

This document contains a list of tenure-line faculty along with descriptions of their research interests aimed at PhD students.

- **Nick Addington:** I work in algebraic geometry. My main technical tool is the derived category of coherent sheaves, but my taste is very much geometric rather than categorical.
- **Shabnam Akhtari:** My main research interests are in Number Theory and Arithmetic Geometry. I study basic arithmetic objects and structures, via a variety of different methods from classical Diophantine approximation and the geometry of numbers. I am also interested in understanding height functions on number fields from both algebraic and analytic viewpoints. Students interested in working with me should have a solid background in both algebra and analysis. More importantly, they should be willing to learn about a broad range of subjects in mathematics.
- **Arkady Berenstein:** My research interests include Representation Theory of Lie algebras and Coxeter Groups, Hopf Algebras, Algebraic Combinatorics and related aspects.
- **Boris Botvinnik:** I study algebraic topology and differential geometry, with a focus on conformal geometry and the space of metrics of positive scalar curvature.
- **Marcin Bownik:** I work in the area of harmonic analysis, frames, and wavelets. My interests span from real-variable harmonic analysis, anisotropic Hardy spaces, frame and wavelet expansions, to more functional analysis topics such as Kadsion-Singer problem and characterization of diagonals of self-adjoint operators.
- **Jon Brundan:** I study representation theory and combinatorics arising from semisimple Lie algebras and algebraic groups, like the Lie algebra $\mathfrak{gl}_n(\mathbb{C})$ of all $n \times n$ matrices over \mathbb{C} and the group $GL_n(\mathbb{C})$ of invertible such matrices. Recently, I have been working on various diagrammatic monoidal categories which have a rather combinatorial flavor, take a look for example at <https://arxiv.org/abs/1709.06589> to see the spirit of the genre.
- **Dan Dugger:** I work in algebraic topology and homological algebra. I am interested in algebraic K -theory and other “motivic” cohomology theories for algebraic varieties, equivariant algebraic topology, and homological questions in commutative algebra. I am only interested in sponsoring thesis projects that center around very explicit computational work (for example, computing equivariant cohomology groups).
- **Ellen Eischen:** My research lies primarily in algebraic number theory and focuses on mainly on topics concerning automorphic forms, L -functions, and p -adic methods. Number theory is a beautiful subject, partly because it contains many statements that are simple to understand but whose proofs rely on hard, deep (but elegant) mathematics. The simplicity with which some questions can be stated and the ease with which one can prove some number theory results using only undergraduate algebra lead some students to the false conclusion that number theory is an especially accessible area of mathematics. In fact, modern algebraic number theory integrates sophisticated results from many areas of mathematics, and so if you work in algebraic number theory, you should have an open mind and be prepared to keep learning different flavors of mathematics.
- **Ben Elias:** I work in the field of categorification, which is the act of taking something you love and replacing it with something far more interesting, and the study of this new and interesting structure. For example, integers are categorified by vector spaces: the number 2 being replaced by

a 2-dimensional vector space, addition being replaced by direct sum, and so forth. However, one can discuss linear transformations between vector spaces, while there is no corresponding structure to be studied between integers. Some of the best examples of categorification come from geometric representation theory. This is a pretty high-tech area of math, but my specialty lies in making it very explicit and hands-on, and in doing lots of calculations. I expect students to do lots of examples and gain expertise through exercise.

- **Laura Fredrickson:** I am interested in the moduli spaces of solutions of gauge theoretic equations (PDEs that have a lot of local symmetries that often have origins in physics). The spaces of solutions of these equations tend to be interesting geometric objects in their own right. At one extreme, the space of solutions might be a manifold with a hyperkaehler structure. One example of this is the Hitchin moduli space. At the other extreme, the space of solutions might be a collection of points, and counting them might be an interesting invariant of something.

Techniques in my work involve differential geometry, nonlinear elliptic PDEs, complex geometry and in particular Kaehler and hyperkaehler geometry.

- **Weiyong He:** I work in differential geometry, geometric analysis and nonlinear elliptic partial differential equations. One of my main interest is the study of complex geometry, including Kähler geometry, complex Monge-Ampere equations, the extremal metrics and Sasaki-Einstein metrics. I also work in geometric evolution equations such as the Calabi flow, mean curvature flow and Sasaki-Ricci flow. To work with me, a student is supposed to take 600 differential geometry course. Depending on your interest, my students can start with a year long reading course including nonlinear elliptic PDE, Riemannian geometry and complex geometry.
- **Patricia Hersh:** I am interested in topological and algebraic combinatorics, including studying combinatorial-topological structure of partially ordered sets (posets) and of stratified spaces arising e.g. from combinatorial representation theory and total positivity theory. I especially like advising students in poset topology, including working with techniques such as shellability and discrete Morse theory and studying group actions on posets.
- **Alexander Kleshchev:** I study representation theory of Lie algebras, algebraic groups and related objects, such as symmetric groups, Hecke algebras, quantum groups, etc. You can find more details on my web page.
- **David Levin:** My research is in probability theory, including: random walks, Markov chains, multiparameter processes, jump processes, and related potential theory. Recently, I am interested in quantitative estimates on the time for ergodic Markov chains to equilibrate.
- **Huaxin Lin:** Research interests: Functional Analysis, Operator algebras and C^* -algebras. Using analysis to study algebraic structure of algebras of operators. I am currently interested in the structure of C^* -algebras and applications of C^* -algebra theory in classical topological dynamical systems and non-commutative dynamical systems.

