Topics in Category Theory

A Spring School

ICMS, Edinburgh

11-13 March 2020

Contents

Welcome

Welcome to Edinburgh, and to the Spring School!

The goal of this meeting is to gather together an international crowd of junior mathematicians who are using category-theoretic ideas and techniques in their research, and to create a forum where we can learn together, from experts and from each other. The emphasis will be on interactions between pure category theory and other areas of mathematics, including geometry, topology, algebra, and logic.

At the heart of the programme is a series of three short courses, delivered over three mornings by our invited speakers, Olivia Caramello, Constanze Roitzheim and Greg Stevenson. The courses will each introduce an area of active research in category theory with wide-reaching relevance for other areas of mathematics: the study of Grothendieck toposes; of stable model categories; and of derived and triangulated categories.

In the afternoons we'll hear short talks contributed by PhD students and post-docs, and on Wednesday evening there will be a poster session accompanied by a wine reception. Along the way there will be plenty of coffee, hearty lunches, and lots of opportunities to get to know each other.

We hope you will find the Spring School useful and enjoyable. If you have any questions, comments, or suggestions, we will be glad to hear them.

Guy Boyde
University of Southampton

Aryan Ghobadi
Queen Mary University of London

Emily Roff
University of Edinburgh

Short courses

Grothendieck toposes

Olivia Caramello
University of Insubria

The course will provide an introduction to the theory of Grothendieck toposes from a meta-mathematical point of view. It will present the main classical approaches to the subject (namely, toposes as generalized spaces, toposes as mathematical universes and toposes as classifiers of models of first-order geometric theories) in light of the more recent perspective of toposes as unifying 'bridges' relating different mathematical contexts with each other and allowing to study mathematical theories from multiple points of view.

Stable model categories

Constanze Roitzheim
University of Kent

Model categories are categories with a formal notion of homotopy between morphisms. However, the axioms allow for many other useful constructions which lead to the notion of a stable model category. We will give an overview of the relevant techniques (homotopy, suspension, loops, generating cofibrations, Bousfield localisations) and how they are applied in stable homotopy theory.

Derived and triangulated categories

Greg Stevenson
University of Glasgow

The aim of the course is to give an introduction to (algebraic) triangulated categories, focussing on intuition, and building on our understanding of abelian categories. The emphasis will be on viewing triangulated categories as solutions to a stabilization or symmetrization problem, in order to try to make the axioms seem as natural as possible and to highlight ideas which are common to algebra and topology.

In the unlikely event that time permits, we'll sketch current research directions and discuss some open (but accessible) problems.

Contributed talks

Each talk will be 20 minutes long, with two minutes for questions, so it will be a great help if questions can be kept concise. At the end of the conference, two talks will be selected by the invited speakers to receive a prize, chosen from a list of recent texts in category theory provided by Cambridge University Press.

Wednesday, 11th March

An elementary approach to localizations

Nima Rasekh

École Polytechnique Fédérale de Lausanne

One important tool in category theory is the theory of localizations. However, usual approaches to localizations require careful set-theoretical considerations.

In this talk we give an internal construction of localizations, which can be applied to certain categories without infinite colimits. We will then use it to describe truncation functors for certain non-standard categories of spaces.

Simplicial categories as double categories

Redi Haderi

Bilkent University

Simplicial categories (that is, simplicial objects in **Cat**) may be regarded as a double categorical structure. As a matter of fact they are a double categorical version of simplicially enriched categories. This way a variety of concepts from double category theory apply, in particular double colimits.

We will construct a simplicial category of simplicial sets as a main example. As an application we will sketch how certain homotopy colimits are actually double colimits. Time permitting we will also point out how our example realizes Lurie's prediction that inner fibrations are classified by maps into a 'higher category of correspondences'.

The topoi of higher Segal spaces

May U. Proulx
University of Leicester

The Segal condition for simplicial sets detects nerves of small categories, or a nerve-like space of composable morphisms in the case of general simplicial spaces. Since 2012, there has been a push to study 'higher' Segal conditions which correspond to progressively weaker relationships to genuine categories. 2-Segal spaces correspond instead to (co)associative, (co)algebras: associativity still holds but composition is no longer unique (where it exists). For n larger than 2 the story is less clear. The aim of this talk is to illustrate the 'geometric' nature of these conditions by introducing an alternative characterization of n-Segal spaces as objects in sheaf topoi over thickened stratified n-simplicies.

