The University of Arizona

Program in Applied Mathematics

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Greetings from the Chair, Program in Applied Mathematics

Michael "Misha" Chertkov, Chair, Program in Applied Mathematics

Dear Students, Alumni, Professors, and Friends of the Applied Math Program at UArizona,

I hope that this newsletter finds you well. The past year was another unique one, but despite the challenges posed by the ongoing pandemic and other world events, we are proud to report a successful year for the Applied Math Program.

In 2022, our new core curriculum, which launched in 2019, saw a rotation of instructors for the first time. Professor **Laura Miller** taught "Methods in Applied Mathematics" (Math 581a) in the fall and I am teaching Math 581b in the spring. Professor **Chris Henderson** took over "Theoretical Foundations of Applied Mathematics" (Math 584a,b), previously taught by

Professor **Shankar Venkataramani**. Professor **Leonid Kunyansky** taught the fall component of "Numerical Analysis and Algorithms of Applied Mathematics" (Math 589a), and Professor **Misha Stepanov** is teaching the spring component of the same course.

We extend our gratitude to all instructors for bringing their expertise and energy to the core classes and making them modern and of high quality. We are also grateful to **Colin Clark** for his continued effort in the inter-core recitations, greatly appreciated by students, instructors, and the program office. We would also like to extend our warmest congratulations to Colin for becoming a first- time father.

This year brought a change to our super-TAs, now referred to as "recitation instructors". Our new cast includes—**Aaron Larsen** who is teaching Math 581, **Ari Bormanis** teaching Math 584, and **Robert Ferrando** teaching Math 589. All three completed the new version of the core courses for their PhD qualifications.

Our core curriculum has largely stabilized, but we aim to continue its evolution to reflect the rapidly changing field of applied mathematics. We will continue to experiment with different teaching formats. We would also like to invite our members, affiliates, students and alumni to bring new ideas towards developing new and upgrading existing advanced (post qualification) courses in applied math.

We are grateful for the support of UArizona leadership, which has approved our shared hire proposals for the past three years. This has allowed us to bring in new affiliates, including **Marat Latypov** (Materials Science and Engineering) in 2021 and **Charlie Gomez** (School of Sociology and School of Information) in 2022. We are currently working with the Departments of Mathematics and Computer Science to bring in two more shared hires in 2023.

We are collaborating with the Department of Mathematics and College of Science to establish an MSc program in Applied Mathematics. We believe that this will benefit the Applied Mathematics GIDP, which continues to focus primarily on PhD studies, by providing an opportunity for undergraduates to start their graduate studies earlier. The MSc program will also offer more flexibility for students who are employed (often part-time) by our industrial and national lab partners.

With the successful continuation of the Arizona-Los Alamos days, our program remains dedicated to contributing PhD level workforce pipeline for National Labs. The most recent meeting was held in-person in Los Alamos in August 2022, and the next meeting will take place in Tucson/Biosphere-2 in April 2023. We extend collaborations with many other National Labs and Industrial partners – most straightforwardly via joint research seminars and recruitment events for internship and future employments. Raytheon – Applied Math days took place in September of 2002 for the second time. Be sure to check the program website for updates on these activities, as well as seminars, colloquia, working groups, and conferences organized or co-organized by the program.

Finally, I would like to express our collective gratitude to Stacey and Keri for their invaluable contributions to keeping all aspects of the program running smoothly.

Sincerely Yours, Misha.

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Al Scott Lecture: Hannah Kravitz (PhD 2022)

Hannah Kravitz (PhD 2022), Assistant Professor of Mathematics, Portland State University

In April of 2022 I was given the honor of presenting the Al Scott prize lecture for the Program in Applied Mathematics. Though I was never fortunate enough to meet Dr. Scott, he was a postdoc mentor for my collaborator Jean-Guy Caputo. The topics they explored together included Josephson junctions and solitons, topics that eventually lead Dr. Caputo to the field of metric graphs. While visiting Dr. Caputo on sabbatical, my advisor Moysey Brio was introduced to the field of metric graphs which he then brought back to Arizona for me to work on.

My lecture in memory of Dr. Scott focused on the research area that he indirectly introduced me to. I began by defining a metric graph: a series of one-dimensional line segments (edges) of varying lengths joined by junctions (graph vertices). Along with boundary conditions at the junctions, this creates a structure on which PDEs can be solved. As I discussed in my talk, I use the metric graph structure to model a network of populations living at the vertices with travel routes of different lengths between them. This leads to a Susceptible-Infected-Removed model of disease spread in a mobile population, using the structure of a metric graph embedded in a diffusive 2D region with 1D/2D exchange occurring along the edges.

