Calum Hughes

Contact Information

Email: calum.hughes@postgrad.manchester.ac.uk
Website: calum-hughes.github.io

Research Interests

Higher category theory, homotopy theory, type theory, and logic.

Education

PhD in Pure Mathematics, University of Manchester, 2022-2026.

- Thesis: "Logic in 2-categories of internal categories".
- Supervisor: Prof. Nicola Gambino.
- Finishing date expected by March 2026.

MMath in Mathematics, University of Sheffield, 2018-2022.

- First class honours.
- Masters Thesis: *"The Dold-Kan Correspondence"*
- Supervisor: Prof. Sarah Whitehouse.

Research output

1. The elementary theory of the 2-category of small categories, with Adrian Miranda. Published *Theory and application of categories*, Vol. 43, 2025, No. 8, pp 196-242.
   This paper categorifies Lawvere's elementary theory of the category of sets and provides a suitable setting for a 2-categorical foundation for mathematics. Important concepts we introduce are the full subobject classifier and the categorified axiom of choice.
2. Colimits of internal categories, with Adrian Miranda, 2025.
   Preprint: arXiv:2501.17769. (Submitted, Bulletin for the Belgian Mathematical Society)
   This paper develops an explicit method for calculating coequalisers of internal categories, generalising the previously known setting for this substantially.
3. The algebraic internal groupoid model of Martin-Löf type theory, 2025.
   Preprint: arXiv:2503.17319. (Under review, Annals of Pure and Applied Logic)
   This paper shows that the 2-category of internal groupoids forms a strict model of Martin-Löf type theory, generalising Hofmann and Streicher's groupoid model of type theory and providing a host of new examples of type theories all with their own flavours.

Selected Talks

1. *Categorified Choice Principles*, British Logic Colloquium 2025, September 12 2025.
2. *Class* 2*-categories*, HoTT-MURI meeting 2025, Carnegie Mellon University, Pittsburgh. August 7 2025.
   This was an invited talk to a select group of around 40 experts in the field of Homotopy Type Theory.

3. *Internal categories, algebraic model structures and type theory*— International Category Theory conference, Masaryk University, Brno, July 18 2025.
   This conference is the largest conference on category theory and had 214 registered participants this year.

4. *An algebraic internal groupoid model of Martin-Löf type theory*— TYPES 2025, University of Strathclyde, Glasgow, June 9 2025.
   This is a computer science conference, and had over 180 participants.

5. *Colimits of internal categories*— 110th Peripatetic Seminar on Sheaves and Logic (PSSL 110), May 3 2025. Abstract, Slides

6. *The elementary theory of the* 2*-category of small categories*— Masaryk University Algebra Seminar, June 5 2024. (Invited)

7. *Models of Martin-Löf type theory and algebraic model structures*— University of Birmingham theoretical computer science seminar, May 17 2024. (Invited)

8. *The elementary theory of the* 2*-category of small categories*— The University of Sheffield ShEAF seminar, March 12 2024. (Invited)

9. *Homotopy Theory and Logic*— British Mathematics Colloquium 2024, June 19th 2024.

10. *A Mathematical Interlude: Winning the Lottery with 27 tickets* — Mathematics Students' Research Conference 2023, September 29 2023.

11. *A visual introduction to homology and homotopy*— The University of Sheffield Pizza Seminar, April 28 2022.

12. *An Introduction to Simplicial Sets*— Tomorrow's Mathematicians Today conference, The University of Greenwich, March 2021.

See more talks on the "talks" section of my website.

Teaching experience

I have taught tutorials in the following modules as a Graduate Teaching Assistant.

1. MATH 34011 Complex Analysis and Complex Analysis with applications, Autumn 2025.
   This is a problem solving class of around 60 students with the course lead. The students are from mathematics, many on joint honour programmes together with physics and computer science.

2. MATH32072: Number Theory Spring 2025.
   This was a problem solving class for a mathematics course of around 60 students.

3. MATH20062 Mathematical Communication and Group Projects, Spring 2025.
   This involved leading an interactive tutorial class in which questions were mostly about presentation style, mathematical communication and LaTeX.
   This was a drop in session, but at times had 90 students.

4. MATH 19661 Mathematics 1M1, Autumn 2024.
   This was a service course to aerospace engineering students. I lead a tutorial class of 30 students.

5. MATH 34011 Complex Analysis and Complex Analysis with applications, Autumn 2024.

6. MATH20062 Mathematical Communication and Group Projects, Spring 2024.

7. MATH 34011 Complex Analysis and Complex Analysis with applications, Autumn 2023.

8. MATH11112 Analysis, Spring 2023.
   This is a first year course to mathematics students. I lead the tutorial class of around 30 students.