General comodule-contramodule correspondence

Katerina Hristova
University of East Anglia

Given a coalgebra C, one can define two categories of modules over C—the well-known category of C-comodules, and, the less well-known, category of C-contramodules. Positseltski establishes an equivalence between certain 'exotic' versions of the derived categories of these two categories.

We explain how this can be generalised to the setting of comodules and modules over a comonad-monad adjoint pair in a closed monoidal category. This is joint work with John Jones and Dmitriy Rumynin.

A categorical approach to difference-differential algebra

Antonino Iannazzo
Queen Mary University of London

Our main objective is to generalise the category theory inspired approach to difference algebra by I. Tomasic to the difference-differential context. We define internal hom objects between difference-differential modules, and show how to use them to develop difference-differential homological algebra. Our methods are essential in the case of non-inversive difference operators.

Factorization algebra vs. algebraic QFT

Marco Perin
University of Nottingham

Generally speaking a quantum field theory (QFT) is a method to assign observables (things that can be measured) to regions of a manifold in a functorial way. In the Lorentzian case further axioms are sometimes required: it is reasonable to ask the measurements of two laboratories located on causally disjoint regions of a Lorentzian manifold to be independent; on the other hand when we know how observables behave on a big enough region of a manifold we should also know how they behave on the whole region. Trying to axiomatize these behaviours is a long-standing problem and during the last few years a new candidate to do it has emerged: factorization algebra. The issue with this new method is that no comparison was given to the older and well-developed approach of algebraic quantum field theory (AQFT) and it was not clear whether the two theories agreed or not. The aim of this talk is to introduce these axiomatizations in an intuitive fashion and to show that they are actually the same using basic techniques from category theory. Our hope is to show the effectiveness and support the use of category theory in mathematical physics, but also to introduce category theorists to new problems in applied category theory.

Thursday, 12th March

Classifying topos for existentially closed models

Hisashi Aratake
Kyoto University

The model-theoretic notion of existentially closed (e.c.) models of first-order theories generalizes the notions of algebraically closed fields and many other 'closed' structures. Blass and Scedrov constructed the classifying topos for e.c. models. We will review the construction by relating it with an omitting-types characterization of e.c. models. We will also make some categorical analysis on this classifying topos and derive some model-theoretic results.

Measures for enriched categories

Callum Reader
University of Sheffield

If we take a measurable space and consider the set of probability measures on it, this set has a canonical measurable space structure. This fact allows us to define an endofunctor on the category of measurable spaces. Work by Giry and Lawvere showed that this endofunctor can be given a monad structure.

In 2017 Fritz and Perrone introduced an analogous monad for the category of metric spaces. Originating as the solution to a transport optimisation problem, between any two probability measures on a metric space we can define the so-called earth-mover's distance. If we consider two probability measures on a metric space as some distribution of a unit mass of earth, then we define the distance between them to be the 'minimum amount of work required to rearrange one distribution into the other'. This gives the set of probability measures a canonical metric space structure.

Here, by considering Lawvere's observation that metric spaces are a form of enriched category, we show how earth-mover's distance is the enriched analogue of natural transformations, and explore what this means when we choose other bases for enrichment.

Torsion models for tensor-triangulated categories

Jordan Williamson
University of Sheffield

I will describe how to build a model for (sufficiently well-behaved) tensor-triangulated categories from the data of torsion and local objects determined by their Balmer spectra. The idea is to mirror constructions in commutative algebra such as torsion and localization at prime ideals. This in particular recovers the torsion model for rational $SO(2)$-spectra discovered by Greenlees and promotes it to a Quillen equivalence. I will discuss examples arising from algebra, chromatic homotopy theory and equivariant stable homotopy theory. This is joint work with Scott Balchin, J.P.C. Greenlees and Luca Pol.

Cofree G-spectra and completions

Luca Pol
University of Sheffield

Equivariant Borel cohomology is a prominent example of an equivariant cohomology theory and it is part of an interesting class of equivariant objects, that of cofree G-spectra, that naturally appears in equivariant stable homotopy theory. It was first noticed by Atiyah and then extended by Greenlees-May, that the homotopy theory of cofree G-spectra is intrinsically related to several completion phenomena in algebra.

In this talk, I will reinforce this connection between algebra and topology by showing that the homotopy theory of rational cofree G-spectra can be modelled by the homotopy theory of complete modules over the group cohomology ring. This is joint work with J. Williamson.

