BARINDER SINGH BANWAIT

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RESEARCH INTERESTS

Computational Number Theory | Arithmetic Geometry | Modular Forms | ML for Number Theory

My research is in **computational number theory**: how computer software systems can be used to solve open problems about the whole numbers. I have worked mainly with **elliptic curves** over number fields, and the maps between them ('isogenies'), proving results that generalize classical results from the 60s. See my list of publications below for more.

Recently I have become interested in **formal verification** of mathematics, and using strongly-typed functional programming languages to build a database of mathematical statements and proofs that a computer can understand, and that an AI can one day be trained upon. My latest research paper is an effort in this direction.

CURRENT POSITIONS

Postdoctoral researcher

Boston University

Sep 2022 – present — Boston, MA, USA

Mentor: Prof. Jennifer Balakrishnan

Visiting Scientist

Massachusetts Institute of Technology

Sep 2024 – present — Cambridge, MA, USA

Mentor: Prof. Andrew Sutherland

PREVIOUS ACADEMIC APPOINTMENTS

Postdoctoral researcher in Mathematics

Ruprecht-Karls-Universität Heidelberg

Oct 2021 – Apr 2022 — Heidelberg, Germany

Mentor: Prof. Dr. Gebhard Böckle

Postdoctoral researcher in Mathematics

Harish-Chandra Research Institute

Feb – Sep 2021 — Prayagraj, India

Visiting Scientist

Max-Planck-Institut für Mathematik

Oct 2016 – Nov 2016 — Bonn, Germany

Host: Prof. Alex Bartel

Postdoctoral researcher in Mathematics

Universität Duisburg-Essen

Jan 2015 – Jan 2017 — Essen, Germany

Mentor: Prof. Dr. Ulrich Görtz

Postdoctoral researcher in Mathematics

Institut national de recherche en informatique et en automatique (INRIA)

Jan – Dec 2014 — Bordeaux, France

Mentor: Dr. Andreas Enge

PAPERS AND PREPRINTS

1. **Machine Learning Approaches to the Shafarevich-Tate Group of Elliptic Curves**, with A. Babei, A. Fong, X. Huang and D. Singh. To appear, *Advanced in Theoretical and Mathematical Physics* (2025).
2. **Torsion subgroups of elliptic curves over quadratic fields and a conjecture of Granville**, with M. Derickx. To appear, *Algorithmic Number Theory Symposium XVI* (2024).
3. **Towards strong uniformity for isogenies of prime degree**, with M. Derickx. Submitted, *arXiv:2302.08350* (2024).
4. **Computing nonsurjective primes associated to Galois representations of genus 2 curves**, with A. Brumer, H. J. Kim, Z. Klagsbrun, J. Mayle, P. Srinivasan and I. Vogt. *Contemporary Mathematics 796* (2023).
5. **Modularity over $\mathbb{C}$ implies modularity over $\mathbb{Q}$**. To appear, *Modularity and the Generalised Fermat Equation*, *arXiv:2212.14412* (2022).
6. **Explicit isogenies of prime degree over number fields**, with M. Derickx. To appear, *Algebra and Number Theory*. *arXiv:2203.06009* (2022).
7. **Cyclic isogenies of elliptic curves over fixed quadratic fields**, with F. Najman and O. Padurariu. *Mathematics of Computation* (2023).
8. **Explicit isogenies of prime degree over quadratic fields**. *International Mathematics Research Notices.* 2023(14):11829–11876 (2023).
9. **Examples of abelian surfaces failing the local-global principle for isogenies**. *Research in Number Theory.* 7(55) (2021)
10. **Correction: Examples of abelian surfaces failing the local-global principle for isogenies**. *Research in Number Theory.* 8(98) (2022)
11. **Del Pezzo surfaces over finite fields and their Frobenius traces**, with F. Fité and D. Loughran. *Mathematical Proceedings of the Cambridge Philosophical Society.* 167(1) (2019) 35-60.
12. **Tetrahedral Elliptic Curves and the local-global principle for isogenies**, with J. Cremona. *Algebra and Number Theory.* 8:5 (2014) 1201-1229.
13. **On some local to global phenomena for abelian varieties**. PhD Thesis, University of Warwick (2013).

