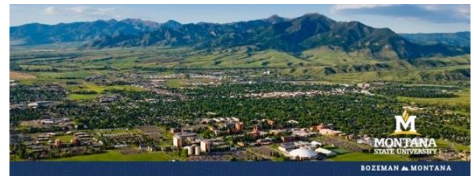
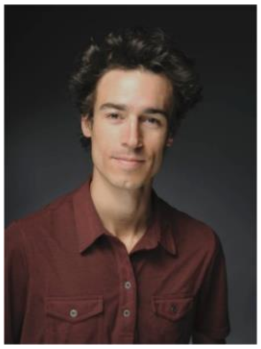
Montana State University
Department of Mathematical Sciences Faculty



Mathematics Faculty



Dr. David Ayala
My work uses methods in algebraic topology to study manifold topology. Specifically, my work concentrates on how to obtain sensitive manifold, and embedding, invariants from purely algebraic, or higher categorical, input. Such manifold invariants are inspired by rigorous approaches to quantum physics, and abide by a nuanced local-to-global principle. My work develops factorization homology as the essential maneuver connecting higher categories and manifold topology. Through factorization homology, unforeseen dualities among manifold invariants, notably invariants arising as partition functions of quantum field theories (QFTs) thereon, correspond to deformations of higher categorical structures (Koszul duality). This duality often exchanges affine with non-affine input, thereby explaining and resolving certain divergence issues in QFT.

Here is the essence of the idea. Fix a compact Riemannian manifold M. Fix a particle type on this manifold (which is to say a vector bundle over M, whose local sections are equipped with an action of its Lie algebra of infinitesimal isometries of M). Consider one such particle in M. Compactness of M grants a lowest-energy state of the particle. Self-interference of this particle results in some 'resonance' for where one might find it in M. This resonance is governed by a complex number Z(M). This feature of lowest energy, grants that Z(M) is independent of the Riemannian metric. Therefore, Z(M) is an invariant of the manifold. Furthermore, one might imagine finding Z(M) by chopping M into chambers, and understanding the resonance of the particle in each chamber, compatibly across interfaces between these chambers. The effect is that one can, in principle, calculate Z(M) through a local-to-global principle. Formalizing, and organizing, this procedure is conveniently accommodated through higher category theory, and its relationship with stratifications. Poincare' duality intertwines with a duality among higher categories (Koszul duality), resulting in peculiar dualities among such manifold invariants.

Dr. Blair Davey
Blair Davey's research interests are in partial differential equations (PDEs), harmonic analysis and geometric measure theory (GMT). She studies the theory of elliptic PDEs through the perspectives of unique continuation, solvability of boundary value problems, and the connections to parabolic theory. Her work on unique continuation is motivated by Landis' conjecture, which seeks to determine the optimal rate of decay at infinity of entire solutions to Schrodinger equations. She uses harmonic analysis techniques to understand when systems of generalized Schrodinger equations are uniquely solvable subject to certain boundary conditions. She relies on probabilistic tools to understand the non-trivial connections between elliptic and parabolic theory. She also works on GMT, studying purely unrectifiable (fractal) sets, generalized Favard lengths, the Besicovitch projection theorem, and various quantifications of these notions.

Dr. Lisa Davis
Dr. Davis's research interests are in the areas of computational mathematics, sensitivity analysis and mathematical modeling of biological and ecological processes. She studies efficient and robust computational algorithms for solving problems in various areas of applied mathematics. She has a background in finite element methods as well as finite volume methods for various numerical simulation of systems governed by partial differential equations. Her research has received national funding from the NSF, DEPSCoR and AFOSR. Her most recent work is in the area of model construction and numerical simulation for bio-polymerization models. She has taught courses ranging from first year calculus to graduate level courses in numerical analysis and linear algebra. Lisa

enjoys directing PhD students, and she is currently the Chair of the Graduate Program Committee. She is also active in advising and mentoring students involved in undergraduate research programs such as the Undergraduate Scholars Program and Montana INBRE. She is currently the PI on a grant focused on broadening the career pathways for doctoral students in Mathematics and Statistics through interdisciplinary research projects, internship opportunities and targeted course work and professional development called MT PEAKS.

