

Research Areas

The five main areas of concentration are **Algebra, Analysis, Combinatorics, Geometry/Topology**, and **Statistics/Probability**. Below are more specific research areas along with the names of faculty members most closely involved for the 2023–2024 academic year.

<p>Algebraic and Geometric Topology</p> <ul style="list-style-type: none"> ▪ Laura Anderson ▪ Michael Dobbins ▪ Ross Geoghegan ▪ Cary Malkiewich ▪ Pedro Ontaneda ▪ Jenya Sapir ▪ Daniel Studenmund ▪ Jonathan Williams 	<p>Graph Theory</p> <ul style="list-style-type: none"> ▪ William Kazmierczak ▪ Thomas Zaslavsky
<p>Algebra related to logic and computer science</p> <ul style="list-style-type: none"> ▪ Fernando Guzman 	<p>Group Theory</p> <ul style="list-style-type: none"> ▪ Benjamin Brewster ▪ Matthew Brin ▪ Ross Geoghegan ▪ Fernando Guzman ▪ Luise-Charlotte Kappe ▪ Marcin Mazur ▪ Daniel Studenmund ▪ Inna Sysoeva ▪ Hung Tong-Viet
<p>Applied and Computational Mathematics</p> <ul style="list-style-type: none"> ▪ Minghao Rostami ▪ Jia Zhao 	<p>Number Theory</p> <ul style="list-style-type: none"> ▪ Alexander Borisov ▪ Luise-Charlotte Kappe ▪ Marcin Mazur ▪ Adrian Vasiu ▪ Sailun Zhan
<p>Arithmetic Algebraic Geometry</p> <ul style="list-style-type: none"> ▪ Alexander Borisov ▪ Adrian Vasiu ▪ Sailun Zhan 	<p>Partial Differential Equations</p> <ul style="list-style-type: none"> ▪ Paul Loya ▪ Emmett Wyman ▪ Xiangjin Xu ▪ Gang Zhou
<p>Combinatorial Geometry</p>	

- [Laura Anderson](#)
- [Michael Dobbins](#)
- [Thomas Zaslavsky](#)

Combinatorics

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Geometric Analysis

- [Paul Loya](#)
- [Pedro Ontaneda](#)
- [Emmett Wyman](#)
- [Xiangjin Xu](#)
- [Gang Zhou](#)

Geometric Group Theory

- [Matthew Brin](#)
- [Ross Geoghegan](#)
- [Fernando Guzman](#)
- [Jenya Sapir](#)
- [Daniel Studenmund](#)

Geometry of Manifolds

- [Pedro Ontaneda](#)

Probability

- [Vladislav Kargin](#)
- [David Renfrew](#)
- [Anton Schick](#)

Representation Theory

- [Alex Feingold](#)
- [Dikran Karagueuzian](#)
- [Hung Tong-Viet](#)

Statistics

- [Guifang Fu](#)
- [Vladislav Kargin](#)
- [Rakhi Singh](#)
- [Aleksey Polunchenko](#)
- [Xingye Qiao](#)
- [Anton Schick](#)
- [Qiqing Yu](#)

Statistical Machine Learning

- [Guifang Fu](#)
- [Rakhi Singh](#)
- [Xingye Qiao](#)

Faculty research interests

[Laura Anderson](#)

My research focuses on interactions between combinatorics and topology, particularly those involving oriented matroids, convex polytopes, and other concepts from discrete geometry. Much of my work involves combinatorial models for topological structures such as differential manifolds and vector bundles. The aims of such models include both combinatorial answers to topological questions (e.g., combinatorial formulas for characteristic classes), and topological methods for combinatorics (e.g. on topology of posets).

Alexander Borisov

My general research area is algebraic geometry and number theory, broadly interpreted. Particular topics of interest include birational geometry, toric geometry and convex discrete geometry, polynomial morphisms, integer polynomials, Arakelov geometry.

Benjamin Brewster

Algebra, group theory. Topics of particular interest:

1. Sylow subgroups, how the group acts on them via conjugation, and how they intersect.
2. Solvable groups-their conjugacy classes of subgroups.
3. Subgroup lattices-intervals in the lattice and the influence of permutable subgroups on this lattice.
4. Characterizing subgroups with embedding properties in direct products.