- **Robert Lipshitz:** I work on applications of symplectic geometry and related tools to smooth 3- and 4-dimensional topology. This involves techniques from algebraic topology, differential geometry, partial differential equations, and homological algebra. Some background and interest in all of those subjects is needed in order to make progress, but which subjects are most important depends on the problem.
- **Peng Lu:** My research is in geometric analysis. Currently I am working on Ricci flow, a heat type equation which evolves Riemannian metrics by its Ricci curvature. More precisely I am interested in the ancient solutions and the singularity analysis of Ricci flow. I am willing to take one student.
- **Luca Mazzucato:** I was trained as a theoretical physicist (string theory), with a focus on how macroscopic phenomena emerge from the collective dynamics of strongly coupled degrees of freedom. My current research interests are in theoretical neuroscience. My goal is to understand the neural basis of sensory perception, how it is modulated by expectations leading to behavior. Some of my recent projects address the following questions: Which mechanisms underlie associative learning at the level of synaptic plasticity in local cortical circuits? How does behavior emerge from the temporal dynamics of cortical networks?

To study these questions, I use methods from statistical physics, information theory, machine learning, and dynamical systems. I combine statistical analysis of neurophysiological and imaging data from large populations of neurons in behaving animals with theoretical models based on neural networks. My projects rely heavily on numerical analysis and computer simulations of recurrent networks.

- **James Murray:** My research is in theoretical neuroscience. The scientific questions that my group seeks to address focus on how neurons within and between different brain regions learn things such as selecting actions or how to perform a new motor skill. First, we address these questions by developing mathematical models that draw on random matrix theory, dynamical systems, spin glass theory, stochastic processes, optimal control theory, and reinforcement learning. Second, our group's research also leverages connections between the fields of neuroscience and artificial intelligence, which works by training artificial neural networks to perform tasks ranging from face recognition to playing video games. Much of our research takes inspiration from recent AI advances, applying them to questions about the architectures of neural circuits in the brain and the algorithms that they use to learn. Finally, our group works together with experimental collaborators, where our role is to use modeling and data analysis to interpret data and to contribute to experimental design by generating predictions that can be tested in future experiments. I would be happy to talk to students interested in mathematical model building and/or deep learning who are also eager to learn about and apply their research to address neuroscience questions.
- **Victor Ostrik:** Current research interests: categorification of ring theory, that is study of tensor categories and module categories over them; geometric representation theory: study of representation theoretic questions using tools from algebraic geometry (perverse sheaves and D-modules). Possible areas for PhD: combinatorics of module categories related with fusion categories. It is known that this combinatorics in the simplest case of $SL(2)$ is described by the famous ADE classification pattern. So the study of further examples (related say with $SL(3)$) can be considered as a study of "higher Coxeter systems". I will be happy to consider one or two students.

- **N. Christopher Phillips:** I study C*-algebras, which are special algebraic structures which arise in analysis. The easiest examples of C*-algebras are $C(X)$, the algebra of all continuous functions on a compact Hausdorff space X , and $L(H)$, the algebra of all continuous linear operators on a Hilbert space H . The combination of strong extra structure and usefulness in applications has made C*-algebras a broad and very active branch of mathematics. For example, the C*-algebra associated to a locally compact group G is connected to the representation theory of the group. More generally, the crossed product $C^*(G, A)$ is made from an action of G on a C*-algebra A . When $A = C(X)$, the study of the crossed product connects with dynamical systems. Much of my current research concerns group actions on C*-algebras (often ones of the form $C(X)$), with emphasis on but not limited to the structure and classification of crossed products. Even when the group is \mathbb{Z} and the C*-algebra is $C(X)$, or when the group is $\mathbb{Z}/2\mathbb{Z}$ and the C*-algebra is simple, many questions remain open. I have also done some work on operator algebras on L^p spaces. This is a very new area, and there are many problems which nobody has looked at yet.

I am happy to consider taking further students. I have students (one visiting from elsewhere) working on several problems on crossed products of C*-algebras and also on L^p operator algebras, so any student staring in either area will be able to talk to other students about the area.