Topos-theoretic invariants as properties of monoids

Morgan Rogers
University of Insubria

Given a monoid (a set equipped with an associative operation and an identity element) we can consider the category of actions of that monoid on sets, which can be understood as a direct generalisation of group actions. Viewing a monoid as a one-object category, we see that this category of actions is a special case of a category of presheaves, and so is a topos. Many of the most studied properties of toposes come from geometry, since these categories can be thought of as generalised spaces, but what do such 'geometric' properties mean in the context of toposes of monoid actions? In this talk we present some answers to this question, as well as a few related results hinting at the directions that this research might take in the future. This is joint work with Jens Hemelaer (University of Antwerp).

Model categories for functor calculus

Niall Taggart
Queen's University Belfast

Over the past few decades, several different variations of functor calculus have been developed and shown to have far-reaching applications. The idea is a simple one, given a functor, one can construct polynomial functors which approximate the functor, and produce a Taylor tower, similar to the Taylor series from differential calculus. In this talk, I will describe how some of these variants of functor calculus fit into the language of model categories and highlight how this model category perspective has aided our ability to perform calculations.

Auslander-Reiten triangles and Grothendieck groups of triangulated categories

Johanne Haugland
Norwegian University of Science and Technology

We recall the construction of the Grothendieck group of a triangulated category and investigate the defining relations for this group. If the Auslander-Reiten triangles generate these relations and our category has a cogenerator, then we have only finitely many isomorphism classes of indecomposable objects up to translation. This gives a triangulated converse to a theorem of Butler and Auslander-Reiten.

Interactions of the Grothendieck construction with structured categories

Joe Moeller
University of California, Riverside

The Grothendieck construction gives a systematic way of constructing a single category carrying the same data as a family of categories indexed by a category. Moreover, this category comes equipped with a fibration, in the sense of Grothendieck. This construction extends to a 2-equivalence between the 2-categories of indexed categories and fibrations. This talk focuses on two monoidal variants of the Grothendieck construction, a global version and a fibre-wise version. Under certain conditions these are equivalent, so one can transfer fibre-wise monoidal structures to the total category. We give some examples demonstrating the utility of this construction in applied category theory and categorical algebra, and describe various ways to potentially extend the ideas here to other structures with which a category may be equipped.

Friday, 13th March

Fracture theorems for tensor-triangulated categories

Scott Balchin

University of Warwick

In this talk I will discuss various ways of decomposing tensor-triangulated categories arising from the homotopy category of a suitable model category into simpler parts. The key input for this fracturing is the data of the Balmer spectrum, that is, the collection of prime tt-ideals. This retrieves the classical Hasse square in the case of $D(Z)$ and the chromatic fracture cube in the stable homotopy category. This is joint work with J.P.C. Greenlees.

Derived categories of second kind

Ai Guan

Lancaster University

Many important results in algebra and geometry are statements that there are certain equivalences of derived categories. One such theorem is Koszul duality, which classically says that there is an equivalence between certain bounded derived categories. In more modern formulations of Koszul duality, due to Keller–Lefèvre and Positselski, the boundedness conditions are removed by replacing the derived category on one side by a 'coderived' category, also called a derived category 'of second kind'. We will introduce these coderived categories and then show how further generalising Koszul duality leads to other, more exotic, derived categories of second kind.

Handlebody group representations from ribbon Grothendieck-Verdier categories

Lukas Müller

Heriot-Watt University

In this talk I will present a classification of cyclic algebras over the framed little disk operad in terms of ribbon Grothendieck-Verdier categories. As an application we use the derived modular enveloping construction of Costello to construct a large class of handlebody group representations.

The talk is based on joint work in progress with Lukas Woike.

Poster session

The poster session will be held in the breakout area during the wine reception on Wednesday evening. One poster will be selected by the invited speakers to receive a prize, chosen from a list of recent texts in category theory provided by Cambridge University Press.

Threefold flops and their Donaldson-Thomas invariants

Okke van Garderen

University of Glasgow

Donaldson-Thomas invariants arose in geometry as a method of counting moduli of sheaves supported on curves. However, DT invariants can be defined for any sufficiently nice category, given a stability condition and a Calabi-Yau symmetry. This more general approach allows a shift from geometry to algebra, which makes computations of these invariants feasible.