Activities that relate to teaching:

- Creating all Tikz Diagrams for the lecture notes of MATH 34011 (Complex Analysis and Complex Analysis with applications).
- Marking for MATH11412/11422 (Introduction to Ordinary Differential Equations/ Ordinary Differential Equations and Applications).
- Marking for MATH19861 (0N1 Mathematics for Foundation Year).
- Invigilating for MATH32012 (Commutative Algebra).
- Invigilating for MATH32072 (Number Theory Spring).
- Attended Teacher Training modules in the following: FSE GTA Learning Outcomes and Lesson Plans, FSE GTA Teaching Skills, FSE GTA Roles and Expectations, Data Protection and Cyber Security.
- I am currently working to get accredited by AdvanceHE, the Professional Standards Framework for teaching and supporting learning in higher education in the UK. By the time my PhD is complete, I will be an associate fellow for Associate Fellow of the Higher Education Academy.

Organisational experience

- Local organiser of the British Logic Colloqiuim 2025.
- Organiser of Student logic seminar, the University of Manchester, 2023-2024.
- Creator and maintainer of the website for the University of Manchester category theory group (manchester-ct.github.io), 2024-present.
- Local organiser for Categorical Logic and Higher Categories conference, The University of Manchester, 16-19th Decemeber 2024.
- Organiser for the Mathematics Students' Research Conference 2023 (29/09/2023). This conference which had over 60 attendants and involved sourcing £1500 funding from two institutes (Heilbronn Institute of Pure Mathematics and The University of Manchester School of Mathematics), organising catering, speakers and a poster session.
- Co-organiser for the Topos Theory Reading Group (2024-present).
- Local organiser for the British Mathematics Colloquium 2024.

Research Funding Acquired

- **Dame Kathleen Ollerenshaw PhD award** September 2022-March 2026. This highly prestigious studentship funds my PhD position.
- Secured £1500 from Heilbronn Institute of Pure Mathematics and The University of Manchester School of Mathematics as funding for the conference Mathematics Students' Research Conference 2023 (29/09/2023).
- Secured £350 from the Sustainable Travel Top-Up Fund to travel sustainably to Brno, Czechia from Manchester UK.
- Awarded Undergraduate Research Bursary from the London Mathematical Society 2021 for the project of our own design: "Dynamics of Linear Operators: Limit Sets in Finite Dimensions" supervised by Dr. Dimitrios Roxanas. This was a competitive UK-wide place to research a 2-month project.

- Awarded Undergraduate Research Internship bursary from the University of Sheffield School of Mathematics and Statistics, 2020 for the project "Simplicial Sets" supervised by Dr. James Brotherston. This was a competitive position and ran for 3 months.

Prizes and Awards

- **T. M. Flett Prize in Pure Mathematics** for the best performance in Pure Mathematics modules 2022.
- **T. M. Flett Prize in Pure Mathematics** for the best performance in Pure Mathematics modules 2020.
- Best pure mathematical poster at Mathematics Students' Research Conference, September 27 2024. (See here)
- **Best Team Submission** in the School of Mathematics and Statistics annual team Mathematics challenge, 2018.

Research visits

- Research visit to Carnegie Mellon University to work with Steve Awodey, August 2024.
- Research visit to Carnegie Mellon University to work with Steve Awodey, August 2025.
- Research visit to Birmingham University to work with Sam Speight, May 2024.
- Research visit to Birmingham University to work with Sam Speight, September 2025.
- Research visit to Masaryk University to work with John Bourke, Novemver 2025.

Wider Research Skills

- Referee work for the journal *Theory and Applications of Categories*.
- Presented a poster at the International Category Theory conference 2024.
- Through my research I have gained a competency in programming languages such as Python, LaTeX, R, Adga, Haskell.
- I have taken postgraduate courses in: category theory, enriched catgeory theory, model theory, homological algebra, set theory, representation theory, groups and languages, commutative algebra, algebraic topology, algebraic number theory, functional analysis.

Outreach

- I was part of the academic panel for MIMUC 2024, the Manchester Interdisciplinary Mathematics Undergraduate Conference. This involved answering students' questions about academia and PhD life.
- In 2022, 2023, and 2024 I gave feedback on 30 minute talks that Manchester Masters' students gave in preparation for the presentation component of their Masters' Project module.
- I helped out with the Univeristy of Sheffield's open days for the School of Mathematics and Statistics. This involved helping out on the open desks, chatting to people about what doing a maths degree was like, and giving a talk about my experience in the SURE internship scheme.