Not being an expert in epidemics or traffic flow, I was originally hesitant to introduce this admittedly oversimplified model. Dr. Scott too approached his work on protein structures cautiously. As he describes in a 1984 interview with Los Alamos Science journal, a mathematical biologist with “some idea or differential equation […] goes around in the biological world looking for a place to apply it, making all sorts of assumptions and approximations that aren’t justifiable from the biologist’s point of view. Biological scientists are sensitive to that […] and rightly so.” However, after working alongside physicists, biologists, and mathematicians, Dr. Scott was able to create a nonlinear model that could be taken seriously. In doing so, he founded the Center for Nonlinear Science which has been able to proliferate his research ideas long after his death.

I too am beginning with a PDE approximation for a biological phenomenon. Populations do not necessarily fit neatly in a metric graph, nor do populations always travel in a way that can be described by simple PDEs. However, I begin with a basic model that can be studied mathematically and refine it over time. It is my hope that my coupled 2D/metric graph model will eventually be accepted by epidemiologists as one option to model disease spread through connected population groups.

After earning my PhD from the Program in Applied Mathematics, I began work as an Assistant Professor at Portland State University in Oregon. Though I’ve only been here one academic quarter I am so thankful that I was able to get my “dream” position right out of graduate school. I have already begun making connections with mathematicians all over the world and look forward to future collaborations at Portland State and beyond. Al Scott worked hard to make math accessible for everyone. He wrote 6 books and numerous articles that are highly readable for even amateur mathematicians. I strive to do the same, both in my teaching and in my research. Having more people understand and appreciate mathematics can only benefit the field.

New Program Affiliate Members

Charles Gomez, Assistant Professor, School of Sociology and School of Information

I am a computational and mathematical sociologist in the School of Sociology and the School of Information here at the University of Arizona. Computational and mathematical sociologist are an exciting arena recently injected with new life from the burgeoning interdisciplinary subfield of computational social science. In fact, many of the techniques and methods bundled together and associated with the more well-known computational social science subfield have their intellectual roots in sociology. This includes agent-based modelling (ABMs) and social network analysis. My research centers on constructing new measures of knowledge production and diffusion between countries. These measures help us to understand the impact of inequalities in the international arena. These issues are of growing concern. Despite the promises of globalization and a more open and flatter world, my work finds that not only are inequalities growing and increasingly excluding ideas and conversations from middle and low-income countries, but the rate of new knowledge generation and novelty may be on the decline as a result.

I use science as my empirical focus. This is for two reasons. First, science as a social institution is the ideal type for studying the generation and diffusion of knowledge. No other human enterprise systematically produces knowledge in the same breadth and depth as science. And as source of large-scale data, studying scientific knowledge is advantageous in its accessibility. The metadata of scientific publications that are publicly afforded allow me to construct proxy measures of knowledge production and diffusion vis-à-vis citation networks, mobility networks, and collaborative networks. The second reason—and the more important one—is because of my own background. I started my intellectual journey intending to become a physicist. I originally hoped to study quantum computing and networks. And as all good story arcs would have it, I took introduction to sociology in my very first year of undergrad. Many of the concepts and ideas piqued my interest, but I naively considered it more of a dalliance than a "true" intellectual pursuit at the time. I wanted rigor! I wanted equations! I wanted models! How boneheaded I was. Thankfully, sociology didn't give up on me. Over time, and after many a late-night reflection, I found a way to suture my methodological training and my insights as a physicist with what's referred to as my "sociological imagination." I remind students and colleagues that sociology was originally dubbed "social physics," so my journey back home was preordained. The Universe is not without a sense of humor.

My current work is a study of how growing international scientific influence is potentially stifling novelty and innovation. Global scientific research output is exponentially growing, researchers have more access to new knowledge, scientists move more readily between countries, and there is greater exposure to international diversity. This all tends to promote better outcomes and solutions in scientific problem-solving collaborations. However, the production of scientific knowledge and, more critically, the attention to this knowledge is concentrated among researchers in elite countries like the U.S. and those in Western Europe. I apply advanced topics models to scientific publication metadata from OpenAlex, a repository of millions of academic papers. I find that these two trends result in a growing global homogeneity as to what is considered important in fields, increasingly dictated by these countries. So, researchers who may otherwise bring a diversity of perspectives inadvertently coalesce around concepts and ideas from elite and overly influential countries instead of generating new ideas. This stifles the introduction of new and potentially innovative ideas from future scientific knowledge production. The resulting rise in unequal global scientific influence inhibits the introduction of novel ideas, threatening future innovations and breakthroughs.