Dr. Jack Dockery

Dockery's research interest are in the area of mathematical modeling, analysis and numerical simulations of complex systems. He has written papers on traveling waves in the Belousov–Zhabotinsky reaction, biofilm modeling, population dynamics, chemical reaction systems, coupled systems of neurons, fluid dynamics, systems biology modeling of quorum sensing, traveling waves in coupled neuron systems, pattern formation in reaction diffusion systems and bifurcation analysis of Burgers equation. He has a current research project on quorum sensing using deterministic and stochastic modelling, funded through the National Science Foundation's collaborative research program with Martin Schuster, a microbiologist at Oregon State University.

Dr. Tomas Gedeon

Tomas Gedeon is interested in mathematical biology, in particular cell biology, gene regulation, immunology and microbial communities. The main focus of his research is development of mathematical techniques that allow description of dynamics of gene regulatory networks. In collaboration with K. Mischaikow from Rutgers and S. Haase from Duke University, they developed an approach based on switching network models that allow combinatorization of phase space and parameter space, and allow finite characterization of dynamics in terms of Morse graphs. In collaboration with Dr. Carlson from Chemical and Biological Engineering (CHBE) Department at MSU he works on understanding metabolic exchanges that allow microbial consortia to outcompete monocultures in nature. In collaboration with Prof. Davis, he works on models of the transcription process in prokaryotes, where the main emphasis is on the understanding the constraints that this process imposes on speed of mRNA production, and ultimately, the growth rate of the bacteria. Finally, in collaboration with Prof. McCalla from Chemical and Biological Engineering Department at MSU they work on development of set of chemical reactions that could amplify micro RNAs, that indicate presence of a certain diseases like cancer, malaria, TB and traumatic brain injury. Several of his projects are currently funded by federal agencies like NSF, NIH and DARPA.

Dr. Lukas Geyer

Dr. Geyer’s research interests are in the area of complex analysis, complex dynamics, fractal geometry, and analysis on graphs. Complex dynamics is the study of iteration of analytic functions in the complex plane. It turns out that even very simple families of functions exhibit very complicated behavior such as fractal invariant Julia sets and very complicated bifurcation loci, most famously the boundary of the Mandelbrot set for a family of quadratic polynomials. His own work in this area has mostly centered around small divisor problems and stability of fixed points, periodic points, and invariant circles. Dr. Geyer’s work in fractal geometry has been mostly concerned with questions of conformal dimension of self-similar fractals, studied through analysis on finite graph approximations.

Dr. Ryan Grady

Ryan Grady holds a PhD from the University of Notre Dame (2012). His research entails applying rigorous quantum field theory to understanding of geometry and topology of manifolds. Here, a 'manifold' is an abstraction of a set of arrangement-states of physical system. Passing to a 'quantum' physical system involves examining solutions to a wave equation on the given manifold. It is a well-developed research program within algebraic topology to ask how much about the given manifold can be recovered just from knowledge of how quantum particles 'resonate' within it. Motivated through this program, Ryan's work uses abstract algebra, topology, and multi-variable calculus to study abstract geometry. Ryan is very interested in advising at both the undergraduate and graduate level.

Dr. Samuel Gunningham

Dr. Gunningham's work broadly in the field of Geometric Representation Theory. His research utilizes ideas and tools from all over geometry, topology, mathematical physics, and related areas. Many of the phenomona he is interested in can be understood through the lens of topological field theory (TFT). In physics, TFTs arise when you consider a quantum field theory such that there is no dependence of the spacetime metric (often this will require some ``twist'' or limit of the original theory). Mathematically, a TFT may be understood as a certain gadget that assigns numerical and linear algebraic data to manifolds (i.e. pieces of spacetime). Deep and mysterious dualities predicted by physics (in particular, by string theory) thus give rise to concrete mathematical predictions which can (hopefully!) be precisely formulated and proved. A rich example of this phenomenon is the (geometric) Langlands program. This program has its origins in number theory, in particular the theory of modular and automorphic forms; physically, it corresponds to so-called S-duality in 4d N=4 super Yang-Mills. The space of states of this theory on a 3-dimensional spacetime slice is closely related to the skein module: a vector space built out of all possible knots and links modulo certain ``skein relations''. One long-term research goal is to understand how Langlands duality manifests itself in terms of knots and links in 3-manifolds.