INDUSTRY EXPERIENCE

Quantitative Analyst

Quantile

Sep 2019 – Mar 2020 | London, UK

- Linear, mixed-integer, and multi-objective optimisation for compression of interest-rate derivative portfolios using Gurobi.
- Visualisation of FX trading datasets across several client investment banks.
- Modelling of reset risk and PV01 for swaptions.
- Git code management with Bitbucket.

Research Engineer

CMR Surgical

Jan 2018 – Sep 2019 | Cambridge, UK

- Research and optimisation of robotic control algorithms, including inverse kinematics and mass-spring-damper models.
- Mathematical modelling in Matlab, with Robotics and Control Systems toolboxes.
- Writing production-level, safety-critical embedded C code, compliant with MISRA C and International Standard IEC 62304.
- Time-series telemetry processing in Python, using pandas, numpy, and matplotlib.
- Analysis and visualisation of system log messages with Elasticsearch and kibana.
- Development with Amazon Web Services, including Lambda, S3, and Athena.
- Implementing machine learning algorithms for robot arm condition monitoring, using scikit-learn and Tensorflow.
- Unit and Regression tests in C, C++, and Matlab, including Google Test framework, continuously integrated with TeamCity.
- Agile software development with SVN and Git.

EDUCATION

PhD Mathematics

University of Warwick

Jan 2010 – Sep 2013 | Coventry, UK

Supervisor: Prof. John Cremona

BA and MMath Mathematics

University of Cambridge - Christ's College

Oct 2005 – June 2009 | Cambridge, UK

MMath (*Part III of the Mathematical Tripos*) - Distinction
Part III Essay: Class Field Theory (Cohomological Approach), supervised by Dr. Tim Dokchitser

INVITED TALKS

(recent)

- Arithmetic on Curves, ICERM, Providence RI, June 2025
- Algebra Seminar, University of Connecticut, Storrs CT, Nov 2024
- Algorithmic Number Theory Symposium XVI, MIT, Cambridge MA, Jul 2024
- Modular curves and Galois representations, Zagreb, Croatia, Sep 2023
- Rational Points, Schney, Germany, Jul 2023
- MIT Number Theory Seminar, Cambridge MA, Nov 2022
- Boston University Number Theory Seminar, Boston MA, Nov 2022
- Séminaire de Théorie des Nombres, Université de Strasbourg, France, Apr 2022
- Séminaire de Théorie des Nombres, ENS de Lyon, France, Apr 2022
- Séminaire de Théorie des Nombres, Université Blaise-Pascal, Clermont-Ferrand, France, Apr 2022
- Bhaskaracharya Pratishthana, Pune (online), Feb 2022
- Atelier PARI/GP 2022, Besançon, France (online), Jan 2022
- Arithmetic Geometry Seminar, Universität Bayreuth (online), July 2021
- VaNTAGe Seminar (online), June 2021
- Effective Methods in Algebraic Geometry (online conference), June 2021
- Algebra Seminar, Rijksuniversiteit Groningen (online), June 2021
- Mathematics Colloquium, Indian Institute of Technology, Hyderabad (online), June 2021
- University of Washington Number Theory Seminar (online), June 2021
- Séminaire de Théorie Algorithmique des Nombres, Bordeaux (online), May 2021
- Stat-Math Unit, Indian Statistical Institute, Delhi (online), Apr 2021
- Mathematics Colloquium, Indian Institute of Science Education and Research, Mohali (online), Apr 2021
- Joining Seminar, Harish-Chandra Research Institute, Prayagraj (online), Feb 2021
- Zagreb Number Theory Seminar (online), Jan 2021

RESEARCH PROJECT LEADER

Effective Algebra and the LMFDB

Jan 2025 | Kampala, Uganda

Running project *L-functions and Galois representations*.

Rethinking Number Theory 5

June 2024 | Online

Running project *Machine-Learning the rank and Shafarevich-Tate group of a rational elliptic curve*.

CONFERENCE AND WORKSHOP ORGANISER

- *Arithmetic geometry with a view toward computation*, JMM Special session, San Francisco, CA, Jan 2024
- *Young Researchers in Mathematics*, University of Warwick, Apr 2011

ACADEMIC MEMBERSHIPS

Member of the *L-functions and Modular Forms Database*. 40 pull requests merged since October 2020 across the codebase, including Classical and Bianchi Modular Forms, Testing utilities, and Dirichlet Characters.