My other projects explore how scientific knowledge is shaped and diffused across national borders. I applied advanced topic models and social network analysis to large-scale scientific publication metadata and used ABMs of collective problem solving to study influence, diversity, and innovation in this context. For one project, I show how the scientific work published by researchers in most middle-income and developing countries are vastly under-recognized, while researchers in the U.S., Western Europe, and increasingly China receive disproportionate attention. This paper was published earlier this year at Nature Human Behaviour. For another project, I combine traditional social network measures of knowledge diffusion using citations to develop a new text-based measure of inequality across 180 fields and 200 countries. Finally, I also use ABMs to show how diverse problem-solving ventures that actively seek out interactions with diverse members outperform similarly diverse teams that only seek out other members based on their performance.

My new project will focus on how scientists negotiate and navigate geopolitical tensions with their careers and collaborations, especially for those in contentious fields like artificial intelligence (AI) research. The study of AI is an exemplar for this. AI is a disruptive technology that aims to automate activities associated with human thinking, including decision-making, problem-solving, and learning. While AI may bring about profound improvements to education, commerce, and medicine, it also poses significant risks related to privacy, jurisprudence, security, and armed conflicts. The rising tension between economically intertwined superpowers, with a focus on a technology with impacts beyond defensive and offensive capabilities, offers a prescient case study. The project will map out the development of fields like AI to explore issues related to international politics, sociology, and economics using computationally intensive natural language processing models and in-depth qualitative analyses of interviews with researchers.

I am also excited for my new class offerings here at the University of Arizona. This includes INFO 514: Computational Social Science, the introductory class for the computational social science graduate certificate. This class will likely be of interest to many students in the applied math GIDP. I take a "choose your own adventure" approach with the class, allowing students to pursue an emphasis on research design or methods, or both.

Finally, I am eager to learn more about students in applied math! This is perhaps one of the most opportune times to study applied math, as the potential exciting applications to the social sciences are unbounded. I am very excited to join the applied math faculty and to hopefully collaborate on future projects together!

Marat Latypov, Assistant Professor, Material Science and Engineering

I never planned to be a materials scientist. Like many school students, I did not even know the field existed. Early on, I was fascinated by physics and astronomy. By the time I was in high school, I was passionate about programming and was sold on pursuing a degree in computer science. However, my score in SAT-like exam was not high enough to get into popular (and competitive) computer science programs supported by scholarships. So, I picked a major with the least competition at the time, which happened to be Physics of Metals. Given my continued interest in computer science, I felt remorse for my choice of the major for a little while.

The turning point was a lecture by one of our materials professors, who said something along the lines "everyone wants to do computer science, while there are tons of opportunities to do programming and computational work in materials science". Years later, after a graduate school in South Korea, two postdocs in Europe and U.S., an industrial R&D experience, and finally one year as a faculty member at UArizona, this sentence still well reflects my work in (now well familiar to me) field of Materials Science and Engineering.

My research focuses on computational and data-driven research of structural alloys. Structural alloys, such as aluminum-, nickel-, or iron-based alloys, represent an important class of materials needed across all essential industries, including energy, defense, transport, and infrastructure. Properties of structural alloys are often the bottleneck for (and enablers of) advanced engineering performance in critical applications. For example, the efficiency of a jet engine is dictated by the highest operating temperature at which the structural alloy constituting the turbine blade can maintain its superior properties. These properties allow the blade to bear mechanical load without failure and without even a slightest change in shape. Pushing the limits of performance by designing new alloys is not a trivial task. The properties and performance depend not only chemical composition but also on the internal structure (microstructure) of the alloys spanning multiple length scales – from atomic structure and defects all the way to features visible by naked eye. The microstructure in turn is sensitive to thermomechanical conditions at which the alloy is processed. It should be clear that the alloy and process design space is vast, whose exploration is further challenged by the time, labor, and cost required for probing each set of parameters. Indeed, every new composition, every new combination of process conditions to be tested require an expensive, time-consuming, and laborious experiments.

These challenges emphasize the need in computational tools for digital alloy design and process optimization. Such tools could allow most of design and optimization iterations to be done on a computer with a significantly reduced need in lab experiments, whose role would become mostly validation. My research aims to make advances towards this Holy Grail of fully digital alloy design. Below, I describe a couple of specific research directions intended to provide a flavor of my current research.