- **Sasha Polishchuk:** My general area of research is algebraic geometry. More specifically, recently I work with problems involving derived categories of coherent sheaves on algebraic varieties, noncommutative geometry and higher homotopy structures (such as A_∞ algebras) appearing in algebraic geometry. I would be happy to take one or two new students.
- **Nicholas Proudfoot:** My interests lie at the interface between algebraic geometry, combinatorics, representation theory, and algebraic topology. In practice, this usually means that I start with some combinatorial data (such as a collection of hyperplanes in a vector space), use it to build an algebraic variety (such as the complement of the hyperplanes, or some compactification thereof), and study algebraic invariants of this variety (such as its cohomology). Here is an example of a problem that I have worked on:

Suppose you are given a set of 53 hyperplanes in \mathbb{R}^{10} whose common intersection is the origin, and you look at all of the vector spaces of any dimension that can be obtained by intersecting some of these hyperplanes. Then the number of 3-dimensional vector spaces that you get is at least as great as the number of 7-dimensional vector spaces. This was an open conjecture for over 40 years, and was recently proved by studying the cohomology ring of a certain variety.

My mathematical tastes run toward the concrete. I respect abstraction and I use categories a lot in my work, but I'm happiest working on problems in which the abstract tools can be used to tell you something about actual numbers.

- **Peter Ralph:** I work at the interface of computational biology, evolutionary theory, stochastic processes, and data analysis. The general goal of my work is to better understand how evolution works - how species adapt to environmental change, how they can maintain useful genetic differences across diverse conditions, and how one species splits into two (or many, or two merge into one) - and how we can learn about evolution by looking at genomes. The basic rules (called "population genetics") are about as well understood as those of thermodynamics, but there are many major outstanding questions about how evolution works in practice, and to resolve them we need both new mathematical models and new methods for analyzing large-scale genomic data. I am

particularly interested in problems related to geography (2D stochastic processes) and inference with ill-posed inverse problems.

Students working with me might try to identify universality classes for stochastic models of genetic change in populations, or might spend a lot of time on the computer analyzing large genomic datasets, or something in between.

- **Hal Sadofsky:** I work primarily in stable homotopy theory which is the part of algebraic topology concerned with properties of maps which are preserved after “suspending” (cross X with the unit interval, and identify $X \times 0$ to a point and $X \times 1$ to a point). At the moment the questions I’m working on concern understanding how to compute generalized homology theories (functors from spaces to graded groups which obey most of the axioms of homology theory) on certain types of spaces arising from limit constructions, and their applications. I’m also working on understanding the relationship between operads and a certain kind of homotopy approximation that is analogous to Taylor approximations.
- **Yefeng Shen:** I am interested in algebraic geometry and mathematical physics. My recent work focus on curve counting theories, such as Gromov-Witten theory and Fan-Jarvis-Ruan-Witten theory, and the mirror symmetry beyond them. These theories have deep connections to complex geometry, number theory, and representation theory.
- **Chris Sinclair:** I work in random matrix theory, mathematical statistical physics and number theory. Specifically I study the statistics of eigenvalues of random matrices and roots of random polynomials especially as applied to electrostatic systems and the distribution of algebraic numbers. The background to approach such problems should include measure theory, linear algebra and probability (and algebra for number theory). If you think you may be interested in working with me, I am always happy to chat about my research and/or develop a plan of study of mutual interest.
- **Dev Sinha:** I work in a range of areas in topology, mostly in algebraic topology but some in geometric topology as well. I like to see the geometry which underlies homotopical structures. My interests are broad, with my most recent projects being in cohomology of alternating and symmetric groups, in group theory related to rational homotopy theory, in knot theory, and in neural networks. Configuration spaces are a part of much of what I do, and I like to study topology, geometry, algebra and combinatorics related to them. Some of my research along with other topics of interest in algebraic topology are the subject of a lecture series available at:

<https://pages.uoregon.edu/dps/GeometricAlgebraicTopology/>

- **Arkady Vaintrob:** I study algebra and geometry motivated by physics. My current interests involve algebraic geometry, in particular orbifolds. My past interests have included knot theory and representation theory.
- **Micah Warren:** study Geometric Analysis and Geometric PDE. Recently I have been considering problems dealing with optimal transportation, including synthetic constructions of Ricci curvature, fully nonlinear elliptic PDE such as the Monge-Ampère and special Lagrangian equations, and also some problems in minimal surface theory. I would be happy to talk to anybody who is interested.

- **Yuan Xu:** I work in several areas in analysis: approximation theory, Fourier analysis, orthogonal polynomials and special functions, mostly in multi-dimensional setting. My recent work is on approximation by polynomials in Sobolev spaces on regular domains, and orthogonal polynomial on curves and surfaces.
- **Benjamin Young:** I work in enumerative, bijective and algebraic combinatorics. Most of what I am working on at the moment is related to the dimer model, or to Schubert calculus and the combinatorics of reduced words. To some degree I am also a generalist, solving combinatorial problems from other areas of mathematics. I use computers heavily in my work.