Dr. Jarek Kwapisz

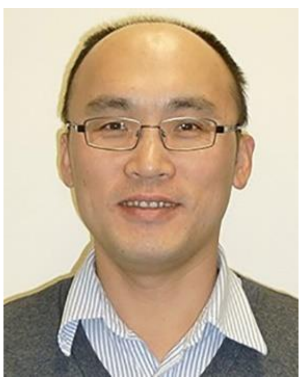
Jarek Kwapisz's intellectual home is in the area of Theoretical Dynamical Systems (DS), which studies qualitative behavior of systems that evolve in time according to some fixed transformation rule (e.g., resulting from a differential equations governing a real-life system). DS methods, developed originally for problems of celestial mechanics, now permeate mathematics and inform many other scientific applications. The connections are often startlingly productive and extend into seemingly unrelated areas, like number theory. In particular, one of Jarek's main research streams concerns aperiodic tilings of space that model quasicrystals. (Such tilings can be viewed as dynamical systems with multidimensional time.) He also has on-going projects in theory of formal languages, Anosov maps on manifolds, geometry of fractals, non-linear fiber optics, and quantum communication.

Dr. John Lund

Professor Lund's research interest has focused on the various applications of sinc function approximation techniques in quadrature and differential equations. He has published in a variety of journals including *Mathematics of Computation*, *Journal of Computational and Applied Mathematics*, *Numerische Mathematik*, *Journal of Computational Physics*, *International Journal for Numerical Methods in Engineering*, *Inverse Problems*, *IMA Journal of Numerical Analysis*, *Numerical Methods for Partial Differential Equations*, and *SIAM Journal on Numerical Analysis*. He is also associate editor of *Journal of Mathematical Systems, Estimation and Control*, co-editor of the volumes Computation and Control I, II, III, and IV and co-author of the book Sinc Methods for Quadrature and Differential Equations.

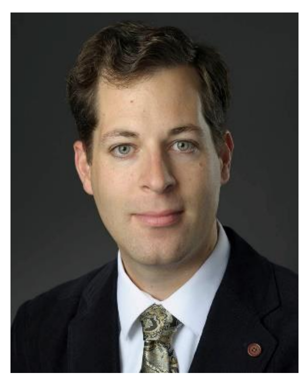
Dr. Scott McCalla
Dr. Scott McCalla applies data-driven modeling, computation, and analysis to understand pattern forming systems stemming from biological, geological, social, and physical systems. His approach is centered in dynamical systems techniques to understand solutions to pattern forming partial differential equations and their instabilities. His work is interdisciplinary and strives to understand varied experiments performed in the Center for Biofilm Engineering on a diverse range of issues such as bacterial ecology and the utility of washing chicken.

Dr. Mark Pernarowski
Dr. Pernarowski is an applied mathematician who has worked on a variety of models in mathematical biology. He has published numerous papers on topics such as the dynamics of excitable media, evolution, and pattern formation in population models, the visual system and genetic circuits. He has applied numerous dynamical system and perturbation techniques to such models with extensive studies of bursting oscillations in the insulin secreting pancreatic beta cell and cortical neurons.