Type space functors in positive model theory

Mark Kamsma

University of East Anglia

For a first-order theory T we can collect the type spaces $\mathrm{S}_n(T)$ in a contravariant functor between the category of finite sets and the category of Stone spaces. Haykazyan generalised this idea to positive theories, replacing Stone spaces by spectral spaces. We characterise those functors that arise as a positive type space functor. This results in a duality between the category of positive theories with strong interpretations and the category of type space functors. Using the Stone duality between spectral spaces and distributive lattices, we can alternatively view type space functors as functors into the category of distributive lattices. This gives another characterisation of the same functors, namely as specific instances of coherent hyperdoctrines. The key ingredient, the Deligne completeness theorem, arises from topos theory, where positive theories have been studied under the name of coherent theories.

Simplicial sets for persistent homology

Jānis Lazovskis
University of Aberdeen

Persistent homology of a finite metric space may be viewed both as a functor from the reals to groups, and as a group-valued constructible sheaf over the stratified real line. We describe a common starting point for these approaches with simplicial sets. Our construction also extends persistent homology to a broader space of finite metric spaces, allowing for changes in the underlying information to be captured as morphisms in the target category.

Coalgebra 1-morphisms in wide finitary 2-categories

James Macpherson
University of East Anglia

The theory of 2-representations of finitary 2-categories developed by Mazorchuk, Miemietz et al. utilises a setup with multiple finiteness restrictions. I consider the extension to infinitely many isomorphism classes of indecomposable 1-morphisms, and utilise pro-2-categories to construct an analogue of a coalgebra 1-morphism associated to a finitary 2-representation for wide finitary 2-representations.

Adelic geometry via topos theory

Ming Ng
University of Birmingham

The adele ring $\mathbb{A}_k$ of some global field k is defined to be the restricted product of all the completions of k, and is an important arithmetic object. In particular, many results in number theory follow Hasse's local-global principle, i.e. some property holds over $\mathbb{Q}$ iff it holds over all the completions of $\mathbb{Q}$. Hence, it is natural to investigate these situations from an adelic point of view, since the adele ring $\mathbb{A}_\mathbb{Q}$ of $\mathbb{Q}$ by construction takes into account all the completions of $\mathbb{Q}$ simultaneously in a symmetric way. In this poster, we will outline a new research programme to develop a version of adelic geometry via topos theory. In particular, we describe our progress towards defining a classifying topos of completions of a global field k (with respect to the places of k), whose generic model will provide a topos-theoretic analogue of the adele ring of k. Along the way, we shall provide a point-free construction of positive real exponentiation. All this is joint work in progress with Steve Vickers.

Rigidity vs exoticity: A friendly match

Nikitas Nikandros
University of Kent

The purpose of this poster is to introduce the notion of an ‘exotic’ model in stable homotopy theory. We will make a brief tour of concepts that are essential in order to put an ‘exotic’ model into context. Namely, we will introduce the chromatic tower and the Johnson-Wilson and Morava spectra that control chromatic phenomena. Lastly we will try to relate the above with our current PhD project with Dr C. Roitzheim.

Sheafification in tensor-triangular geometry

James Rowe
University of Glasgow

Tensor-triangular categories can be studied via the geometry of an associated space, namely the spectrum of prime ideals. The work of Balmer upgrades the spectrum to a locally ringed space, the geometry of which is influenced by nature of the category. We aim to extend the methodology of Balmer, assigning to every object in the category an associated sheaf of modules and studying their behaviour. These sheaves capture local information within the category, and should serve as further means to distinguish between categories. As ever, examples from algebra and geometry behave more nicely than those from the realm of topology.

On Frobenius and Hopf

Paolo Saracco
Université Libre de Bruxelles

We report on some recent advances concerning how Frobenius functors naturally intervene in the study of Frobenius Hopf algebras.

Frobenius algebras originally appeared in representation theory at the beginning of the 20th century, but the interest in these structures has been recently renewed due their connection with 2-dimensional topological quantum field theories and monoidal categories.

Hopf algebras, for their part, are the backbone of the algebraic approach to many questions in geometry, topology, representation theory, mathematical physics, and they are nowadays recognized as the algebraic counterpart of groups, even in situations where ‘groups’ do not strictly make sense (such as non-commutative geometry).

In a recent pair of preprints, we reveal the existence of a deep connection between Frobenius functors on the one hand (a categorical extension of the Frobenius algebra notion) and Hopf algebras and their categories of Hopf modules on the other. We will see how being Frobenius for the free (two-sided) Hopf module functor $-\otimes B$ (the

main ingredient of the celebrated Structure Theorem of Hopf modules) is related to being a Hopf algebra for the bialgebra B and how this can be connected with the theory of Hopf and Frobenius monads.