Computational thermodynamics of sustainable alloys. As mentioned, microstructure plays an important role in defining engineering properties of alloys. For example, excellent high- temperature behavior of nickel-base superalloys utilized in turbine blades are provided by precipitation of strengthening particles during a special thermal procedure of artificial aging. Computational thermodynamics is a powerful modern tool for modeling the thermodynamic equilibria of microstructure constituents (phases), including strengthening precipitates. Computational thermodynamics is based on fitting thermodynamic functions (e.g., Gibbs free energies) to experimental data. The current methodology is designed to fit thermodynamic models to experimental data on simple alloys (typically with one, two, and three chemical elements) for subsequent extrapolation to commercially relevant multi-element alloys (often more than 10 elements). The experimental databases and thermodynamic models are currently well developed and optimized for existing commercial alloys. Given the climate change and urgent need in more sustainable technologies, metallurgists are pursuing new alloys, which can consume large amounts of metal scrap and rely less on primary metals extracted from mined ore. Indeed, metal recycling consumes far less energy and emits far less carbon dioxide compared to reduction of pure metals from ore. At the same time, recycling faces numerous challenges. First, in practice, metal scrap cannot be perfectly sorted into different alloy families. Second, pure metals cannot be separated from a mixed scrap. These challenges result in that producing alloys with increased scrap consumption means more complex chemical compositions, potentially very different from the well-studied commercial alloys. The effects of highly multi-element compositions and the presence of tramp elements on the microstructure and properties of alloys are not well understood. Our research aims to address these challenges by developing thermodynamic models that are better suited for a new generation of scrap-friendly alloys. This research includes automated extraction of data from literature using natural language processing as well as building new machine learning models for thermodynamic functions that can rigorously incorporate rich multifidelity experimental data.

Graph neural networks for modeling microstructure. Computational thermodynamics provides valuable insights into what phases (as well as their amounts) can be expected for different process conditions based on their thermodynamic equilibria. At the same time, engineering properties of alloys are impacted by not only the presence of different phases and their amounts but also by their size, shape, and spatial distributions. To capture these effects on properties, we develop novel representations of microstructures and establish microstructure relationships with properties and process conditions. To this end, we use spatial n-point correlations as well as graphs. n-point correlation functions describe the probability of finding a certain microstructure constituent at n points, which is a rigorous approach to capturing spatial distributions of phases or other microstructural features. Many alloys at the length scale of hundreds of microns consist of numerous crystals (typically called grains) stitched together. The interaction between grains has a significant role in overall behavior of the alloy. To efficiently represent these grain microstructures in 3D and allow advanced machine learning techniques, we leverage graphs and networks. To this end, every grain is represented by a graph node. If any pair of grains share a boundary, the corresponding nodes are connected by a graph edge. This graph representation allows us to incorporate rich microstructural information as node-, edge-, or graph-level attributes with the ultimate goal of machine learning. Typical machine learning tasks in this context include prediction of graph-level properties (e.g. property associated with entire microstructure) given graph structure and individual node/edge attributes, or prediction of node- level properties given graph structure and available node attributes. We address these machine learning tasks by training graph neural networks to data obtained from physics-based simulations. The trained graph neural networks serve as fast and efficient surrogate models to much more computationally expensive direct numerical simulations.

I hope these brief research snapshots shed light on the rich variety of problems present in the field of materials science and engineering. There is plenty of opportunities for developing and applying new computational, machine learning, and applied math methods to address materials problems with real-world impact. In this context, I look forward to fruitful interactions with students and faculty of the Applied Math Program. I also invite Applied Math students to my project-based course entitled “Physics-Informed Machine Learning” offered in Fall semesters.

Program Member Spotlight

Ardith El-Kareh, Associate Research Professor, College of Medicine, and Bio5 Institute

We all hate cancer, but how well do we understand this enemy and our tactics against it? How does chemotherapy actually work (hint: it isn’t the faster growth rate of cancer cells)? To what extent does the immune system contribute to cancer therapy successes? Is drug-induced resistance to chemotherapy permanent or transient? How is the cell cycle, which is aberrant in probably all cancers, controlled?

Questions such as these have preoccupied me. I use mathematical modeling to try to answer them.

In trying to understand and optimize chemotherapy, chemoradiation, and combination treatment, I first started exploring the effects of changing schedules and doses. Clinical trials have shown that altering schedules can significantly improve response,but exploring the parameter space clinically is too expensive to be feasible, making the problem well-suited to mathematical modeling. Initially, the idea was to develop an optimization model to describe treatment all the way from injection into the blood to response of cells at the tumor site. I soon realized that available models for tumor cellular response id not do well at describing data, and that this could greatly skew results from optimization calculations. It was clearly worthwhile to shore up cellular pharmacodynamic models, or there would be little hope of getting meaningful optimization results.

