we will outline some of the progress made since the early 2000s, and then move onto some more recent results. In particular, we will see that all solutions converge monotonically to an explicit solution which we can easily calculate. This talk is based on results jointly obtained with Paschalis Karageorgis, and results jointly obtained with Gurpreet Singh.

The following University of Limerick students presented posters:

- (1) Tiernan Brosnan: *Microlocal Analysis of ISAR Imaging*
- (2) Jessica Crosse: *Stable local determination of a complex anisotropic conductivity of a medium at the boundary*
- (3) Niall Donlon: *Stable Reconstruction of Anisotropic Conductivity in Biological Tissue*
- (4) Attiq Iqbal: *Mathematical modelling of drug release from tablets*
- (5) Eamonn Organ: *Learning from the weather – A spatial statistics viewpoint*
- (6) Mitchell Rae: *Comprehensive Machine Learning Approaches to Modelling State of Charge for LiBs*

The conference website hosts a digital copy of the conference booklet and further information about the event programme and sponsors.

Report by Ben McKeon, University of Limerick

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RIA-ICEDIM WOMEN IN THE MATHEMATICAL SCIENCES DAY  
12 MAY 2025, UNIVERSITY OF GALWAY

The 2025 Women in The Mathematical Sciences Day Conference was hosted by the School of Mathematical and Statistical Sciences, University of Galway, on May 12<sup>th</sup>.

It was organised by the Royal Irish Academy’s Physical, Chemical and Mathematical Sciences committee, and the Irish Committee for Equality, Diversity, and Inclusion in Mathematics (ICEDIM). The event included plenary talks, a poster session, and public talks.

Just over 60 participants attended the conference. They were welcomed by Prof. Cathal Seoighe, Head of the School of Mathematical and Statistical Sciences, University of Galway. Opening remarks were provided by Dr Helen Maher (Vice-President for Equality Diversity and Inclusion, University of Galway), and Prof. Louise Allcock (Member of the Royal Irish Academy, and Professor in Zoology).



FIGURE 1. Participants at the 2025 RIA-ICEDIM Women in The Mathematical Sciences Day Conference

The conference speakers were Nicola Fitz-Simon (University of Galway), Róisín Neurer (University College Dublin), Doireann O’Kiely (University of Limerick), Margherita Piccolo (University of Hagen, Germany), and Myrto Manolaki (University College Dublin); abstracts are provided below.

A novel aspect of the 2025 edition of the conference was the inclusion of public talks, which were given by Victoria Sánchez Muñoz (Université Libre de Bruxelles), and attended by over 100 second-level students.

The local organisers were Nina Snigireva and Niall Madden. Financial and organisational support was provided by the Royal Irish Academy, the Irish Mathematical Society, The School of Mathematical and Statistical Sciences of University of Galway, the University of Limerick and, in particular, by Fionnuala Parfrey (RIA) and Romina Gaburro (University of Limerick, Vice-Chair, RIA Physical, Chemical and Mathematical Sciences committee).

### **Titles and Abstracts**

Nicola Fitz-Simon:

*Using Statistical Models for Small Area Estimation*

*Abstract:* As an applied statistician, I have worked on many studies that combine data and statistical models to aid decision making, especially in the area of human health. I am currently working on a project for the World Health Organization to estimate risk factors related to diabetes at small area level – for example high blood pressure, smoking, diet, physical activity, overweight and alcohol. The WHO collects data that are designed to provide national estimates of the prevalences of these risk factors. However they also want to use the data to help them see the spatial patterns of risk across the country to