Dr. Tianyu Zhang
Dr. Zhang's research interest includes numerical analysis, modeling and simulation of biofilm-related phenomenon, computational fluid dynamics, and data analysis. His current research projects include mathematical modeling of metabolic activity in chronic polymicrobial communities, role of dynamic microbiome in Cystic Fibrosis lung disease, constraint-based approach to model metabolic pathway selection in a multi-species syntrophic network, modeling and time series analysis of data collected in the waste water treatment plants using activated sludge, and modeling the bio-electrochemical denitrification process in wastewater treatment. His current project in modeling the dynamic microbiome contribution to Cystic Fibrosis lung disease, in collaboration with a microbiologist Robert Quinn at Michigan State University, is funded by an NIH-R01 grant. His teaching interest includes courses related to numerical solution of differential equations (finite difference and finite element methods).

Dr. Dominique Zosso
Dr. Zosso is interested in a broad variety of topics in Data Science, Image Analysis, and Computational Mathematics. Before joining Montana State University, he got both a MSc. and a Ph.D. in Electrical Engineering from EPFL in Lausanne, Switzerland, and spent more than four years as Assistant Adjunct Professor in Computational and Applied Mathematics at UCLA. His research projects range from very applied to somewhat theoretical. For example, with Prof. Diane Bimczok in the Department of Microbiology and Immunology, he is working on an image processing pipeline and statistical framework to study the spatial distribution of specific dendritic cells in fluorescent microscopy images of stomach tissue cells, to support her research on Helicobacter pylorii infections. With Prof. Anja Kunze in the Department of Electrical and Computer Engineering, he works on applying and refining Archetypal Analysis for representation and analysis of high-dimensional large scale biomedical data-sets. They are interested in identifying cliques of cells in Calcium-fluorometry image sequences, namely functional groups of synchronously firing cells in neuronal tissue cultures. With Profs. David Nidever and Amy Reines in the Department of Physics, he is researching how cutting edge



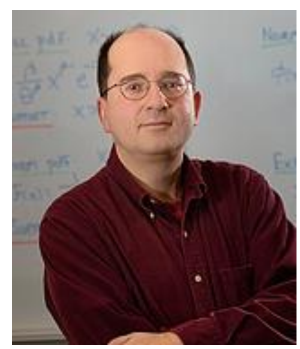
machine learning and data analysis techniques can be applied to astrophysical "Big Data." The techniques they use range all the way from traditional modeling approaches to popular Deep Learning methods. On the more theoretical end of the spectrum, he is focusing on efficient optimization techniques and tricks to make models like Archetypal Analysis applicable to "Big Data" sets. Another current major research effort is "Graph-based Geometric Data Analysis": he is developing a mathematical and algorithmic framework, similar to Topological Data Analysis (TDA), that studies the shape of data in the form of point clouds, using notions of convex and integral geometry. His group currently consists of 1 PhD student and between 5 and 10 undergraduate students (usually as USP/INBRE scholars and Capstone students), which leads to very dynamic and productive group meetings.

Statistics Faculty

Dr. Katharine Banner

Dr. Katharine Banner enjoys working on applied problems that present an opportunity to develop or extend statistical methodology to address research questions in ecology and other sciences, and she is particularly interested in Bayesian methods. She has collaborated with research statisticians, ecologists and bat biologists to develop statistical methodology and visualization tools to help inform the conservation and management decisions of bat populations in North America; with ecologists and engineers who work on designing fish passages for species of concern in MT rivers; and with mathematics educators to develop statistical modeling units for youth that draw upon the youth's community-based problem-solving skills. In all of her work, she firmly believes that when new statistical methods are developed it is the statistician's responsibility to provide tools and practical guidelines (e.g., R packages and data/result visualization tools) so that methods are not used outside of their intended context. She has contributed to the multi-model inference literature to provide such tools for certain applications of model averaging in ecology, and is interested in continuing this work

Dr. John Borkowski



Dr. Borkowski has been a faculty member in the Department of Mathematical Science at Montana State University since 1991 and a Professor of Statistics since 2003. His primary research and teaching interests include experimental design, response surface methodology, sampling, and statistical quality control. His recent research is focused on optimal design of experiments, space-filling designs, designs for mixture experiments, sampling designs having good spatial coverage, and adaptive cluster sampling. He has also been a Visiting Professor at Thammasat University in Thailand since 2005 and Kasetsart University in Thailand since 2009.