This led me to focus on modeling in vitro data for cellular response to drugs, and two-drug or drug-radiation combinations. Such data can show quite complex behavior. Our first models were for single drugs, where we noticed the pattern of diminishing returns on increasing exposure time. Our “peak damage” models were based on the concept that treatment was best described using a time-dependent variable we termed “damage” which depended on kinetics of the drug entering cells, metabolizing, and binding to targets, and that the peak value of this damage over time would determine cell death. These models fit data for commonly used anti-cancer drugs noticeably better than previously proposed models that used integrated measures of exposure.

For drugs with two mechanisms of cell kill, or to model combination treatment, we extended the peak damage concept to "additive damage." Here, we hypothesized that each mechanism added a term to the damage function. In developing these models, I was fortunate to collaborate with Leslie Braziel Jones, who is now a Professor of Mathematics at the University of Tampa, as well as Katie Williams, who earned her doctorate in the Program in Applied Math, and is now a Director at Applied Biomath (Katie's exciting career was profiled in the Jan 2022 issue of this newsletter). More recently I've continued with our peak additive damage model framework for the combination of the two immune cytokines TNF-alpha and IFN-gamma, in collaboration with Maria Liong, an undergraduate in Math and Physiology. That cytokine combination is relevant not only to cancer, but also is implicated in covid-19 cytokine storms.

Another question I'm interested in is how transient chemotherapy resistance is. I'm intrigued by findings of MCB professor Andrew Paek, suggesting that resistance is determined by randomly fluctuating levels of certain intracellular proteins. I'm developing a model to quantify how this affects response to multiple cycles of drug exposure. The paucity of models for multiple drug exposures is remarkable, given that clinically, nearly all cancer patients are given multiple cycles of treatment.

The surprisingly complex question of how chemotherapy actually works led me to the immune system as a possible source of answers. Evidence has accumulated that chemotherapy and radiation, which were once thought to work exclusively through direct tumor cell kill, can also be immunostimulatory. In exploring this, I was fortunate to collaborate with Alain Goriely, a former director of the Program, and Applied Math graduate student Mark Robertson-Tessi, who is now at the Moffitt Cancer Center. We developed models for interactions between the adaptive immune system and a tumor. A few years later I had the privilege of working with Applied Math graduate student Victoria Gershuny. Her dissertation evolved into a fascinating exploration of the role of the immune system in a commonly used chemotherapy regimen for colorectal cancer, as well as the many roles of the highly pleiotropic cytokine IFN-gamma. Her findings were thought-provoking, and led me to rethink the contact-kill model for T cell kill of tumor cells that is used in every mathematical model of tumor-immune interactions that I've seen so far, including our own. Subsequent to Victoria's graduation I've been working on this problem of developing mathematical models for what T cells inside a tumor are in fact doing, and Maria Liong has joined me in this. As with cellular pharmacodynamics, this is a case where some retrenchment to shore up a component model has been necessary before returning to use it in a larger model.

Another plausible explanation for how chemotherapy works may be that it exploits the dysregulation of the cell cycle in probably all cancers, which has led to my interest in modeling cell cycle control. Katie, Tim Secomb, and I have a manuscript with a new model for cell cycle control currently under review in the Journal of Theoretical Biology. Tim Secomb, who is a former director of the Applied Math program, has been an exceptionally helpful mentor to me, and I'm very appreciative of his support and contributions to my research. I am grateful for all the connections I've had with the Applied Math program, which have made my research more exciting.

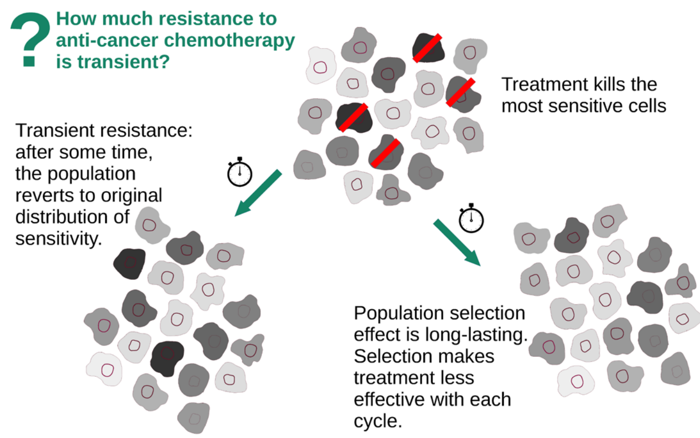


Figure caption: Mathematical modeling for multiple cycles of drug exposure must account for whether acquired resistance is transient or permanent, an active area of research.