Matthew G. Brin

I am currently interested in the mathematical interactions of a collection of groups that arose first in logic and universal algebra. The groups are generalizations of three groups first discovered by Richard Thompson. The groups show up in a strong way in logic, homotopy and shape theory, dynamical systems, categorical algebra and its relation to physics, and the combinatorial group theory of the word problem and of infinite simple groups. They are a source of examples or potential examples in geometric group theory, cohomology of groups, string rewriting systems and abstract measure theory.

Michael Dobbins

My research is primarily on discrete geometry, particularly geometric problems arising from computer science. I also work in computational geometry, complexity, convexity, combinatorics, and topology.

Thomas Farrell

Differential topology, in particular on classifying manifolds of a given homotopy type. Related research interests in geometry and algebra. These interests include the study of discrete subgroups of Lie groups and algebraic K-theory.

Alex Feingold

Finite dimensional semisimple Lie algebras, tensor product decomposition of irreducible modules, representation theory of the infinite dimensional Kac-Moody Lie algebras, bosonic and fermionic creation and annihilation operators, affine and hyperbolic Kac-Moody algebras, topics in combinatorics, power series identities, modular forms and functions, Siegel modular forms, conformal field theory, string theory, and statistical mechanical models, vertex operator algebras, their modules and intertwining operators, the theory of fusion rules.

Guifang Fu My main focus is to develop advanced statistical models and computational methodologies to unravel the genetic and environmental mechanisms that regulate complex biological traits, including morphology/shape, biomedical problems and disease. I am particularly interested in high-dimensional, "big data" modeling, and functional data analysis. My genetic leaf shape project was awarded a three-year NSF grant. I enjoy collaborating on interdisciplinary projects, working with researchers from the application domains and addressing real-life data analysis questions.

Ross Geoghegan

I am interested in the interplay between group theory and geometry/topology. In particular: geometric and homological group theory, fixed point theory, and certain parts of dynamical systems. Some of the questions motivating this work are algebraic, involving the algebraic K-theory of rings associated with the fundamental group; this is how I got interested in Nielsen fixed point theory, particularly parametrized versions of that theory. Other questions are about how an action by a discrete group on a non-positively curved space can lead to group theoretic information. I'm also interested in understanding the asymptotic topological invariants of a group. I have recently finished a book on that subject called "Topological Methods in Group Theory".

Fernando Guzman

My mathematical interests are algebraic in a broad sense. From universal algebra, lattice theory and ordered structures, through more classical algebraic topics like group theory and homology to interactions of algebra with computer science and logic.

Luise-Charlotte Kappe

Group theory (properties of groups, Engel conditions, commutator calculus, supplementation, p-groups, nonabelian tensor products); ring theory (derivations, commutativity conditions in rings); number theory (transcendental numbers, diophantine approximations).

Vladislav Kargin

I am particularly interested in random matrices and its applications, in particular,

1. statistical analysis of large data,
2. zeroes of zeta functions,
3. statistical mechanics of random media, and
4. free probability.

Dikran Karagueuzian

My research for the past few years has been primarily in the representations and cohomology of finite groups. For the past few years I have been studying problems in algebra that arise from techniques of algebraic topology. Sometimes there is a theorem hidden behind the feasibility of a well-known method. An example of this phenomenon is my most recent preprint, written in collaboration with Peter Symonds of the University of Manchester Institute of Science and Technology. In this case the theorem was uncovered through exploration with the computer algebra package Magma, which is well worth checking out. Often such software lets us investigate mathematical phenomena which would be very difficult to understand otherwise.

William Kazmierczak

My research interests lie in the general field of graph theory and specifically in the reliability and vulnerability of networks when the components of a network are susceptible to failure. Extremal graph theory results are also of particular interest in my work due to the need to maximize or minimize certain parameters of a graph when seeking best network models.

Hudson Kronk

In addition to graph theory my interests are: mathematical recreations, number theory, cryptology, and coding theory.