OPEN SOURCE SOFTWARE CONTRIBUTIONS

Absolutely simple endomorphism rings - Sage

2021

- First functionality to check for geometric simplicity of Jacobians of genus 2 curves over $\mathbb{Q}$. Appeared in sage-9.5.

TEACHING EXPERIENCE

Course Lecturer

Computational Number Theory

Oct 2021 - Feb 2022 — Heidelberg, Germany

Masters course covering algorithmic and computational topics in elliptic curves, modular forms, and algebraic number theory.

Vertiefung Zahlentheorie

Apr - July 2016 — Essen, Germany

Representability of primes via quadratic forms - from Fermat, Euler, Gauss, and to Artin Reciprocity. Three hours per week for 15 weeks. Lectures given in German.

Einführung in das Computer-Algebra-Paket *Sage*

Sep 2015 — Essen, Germany

Introductory week-long course on *Sage* aimed at final year undergraduates. Course given in German.

Algebraic Number Theory

July 2009 — Linyi, China

Introductory course at summer school aimed at second year undergraduates.

Seminar Organiser

Prime numbers and Cryptography

Apr 2022 — Heidelberg, Germany

Bachelor's level seminar organised with Sriram Chinthalagiri

Abelian Varieties

Oct 2021 - Feb 2022 — Heidelberg, Germany

Masters level seminar organised with Prof. Böckle.

Algebraic Surfaces

Oct 2015 - Jan 2016 — Essen, Germany

Masters level seminar organised with Prof. Görtz.

Teaching Assistant

Linear Algebra	Apr - July 2015	Vytautas Paškūnas	Universität Duisburg-Essen
Modular Forms	Oct - Dec 2012	Mehmet Haluk Şengün	University of Warwick
Algebraic Number Theory	Jan - Mar 2012	Johan Bosman	University of Warwick
Elliptic Curves	Oct - Dec 2011	Lassina Dembélé	University of Warwick
Algebraic Number Theory	Jan - Mar 2010	William Hart	University of Warwick

Undergraduate Supervisor

Oct 2010 - Apr 2013 — University of Warwick

Holding supervisions of groups of 5 undergraduates.

DIVERSITY OUTREACH

CIMPA Schools

Jan 2025 — Kampala, Uganda

Project funded by French government to promote mathematical research in developing countries.

Rethinking Number Theory 5

June 2024 — Online

An AIM Research community to stimulate research by people from under-represented groups and to discuss changing norms of the profession.

Cambridge–Linyi Summer school

June 2009 — Linyi, China

Teaching Algebraic Number Theory to students at Linyi Normal University in Shandong, China.

STEP mentor

Apr 2007 – 2009 — Cambridge, UK

Coaching groups of A-Level students in the *Sixth Term Examination Papers* mathematics entrance exams to increase diversity and access at Cambridge.

REFEREE DUTIES FOR JOURNALS

Mathematics of Computation | International Journal of Number Theory | Algebra and Number Theory | Research in Number Theory | Acta Arithmetica | International Mathematics Research Notices | Algorithmic Number Theory Symposium | Expositiones Mathematicae

AWARDS

Engineering and Physical Sciences Research Council, UK

Jan 2010

- Full funding for PhD studies.

Institute for Advanced Study, Princeton NJ, USA

Jul 2008

- Full funding to attend Undergraduate Summer School Program of Park City Mathematics Institute on Algebraic Geometry in 2008.

Whelan Prize

Oct 2007

- Awarded by Christ's College, University of Cambridge, for outstanding examination performance (top of college in mathematics).

Nuffield Trust, UK

Jul 2007

- Undergraduate Research Bursary to conduct summer research project.
- Supervisor: Dr. Jon Bevan, University of Surrey, UK.

LANGUAGES

English	●●●●●●	**Python**	●●●●●○
ਪੰਜਾਬੀ (Punjabi)	●●●●●●	**Sage**	●●●●○○
Deutsch	●●●●○○	**C/C++**	●●●●○○
हिंदी (Hindi)	●●●○○○	**Magma**	●●●●○○
Français	●●●○○○	**PARI/GP**	●●●○○○