Jack Hoppin (PhD 2003) CEO of Ratio Therapeutics

What a great time graduate school was! Okay, maybe not the first couple of years from a personal performance perspective, but after I squeaked (and I mean really squeaked) by the written quals, I really had a fantastic time at the UofA. **Joceline Lega**, classmate **Emily Lane**, **Michael Tabor** and numerous others really took A LOT of their precious time to get me through those years and I am forever indebted for their patience. They made me a much better student and prepared me well for challenges that lay ahead. I was one of many in the program that joined **Harry Barrett's** group and happily experienced expanded scientific horizons from day 1. The Barrett lab at that time with **Eric Clarkson**, **Matt Kupinksi**, **Don Wilson**, etc. was really an incredibly exciting place to work with a lot of students and faculty working together on medical imaging problems. It was a great education.

I will get to what I have been doing for the past 20 years in a moment, but as I sit here flooded with some great memories, I wanted to share one of that changed my course quite a bit – so please indulge me. Just prior to heading to Los Angeles to visit my brother for Thanksgiving break in my first year, I ran into **Emily Lane** and her husband Chris North (with hindsight, I was sort of their first kid). They were headed off with a group to go rock climbing somewhere near Las Vegas. Having worked for many years delivering pizza in my childhood state of New Jersey (God's country as I like to refer to it), I followed what was our tradition of emptying one's pockets for anyone headed to a casino. I had four dollars. I flew to LA and in addition to seeing my brother, I reconnected with a good friend from college Janna Murgia (I promise that will become relevant). I got to LAX for my return flight with exactly zero dollars to my name x=$0. The great Southwest offered a food and flight credit to be bumped a few hours and I literally sprinted to the counter (no one was seriously injured). While I knew that I would ultimately return to some food in my apartment for subsistence in the coming days, at that moment the McDonald's voucher was huge. Regardless, when picked up upon my return by Emily she handed me four dollars (I had forgotten about that) along with my $140 in winnings!!! Side note - they actually had to add a dollar as there was a $5 minimum – they drove to the casino in their climbing gear, walked around, placed the bet and returned to camp – what I would give for a video.

So back to the education and subsequent career. In the summer of 2003, I defended, drove cross country with and got married to Janna Murgia in Maine (yep – great trip to LA!) and we moved to Aachen, Germany – all of this in a 4-week period. We enjoyed the next few years in Europe. The first two of which I spent as a post-doc with a Humboldt Fellowship at the Research Center Juelich working for Nils Schramm on the development of a microSPECT imaging system for use in preclinical research. An American company by the name of Bioscan decided to license the technology and I decided to make a righthand turn and go into industry. We spent the last year of our stint in Europe primarily in Budapest developing the imaging system in collaboration with a gamma camera company by the name of Mediso; I likely should stop and indulge you with more stories from that era but will resist the temptation. I served as the project then product manager for what was a very intense effort. Janna got her MBA and we moved to NYC where I continued the effort, effectively living on an airplane traveling around managing the product, learning quite a bit across a broad spectrum of research topics beyond tomographic imaging. The imaging system we had developed enabled a novel way to study the dynamic biodistribution of drugs in small animals. By 2008, the system was in 50 or so large-scale university and pharmaceutical laboratories, and I was rather obsessed with the data we could generate. Inspired by a request from a pharmaceutical researcher in Japan, I decided to start a software and services company with a focus on generating great data and address an unmet need of properly visualizing, processing and reporting on such image data. Along with my Juelich officemate Christian Lackas, my Barrett-lab officemate Jacob Hesterman and my wife Janna, we founded Invicro with a mission to do just that in October of 2008. Janna and I moved to Boston, launching the company in our apartment while leveraging use of an imaging laboratory at Northeastern University. We had a customer, some software and a very sincere mission to help people study life-changing therapies. With hindsight it was not particularly well thought through…

Over the next 9 years through organic growth and acquisitions we expanded Invicro on just about all fronts: from discovery into clinical research, from radiology into pathology, from an apartment to an international organization. During that period, we grew at a compounded annual growth rate of 85% employing 350+ people (including 75 PhDs or MDs and 60 data scientists) across 5 discovery labs and 2 imaging centers dedicated to clinical trials. By 2017 we were running around 150 discovery projects and supporting something on the order of 70 clinical trials per year. Much of the work entailed the pharmaceutical biodistribution and imaging biomarker studies with application in various therapeutic indications, primarily solid tumor cancers and neurodegenerative diseases. In 2017, Konica Minolta approached us with a novel technology for doing quantitative immunohistochemistry and we sold the company to them and joined their Precision Medicine group. I stayed on as the CEO of Invicro for a year and then served as the President of their Precision Medicine group comprised of Invicro, their digital pathology division and Ambry Genetics (a large-scale hereditary cancer germline genetic testing company 1000+ people). After 12 years of serving as a CEO in some shape or another I decided to retire in late 2020. Given the quick synopsis of that 12 years, it may sound more "businessy" than technical, though the job was actually very technical throughout.