Paul Loya

The underlying theme of my research is the investigation of topological, geometric, and spectral invariants of (singular) Riemannian manifolds using techniques from partial differential equations. For example, the Euler characteristic of a surface is a topological invariant based its usual definition in terms of a triangulation of the surface. However, it may also be considered geometric in view of the Gauss-Bonnet theorem or spectral in view of the Hodge theorem. I am interested in such relationships on general singular Riemannian manifolds.

Cary Malkiewich

My general research interest is in algebraic topology, and my work is broadly motivated by the study of manifolds and cell complexes by algebraic techniques. I have recently been focusing on topological Hochschild homology, algebraic K-theory, transfers, and stable homotopy theory. There is also an emerging connection between my work and homotopy-invariant properties of topological dynamical systems.

Marcin Mazur

My research interests concentrate around areas where number theory and group theory intersect. Topics of particular interest are group rings, group schemes over rings of algebraic integers, Galois module structures and Galois representations.

Patricia McAuley

My main research interests are fiber spaces of various sorts and local properties of topological spaces with particular interest in “local-implies-global” theorems. A secondary interest is in topological transformation groups, especially group actions on manifolds.

Pedro Ontaneda

My general interest is the geometry and topology of aspherical spaces. I have done some work in the study of the relationship between exotic structures and (negative, non-positive) curvature, and its applications to the limitations of PDE methods in geometry. Other interests: geometric group theory, K-theory, mechanics.

Aleksey Polunchenko

Mathematical statistics and specifically the problem of sequential (quickest) change-point detection, currently focusing on the case of composite hypotheses.

David Renfrew

My research lies in Probability and Random Matrices. I am particularly interested in non-Hermitian random matrices and the interplay between random matrices and free probability. I am also interested in applications to biologic systems.

Xingye Qiao

My main research interest focuses on statistical machine learning, a rapidly growing area of research. Many techniques in statistical machine learning have become essential in big data analytics. Some of my recent works include novel large-margin based classification methods, the classification stability, the subsampling strategy for massive and high-dimensional data sets, and learning data with special structures.

Anton Schick

Uses of large sample theory in statistics, the characterization and construction of efficient estimators and tests for semiparametric and nonparametric models, statistical inference for Markov chains and stochastic processes, estimation and comparison of curves, the behavior of plug-in estimators, optimal inference for bivariate distributions with constraints on the marginal, modelling with incomplete data, and the theory and application of

finite and infinite order U-statistics.

Daniel Studenmund

My research addresses questions arising at the intersection of geometric group theory and the study of discrete subgroups of Lie groups. I am particularly interested in invariants associated to the collection of finite-index subgroups of a given group G . One example is the abstract commensurator $\text{Comm}(G)$, the group of all isomorphisms between finite-index subgroups of G , modulo equivalence. Other examples are growth rates of various functions associated to the collection of finite-index subgroups, which can be thought of as helping to “quantify” residual finiteness of G . I also study other invariants of groups, such as superrigidity and cohomology of arithmetic groups, using algebraic and geometric methods.

Inna Sysoeva

My main research area is group theory. More specifically, in the recent years I have been interested in braid groups and their representations.

Hung Tong-Viet

My main research interests lie in the representation and character theory of finite groups, permutation groups and applications to number theory and combinatorics, and finite group theory in general. I am interested in studying groups or group structures using several important numerical invariants of the groups such as character degrees (ordinary and modular), p -parts of the degrees or character values such as zeros of characters. In permutation group theory, I study derangements, that is, permutations without fixed points, and their applications in number theory and graph theory, permutation characters and permutation polytopes. Recently, I am also interested in studying the influence of real conjugacy class sizes on the group structures.

Adrian Vasiu

My area of research is Arithmetic Algebraic Geometry, which is the common part of Number Theory, Algebra, and Geometry. I am very much interested in moduli spaces, group schemes, Lie algebras, formal group schemes, representation theory, cohomology theories, Galois theory, and the classification of projective, smooth, connected varieties. My research is focused on:

1. Shimura varieties of Hodge type (which are moduli spaces of polarized abelian varieties endowed with Hodge cycles),
2. arithmetic properties of abelian schemes,
3. classification of p -divisible groups,
4. representations of Lie algebras and reductive group schemes,
5. crystalline cohomology of large classes of polarized varieties, and
6. Galois representations associated to abelian varieties.