Coequations, covarieties, coalgebras

Todd Schmid

University College London

For all intents and purposes, Birkoff introduced the notion of an abstract algebra in 1935. Birkoff's definition was given a modern spin during the initial developments of category theory, as they were useful objects for studying monads. The dual notion of coalgebra was acknowledged during this time, and even appears in the development of topos theory, but was not fully realised until its use value to computer science was made clear. These early developments appear in Aczel's work, and were popularized in *Vicious Circles* by Barwise and Moss. The initial study of coalgebra was different in spirit from Birkoff's study of varieties, but found inspiration from universal algebra again in the late 20th century in Rutten's work, and later with Awodey and Hughes' work, culminating in the study of coequations, covarieties, and the coBirkoff covariety theorem.

Categorification of covariance of random variables

Gyan Singh

University of Aberdeen

Under suitable assumptions, for R a ring and C, C' chain complexes of R-modules, the Künneth formula roughly gives a short exact sequence relating the tensor product of homology of the complexes and the homology of the tensor product of the complexes, with Tor_1 of homologies of C and C' as the difference (cokernel). This may be viewed as a (homological) analogue of the fact that for random variables X and Y on a probability space, one has the formula: $\mathrm{E}(X)\mathrm{E}(Y) - \mathrm{E}(XY) + \mathrm{Cov}(X, Y) = 0$ (where $\mathrm{E}(-)$ is expectation and $\mathrm{Cov}(-, -)$ is covariance). Adachi and Ryu defined a conditional expectation functor (the homology functor as per this analogy), categorifying conditional expectations of random variables. We hope to motivate an analogue of Tor_1 in this setting, in order to categorify covariance.

Cohomology in a topos

Ana Luiza Tenorio
Universidade de São Paulo

Grothendieck toposes are generalizations of sheaves with values in the category of sets. Following Peter Johnstone's book *Topos Theory*, we present an extended construction of sheaf cohomology for Grothendieck toposes, indicating an application in group cohomology, and pointing out the advantages and disadvantages of topos' internal language. Additionally, we introduce a notion of Q-set, where Q is a quantale, that will provide a category equivalence with sheaves on quantales. We note that Q-set resembles enriched categories over semicartesian quantales, and observe that this similarity can be used to develop alternative approaches for a Grothendieck topos cohomology.

Practical information

Location

The Spring School is taking place in the International Centre for Mathematical Sciences (ICMS), on the fifth floor of the Bayes Centre, 47 Potterrow, Edinburgh.

From the location marked on the conference website (which is also where Google maps will take you if you ask for the Bayes Centre) go under the arch of the building into the courtyard, and then enter the building through the doors on your right.

On the first day you will be issued with a temporary ID card, which will grant you access to the building for the duration of the Spring School. It is important that you return this before leaving on Friday—otherwise, we will be charged for it!

All the talks will be held in Seminar Room 5.10, which you will find by turning left at the very top of the stairs (just keep following the stairs, you'll get there eventually!) or by turning right out of the lift.

Remote participation

Some people are participating in the conference remotely, so by default each talk will be streamed live to a link that will be shared with all registered participants. Unless we have agreed otherwise with the speaker, the recording will not be kept.

If you are speaking and prefer not to be filmed, or have any questions about the filming, please let us know. If you would like help finding a place to sit where you will not appear on the video feed, please speak to one of the organisers.

Whether you are participating remotely or attending the meeting in person, we encourage you to make use of the Spring School's dedicated Matrix chatroom, `#topicsinct2020:matrix.org`. You can use the room to ask questions during the talks, or to interact directly with other participants, including those who cannot be present in person. To access the room, we recommend using one of these platforms:

- Riot, which has apps for Android and iPhone as well as a browser interface;
- pigeon.digital, a browser interface that is almost identical to Riot, but allows you to type in LaTeX.

More detailed instructions will be provided on a separate sheet.