In my retirement, I turned my attention to being an active director of multiple companies that I had either co-founded and spun out of Invicro or had worked with in some capacity. To be open, I failed miserably at retirement. One of the companies I was helping was a spinout of Weill Cornell named Noria Therapeutics focused on developing targeted radiotherapies (tumor- targeting drugs radiolabeled with beta or alpha emitting isotopes with a goal of delivering significant dose, e.g. >80Gy, to the tumor per cycle – a safer, more

effective alternative to chemo and external beam radiation – see Lutithera and Pluvicto). Cornell Professor and Noria founder John Babich had approached me/ Invicro in 2018 to work on pharmacokinetic modeling and dosimetry of their drugs. It is a long story, but I ultimately joined as lead director and we sold the prostate cancer drug portfolio to Bayer Healthcare in 2021. Simultaneous to that sale we founded Ratio Therapeutics to go all-in on the mission of developing cancer therapies using radiolabeled drugs. We are in start-up mode with 20 employees (15 PhDs including Jacob Hesterman – and again, very interdisciplinary!) and move into the laboratory / headquarters we built in the Seaport next month (Feb 2023).

And now to the important stuff! Janna and I live in South Boston with 6 year-old daughter Tess and 4 year-old son CJ and I while I dislike the Red Sox – the city has been good to us.

Thanks for reading. I can't say enough about my education at the University of Arizona. I would add that I am forever indebted to fellow alum, undergraduate advisor and good friend to this day Ed Soares for pushing me (relentlessly) to head to Tucson.

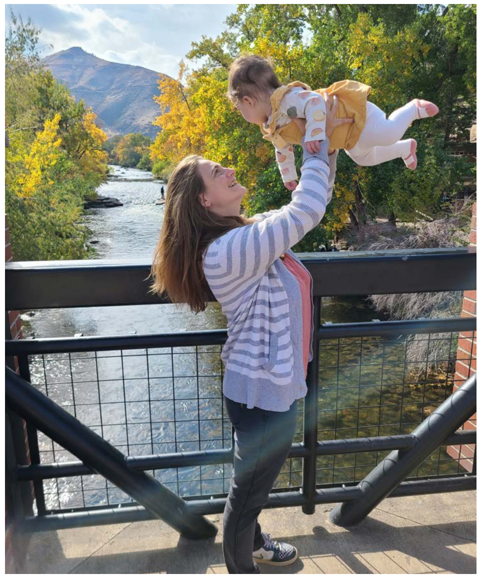
Victoria Gershuny (PhD 2019) Scientist, Center for Drug Evaluation and Research, FDA

When I was an undergraduate student at the University of Colorado, I attended a talk given by a scientist working at Eli Lilly, a company known for pharmaceuticals such as Prozac and insulin. His work focused on using mathematical modeling to predict how a drug would perform in human clinical trials based on the outcomes of mouse studies. It was right then and there that I decided I wanted to apply math modeling to translational medicine and get a PhD in applied math, with a focus on drug dynamics.

Within the first month of joining the Applied Math Program at the University of Arizona, I immediately started working with **Drs. Ardith El-Kareh** and **Tim Secomb** on a project focused on optimization of chemotherapy. This work included developing models of drug and cell dynamics, learning the complexities of the human (and mouse) immune responses, and a significant amount of parameter estimation; all of which were vital skills for the pharmaceutical industry. My final year as a graduate student, a U of A Applied Math alumna recommended I go to the American Conference on Pharmacometrics (ACOP), the premier conference for quantitative scientists from the pharmaceutical industry, and there I made connections that ultimately turned into my first job after finishing my PhD at the US Food and Drug Administration (FDA).

The FDA's role is significantly greater than just the review process of incoming drug proposals from pharmaceutical companies. Outside of drug approvals, the employees of the FDA do a substantial amount of independent research, write policies that shape pharmaceutical approaches, and develop tools to aide in drug development. Joining the Division of Applied Regulatory Science, I was able to focus on novel research with a regulatory and policy focus.