Dr. Nicole Carnegie

Dr. Carnegie's research focuses on the intersections between causal inference, infectious disease modeling, and networks. This includes network-based infectious disease models to inform strategies for HIV prevention and methodologic work on making causal inferences in infectious disease settings, where observations are inherently not independent. She has a line of research developing methods for analyzing potential sensitivity of causal inferences to unobserved confounding in a variety of settings, including multilevel models and Bayesian Additive Regression Trees. For fun, she occasionally enters predictive modeling or causal inference competitions using BART.

Dr. Mark Greenwood

Dr. Greenwood is a Professor of Statistics who does research on statistical methods for high dimensional and correlated data. This includes supervised and unsupervised classification and high-dimensional testing problems such as those encountered when working with functional data (data that are recorded or can be treated as curves). Additional interests include hierarchical and generalized additive models and methods for incorporating measurement error into statistical models. Application areas include health outcomes related to Multiple Sclerosis, osteoarthritis, and long-term body mass index changes, longitudinal environmental data related to hydrology and climate change, and multi-level educational data. Dr. Greenwood is also the Director of the Statistical Consulting and Research Services, so is in involved in a wide array of collaborative statistical projects including working with metabolomics data.

Dr. Shinjini Nandi

Dr. Nandi is primarily interested in development of new statistical theory and methodology in the realm of multiple comparisons. Multiple comparisons is a highly active research area in the broad domain of high dimensional statistical inference. Her current research focuses on development of new methods of multiple comparisons to test complex structures of hypotheses that are frequently obtained from a wide variety of scientific studies including but not limited to genomics, brain-imaging studies, astronomical data, etc. The objective of developing the new methods is to identify signals in high-dimensional datasets with greater precision than existing methods, typical metrics of precision being control on false discoveries and power in identifying the true signals. Shinjini is interested in developing such new multiple comparisons methods using both frequentist and Bayesian techniques. Her other interests lie in collaborative research projects that apply statistical methods to analyze environmental and ecological data, and healthcare data. She is currently involved in collaborative projects investigating the risk of developing cardiovascular diseases in diabetic patients, and analysis of prevalence of colorectal cancer and effectiveness of its screening procedures on the US population.

Dr. Stacey Hancock

Dr. Hancock's research interests lie in statistics and data science education. Research projects in this area include: how students use metaphors and metonymies when learning statistical concepts related to sampling distributions and informal statistical inference, how learning and attitudes towards statistics are affected by one's peers in a flipped-format classroom, and developing and defining data science curricula at the undergraduate and graduate level. She is also involved in an NSF grant to bring computer science to rural and American Indian middle school students in Montana through storytelling. Additional research areas include time series analysis, specifically, change-point detection, and statistical applications in ecology.

Dr. Andrew Hoegh
Dr. Hoegh's research is largely focused on Bayesian computation with an emphasis on multivariate, spatial, temporal, and spatiotemporal modeling. Within that realm, Dr. Hoegh works on collaborative projects related to environmental and ecological research and occasionally sports analytics. Some current projects include: modeling grizzly bear movement in the Greater Yellowstone Ecosystem, understanding species composition in Grand Teton National Park, bio-surveillance for aquatic invasive species in the Northern Rocky Mountains, modeling the transmission of Henipavirus in bats, and predicting the next pitch in baseball. Dr. Hoegh leads an active, collaborative research group that currently includes a group of six students and researchers.

Mathematics Education Faculty

Dr. Elizabeth Burroughs
Dr. Burroughs's research interests involve the teaching of mathematical modeling; the connections between the mathematics pre-service teachers study as undergraduates and the mathematics they will teach to school students; mathematics coaching in elementary mathematics classrooms; and gender issues in mathematics education. She is currently leading a grant-funded project to develop materials that incorporate applications of teaching in undergraduate mathematics courses. She also works with Dr. Carlson on a research study concerning the teaching of mathematical modeling in community settings.