Participant list

Invited speakers

Olivia Caramello, University of Insubria
Constanze Roitzheim, University of Kent
Greg Stevenson, University of Glasgow

Contributing speakers

Hisashi Aratake, Kyoto University
Scott Balchin, University of Warwick
Ai Guan, Lancaster University
Redi Haderi, Bilkent University
Johanne Haugland, Norwegian University of Science and Technology
Katerina Hristova, University of East Anglia
Antonino Iannazzo, Queen Mary University of London
Joe Moeller, University of California, Riverside
Lukas Müller, Heriot-Watt University
Marco Perin, University of Nottingham
Luca Pol, University of Sheffield
Nima Rasekh, École Polytechnique Fédérale de Lausanne
Callum Reader, University of Sheffield
Morgan Rogers, University of Insubria
Niall Taggart, Queen's University Belfast
May U. Proulx, University of Leicester
Jordan Williamson, University of Sheffield

Poster session

Okke van Garderen, University of Glasgow
Mark Kamsma, University of East Anglia
Jānis Lazovskis, University of Aberdeen
James Macpherson, University of East Anglia
Ming Ng, University of Birmingham
Nikitas Nikandros, University of Kent
James Rowe, University of Glasgow

Paolo Saracco, Université Libre de Bruxelles
Todd Schmid, University College London
Gyan Singh, University of Aberdeen
Ana-Luiza Tenorio, Universidade de São Paulo

Other participants

Beatriz Álvarez Díaz, Universidade de Santiago de Compostela
Igor Arrieta, Universidade de Coimbra
Amlan Banaji, University of St Andrews
Ruben van Belle, University of Edinburgh
Nicola Bellumat, University of Sheffield
Valentin Boboc, University of Manchester
Ben Brown, University of Edinburgh
Matteo Capucci, University of Padua
Eleftherios Chatzitheodoridi, University of Aberdeen
Pedro Conceicao, University of Aberdeen
Nuiok Dicaire, University of Edinburgh
Matthew Ferrier, University of Sheffield
Thomas Gaujal, Université de Lille
Harry Gindi, University of Edinburgh
Daniel Heiß, University of Regensburg
Ada Hermelink, University of St Andrews
Chris Heunen, University of Edinburgh
John Huerta, CAMGSD, Lisbon
Ide Ibrahim, Saratov State University
Lukas Ilic, Queen Mary University of London
Kristóf Kanalas, Eötvös Lorand University
Rachael King, Queen Mary University of London
Axel Koelschbach, Max Planck Institute, Bonn
Erik Leino, University of Aberdeen
Eduardo Loureiro, Universidade de Santiago de Compostela
Ioannis Markakis, University of Maryland
Lachlan McPheat, University College London
Anja Meyer, University of Manchester
Hervé Moal
Itamar Mor, Queen Mary University of London
Sean Moss, University of Oxford
William Murphy, City University of London
David Murphy, University of Glasgow
Arthur Pander Maat, Queen Mary University of London
Tomáš Perutka, Masaryk University
Henri Riihimäki, University of Aberdeen
Andrew Ronan, University of Warwick
Riccardo Zanfa, University of Insubria

	Wednesday		Thursday		Friday
9:00-9:45	Registration/Coffee	9:00-10:00	Constanze Roitzheim	9:00-10:00	Olivia Caramello
9:45-10:00	Welcome				
10:00-11:00	Olivia Caramello	10:00-10:30	Coffee	10:00-10:30	Coffee
		10:30-11:30	Olivia Caramello	10:30-11:30	Greg Stevenson
11:00-12:00	Constanze Roitzheim				
		11:30-12:30	Greg Stevenson	11:30-12:30	Constanze Roitzheim
12:00-12:20	Nima Rasekh				
12:30-1:30	Lunch	12:30-1:30	Lunch	12:30-1:30	Lunch
1:30-2:30	Greg Stevenson	1:30-3:00	Hisashi Aratake	1:30-2:30	Scott Balchin
			Callum Reader		Ai Guan
			Jordan Williamson		Lukas Müller
2:30-2:50	Redi Haderi		Luca Pol	2:30-3:00	Closing
3:00-3:30	Coffee	3:00-3:30	Coffee		
3:30-5:00	May U. Proulx	3:30-5:00	Morgan Rogers		
	Antonino Iannazzo		Niall Taggart		
	Katerina Hristova		Johanne Haugland		
	Marco Perin		Joe Moeller		
5:30-7:00	Poster session/ Wine reception				

Supporters

This event was made possible by financial support from the Glasgow Mathematical Journal Trust's Learning and Research Support Fund, the London Mathematical Society, the Edinburgh Mathematical Society, and the School of Mathematics at the University of Edinburgh. We also gratefully acknowledge in-kind support from the ICMS and Cambridge University Press.