Jonathan Williams

I am a low-dimensional topologist mainly interested in smooth 4-manifold topology. This entails a broad range of ideas like knot theory, symplectic topology, n -parameter deformations of Morse functions for $n < 4$, and special fibration structures like open books and Lefschetz fibrations.

Emmett Wyman

I study Laplace-Beltrami eigenfunctions of large eigenvalue and how their asymptotics relate to the geometric or dynamical structure of the space in which they live. This area is related to classical and quantum physics and number theory.

Xiangjin Xu

My research interests are mainly in two fields.

I. Harmonic Analysis on Manifolds: Study the spectral theory of elliptic operators (Laplace operator and Schrödinger operator) on compact and complete manifolds. Mainly focus on the growth estimates (L^p , bilinear, and gradient estimates) of eigenfunctions, multiplier problems, resolvent operators and Carleson measures on compact and complete manifolds.

II. Geometric PDEs: Study Li-Yau type gradient estimates and the heat kernel estimates for heat equations, Schrödinger operators and degenerate parabolic equations on Riemannian manifolds (and Finsler manifolds, metric measure spaces) with negative Ricci curvature bound. Study the control theoretic estimates for the linear and nonlinear parabolic and hyperbolic PDE systems and the existence of periodic solutions of Hamiltonian systems.

Qiqing Yu

My research interests are mainly in three fields.

1. Survival analysis. Since 1987, I have been working in this field, in particular on modeling the interval censored data, studying consistency and asymptotic normality of the generalized maximum likelihood estimator (MLE) of survival function or the semi-parametric estimator under linear regression model.
2. Statistical decision theory. My thesis was on admissibility and minimaxity of the best invariant estimator of a distribution function.
3. Probability model and computing methods for pattern recognition in the Genome project.

Shelemyahu Zacks

During the last ten years my research in statistics and applied probability has been focused on four areas:

1. Prediction Theory for Finite Populations
2. Reliability Theory
3. Adaptive Procedures and Optimal Designs
4. Distributions of stopping Times Defined on Compound Poisson Processes.

Each one of these areas is very wide and rich with problems. The type of problems I have concentrated on are:

1. Optimal predictors of population quantities, like the population total or the population variance. These include Bayesian predictors, minimax admissible, etc.
2. Sequential methods for software testing (detection of errors). In addition I study the operating characteristics of sequential stopping rules for reliability testing and estimation.
3. Adaptive decision procedures are connected with various procedures which converge to the optimal ones, when essential parameters are unknown. These contain "Bandits Problems", the sequential search of optimal dosages in Phase I Clinical Trials, etc.
4. In this area of research I develop the distributions of stopping times, or first-exit times of compound Poisson processes. The results have wide applications in queuing theory (distribution of the length of the busy period), in inventory theory, dam theory and risk theory for insurance.

Thomas Zaslavsky

My research is in combinatorics, especially matroids and their connections with combinatorial geometry and graph theory. The main topic of my work is signed, gain, and biased graphs. These are graphs with additional structure

that leads to new graphical matroids and other new kinds of graph theory, such as colorings and geometrical representations, of which ordinary graphical matroids, colorings, etc., are special cases. In combinatorial geometry I work on arrangements of hyperplanes and lattice-point counting.

Jia Zhao

I position myself as an applied and computational mathematician, aiming to strike a balance between mathematical modeling, numerical analysis, high-performance computations, and machine learning, while my application domains are life science and engineering. For further info, please check out my research website: www.zhaojia.net

Sailun Zhan

My mathematical research is at the confluence of algebraic geometry, number theory, and representation theory. Most of my research is related to rational curves on projective varieties. I am also interested in Hilbert schemes of points and p-adic/motivic methods.

Gang Zhou

1. mathematical physics: the long time behavior of Schrodinger-type equations, relations between quantum and PDE models, non-equilibrium statistical mechanics,
2. geometric analysis: mean curvature flow and Ricci flows by methods different from the classical ones, formation of singularities in finite time, flow through singularities.

Research interests of those who used to work in the department

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