Dr. Mary Alice Carlson
Dr. Carlson's research revolves around teacher learning and teacher change in mathematics; innovative formats for teacher professional development; and mathematical modeling. Her current work involves understanding the knowledge bases all youth bring to problem solving situations and using those knowledge bases to develop modeling tasks centered on issues that directly affect rural communities. She teaches mathematics content and methods courses for elementary and middle grades students, as well as a variety of mathematics education graduate courses.

Dr. Jennifer Luebeck
Dr. Jennie Luebeck's research interests are effective models of school-based professional learning for pre-service and in-service teachers (e.g., lesson study, coaching, learning communities, classroom action research) as well as overcoming barriers to providing content-focused professional development for rural and otherwise isolated mathematics teachers. She also is interested in effective uses of online and blended learning to develop mathematical and pedagogical knowledge for teaching and construction of knowledge through mathematical discourse in the online learning environment. Her teaching interests revolve around mathematics content and pedagogy courses for in-service and pre-service mathematics teachers at elementary (K-5), middle (6-8), and high school (9-12) levels, topics in mathematics education for graduate students and qualitative and action research methods for graduate students

Dr. Megan Wickstrom
Dr. Wickstrom is interested in the development of rich, mathematical tasks based on students' thinking. Through this work, she seeks to understand K-16 students' mathematical understanding and perceptions in relation to mathematical tasks and how best to link research and practice to support pre-service and in-service teachers in task development connected to students' thinking. Her work is situated in the domains of geometric measurement and mathematical modeling and is primarily qualitative. She has been published in a variety of journals including *The Journal of Mathematical Behavior*, *Journal for Mathematics Teacher Education*, *Teaching Children Mathematics*, *Mathematics Teaching in the Middle School*, and *Equity and Excellence in Education.* Her teaching interests include mathematics education content courses for the elementary and middle school teachers and methods courses for middle school and secondary teachers. She especially enjoys teaching mathematics education courses with a focus on geometry and measurement.

Dr. Derek Williams
Dr. Williams is interested in students' experiences while learning mathematics, with specific focus on relationships between student engagement with how and what students learn. This line of research also includes: students' understanding of concepts central to calculus and precalculus, students' mathematical reasoning with technology, and working with teachers to develop positive learning environments for each and every student that promotes engagement with rich mathematics learning. He frequently works with graduate and undergraduate students on his research, which have led to peer-reviewed manuscripts and conference presentations. He enjoys teaching Advanced Mathematics for Teachers, Real Analysis for Teachers, Precalculus, and Calculus.

Research Faculty Members

Dr. Breschine Cummins
Dr. Bree Cummins is an applied mathematician working on the dynamical behavior of networks, specifically genetic regulatory networks and social networks. She is working on the design and diagnosis of synthetic biological regulatory networks, the discovery from time series data of cellular networks, and exponential random graph models of social networks. Her research has both strong theoretical and computational aspects, using tools in differential equations and graph theory. She works with undergraduate and Master's students, and has published papers with them in the SIAM Journal on Applied Dynamical Systems, Physica D, and the Bulletin of Mathematical Biology.

Dr. Kathryn Irvine
I am a Research Statistician with the U.S. Geological Survey at the Northern Rocky Mountain Science Center in Bozeman, Montana. My statistical research evolves from collaborations with ecologists that study bats, plants, and trees and are involved with long-term monitoring to inform management of natural resources. I have mentored Statistics students for writing projects and supported graduate research assistants at Montana State University (MSU). Several of my students have participated in writing peer-reviewed papers during their time at MSU. I encourage students interested in applied statistical work with ecological applications to contact me for possible graduate research assistantships, paid summer work, and other opportunities. my USGS profile page

Dr. Brittany Fasy

Dr. Fasy's research interest is in computational topology - a field at the intersection of mathematics and computer science. Her work explores problems such as data on graphs, defining invariants for directed topological spaces, algorithms for topological data analysis, and the mathematical stability of topological and geometric shape descriptors. Her research is grounded in real-world applications, including road network analysis and prostate cancer prognosis.