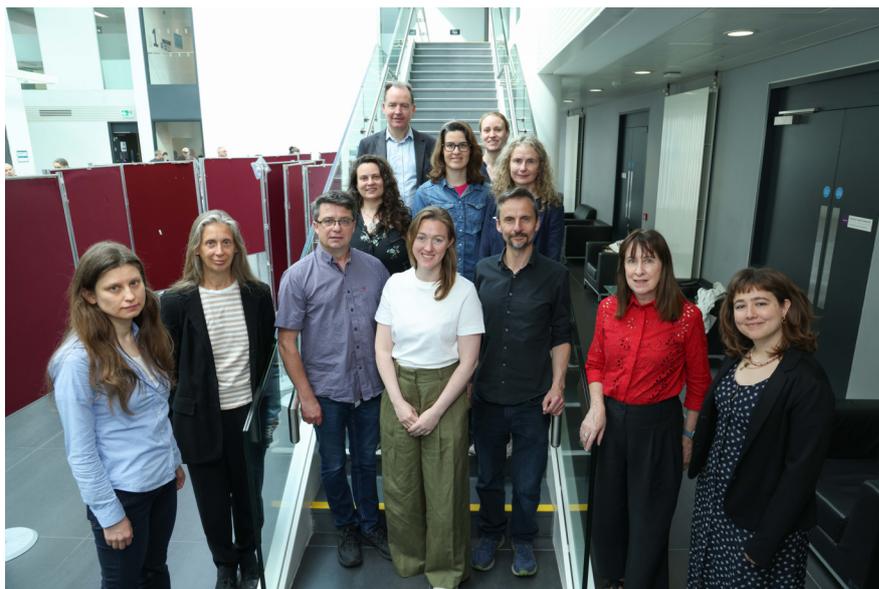


FIGURE 2. Speakers and Organisers. Front Row L-R: Nina Snigireva, Louise Alcock MRIA, Niall Madden, Róisín Neururer, Cathal Seoighe, Helen Maher, Margherita Piccolo Middle Row L-R: Myrto Manolaki, Victoria Sánchez Muñoz, Nicola Fitz-Simon Back Row L-R: Leo Creedon, Doireann O’Kiely Not included: Romina Gaburro.

help them target interventions. The data for each small area on its own are too small to make reliable estimates, but using hierarchical Bayesian statistical models we can borrow statistical strength across areas to make more accurate and precise estimates. A substantial part of this project is on communicating the results to stakeholders, where data visualisation has an important role.

Myrto Manolaki:

*The Irish success at the European Girls’ Mathematical Olympiad 2025*

*Abstract:* The European Girls’ Mathematical Olympiad (EGMO) is the most prestigious mathematical competition for girls, which started in 2012 (Cambridge, UK) and since then is held in April each year. In this talk, after presenting the structure and the historical context of the competition, I will focus on the recent success of the Irish team in Kosovo (one Bronze Medal and three Honourable Mentions, Ireland’s second best performance ever).

Róisín Neururer:

*The problem of problem-solving in post-primary classrooms: What are the challenges and how might we address them?*

*Abstract:* Successive curriculum reforms in Ireland have led to an increased emphasis on problem-solving within the post-primary mathematics curriculum. However, there is little evidence to suggest classroom practices have significantly changed. In this talk I will share teachers’ perspectives on and experiences with these reforms and highlight some of the underlying issues which may be hindering teachers from incorporating problem-solving into their classrooms in a meaningful way. Structured Problem Solving, an approach to teaching mathematics through problem-solving, will be described along with the challenge it poses to teachers. Finally, I will discuss possible supports that might enable teachers to engage more fully with problem-solving in their classrooms.

Doireann O’Kiely:

*Three research projects led by University of Limerick women*

*Abstract:* The MACSI research group at the University of Limerick uses mathematical and statistical techniques to solve problems in society, healthcare and industry. In this talk I will outline three very different projects, where mathematics and statistics were used for under-sea imaging, cancer treatment assessment and structural deformation, and profile the University of Limerick women involved in these projects.

Margherita Piccolo:

*A Wander into the World of Prime Numbers and Groups*

*Abstract:* Prime numbers have fascinated mathematicians and curious minds for centuries — mysterious, fundamental, and endlessly surprising. In this talk, we’ll take a journey through some of the most intriguing ideas in mathematics, starting with prime numbers and the Riemann zeta function - a powerful object that reveals hidden patterns in the distribution of primes. Then, we’ll enter the world of groups, the mathematical language of symmetry. Just as integers are built from primes, many groups are built from simple groups — atomic components in the algebraic universe. We’ll explore how we study groups through their representations, and how these give rise to zeta functions that help us uncover deep structural patterns. Join me in this exploration of hidden connections, elegant abstractions, and the surprising unity of mathematical ideas.

Victoria Sánchez Muñoz:

*Why maths?*

*Abstract:* What’s the best route to go home? How to fit best everything inside the backpack? How can we hide messages so that only your friends can read them? Maths has all the answers to these questions! I’ll give many (daily life) examples of some of the cool things you can do with maths, and I’ll show you that escaping maths is impossible! Because it’s everywhere! Even in literature, in videogames, and in art! I will also explain how I used maths to challenge my insurance company, and if the students are interested on knowing what I do now, I’ll briefly explain why randomness is super important and my current research on how to generate randomness with quantum stuff. This talk will be non-technical (and hopefully fun), thus suitable for any secondary school student. I’ll try to keep it highly interactive, so come along with ideas, with questions, and with some answers to “why maths?”.

Further details about the event, including the full programme, list of poster presentations, and photos, can be found at [this website](#).

Report by Nina Snigireva and Niall Madden, University of Galway  
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