In this division, I have been part of a multidisciplinary team that has answered questions ranging from whether ranitidine converts to N-nitrosodimethylamine (NDMA), a probable human carcinogen, in human subjects to whether opioids combined with different psychotropic drugs cause severe respiratory depression. Using the math modeling and statistical knowledge I gained through my time as a student in the applied math department, I have been able to combine results from clinical trials conducted by the FDA, data and models published in literature, and data provided to the FDA to answer a multitude of questions that fill gaps in regulatory knowledge. One of my recent projects aims to make it easier and less expensive for pharmaceutical companies to develop biological drugs. When a biological product is initially approved by the FDA, it requires a full complement of safety and effectiveness data. A potential biosimilar candidate is then compared to this "reference" product to ensure it is highly similar and there are no clinically meaningful differences between it and the original biologic in terms of the safety, purity, and potency. As opposed to a full clinical trial that must be conducted for the original product, comparative clinical efficacy studies may not be needed to establish biosimilarity if there are sufficient data in humans showing that the drug concentrations are the same and the drugs have the same effects in the body to reduce any uncertainty that there are differences between the two products. A biomarker is anything physiological in the body that can be measured relating to the drug's mechanism of action, that can elucidate such product differences. Whereas biosimilarity has previously been established using biomarkers when they directly correlate to the clinical outcome, my project focused or two specific IL-5 inhibitors for which



the biomarker and clinical outcome are not as clearly tied. Mepolizumab and reslizumab are used to treat, among other things, eosinophilic asthma. Their biomarker, eosinophils, is directly related to mechanism of action of the drug, but not directly related to the clinical endpoint of asthma exacerbations.

Just as I did as a graduate student, a significant part of this project involved developing a model based on mechanisms proposed in literature and estimating parameters to predict how drug concentration would affect eosinophil counts and what the overall study variability would look like for different doses, subject populations, biomarker measures, cell assays, and methods of estimating baseline eosinophil counts. These results were used to determine a dynamic range, where eosinophils could be used to differentiate between different doses (or different products). Although prior FDA policy was to use subtherapeutic doses because they are more sensitive for detecting product differences, the results show that high intersubject variability in biomarkers necessitates the use of higher doses for biosimilarity studies.

This project is one of many where I get to utilize the quantitative skills I gained as a graduate student to contribute to exciting and novel research. I feel so fortunate to be a part of an organization that on a daily basis answers questions that impact millions of people across the country. I am so excited to have the kind of career I envisioned when I was listening to the presentation as an undergraduate student. To all of the current graduate students, I just want to remind you how valuable the skills you are gaining now will be in your future, and that when you leave graduate school and go off into the world, you will be working with a team of people as the resident expert in your field! Best of luck!

On a personal note, since finishing my PhD at the U of A, I got married to a fellow Tucsonite (and volunteer with S.Y.STEM Coalition) David Jones. In May 2022 we welcomed a baby girl, Anastasia, who is currently by my side as I write this.

Disclaimer: The findings in this presentation reflect my views and should not be construed to represent FDA's views or policies. The mention of commercial products, their sources, or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products by the Department of Health and Human Services.

Congratulations

Congratulations to Misha Chertkov for recently being named AAAS Fellow! Following a tradition that began in 1874, the American Association for the Advancement of Science Council elects a new class of scientists, engineers and innovators as AAAS Fellows each year in recognition of scientific and social achievements. The new class of 506 fellows was announced on January 31, 2023. As one of only five UofA recipients, **Professor Michael "Misha" Chertkov** is being recognized for "using methods of statistical physics to make profound contributions to our understanding of diverse systems, such as the power grid, machine learning and turbulence." The new Fellows will receive a certificate and a gold and blue rosette pin (representing science and engineering, respectively) to commemorate their election and will be celebrated in Washington, D.C., in summer 2023.

https://news.arizona.edu/story/five-uarizona-researchers-named-aaas-fellows

David Love (PhD 2013), Manager, Chat Bot Development, American Express

It's been nine years since I graduated from the Applied Math program, but I carry the knowledge I gained with me every day. In this profile I'd like to give an update on my career since I graduated, provide some advice as the person on other side of the interview process. And reflect on some of the skills I've built in the transition to industry.

Since graduating in 2013, I've spent all 9 years as a data scientist at American Express. In this time, I think my career has gone through three distinct stages.

The first stage of my career was as an individual contributor working on a relatively individual project: I was to take historical data of fraudulent transactions and try to identify merchants that were the source of compromised card information. Combating credit card fraud can be a fascinating topic: individual fraudsters tend to work in consistent ways over time, which we can identify and use to link fraud events together, inform the merchants, and protect our card members from future fraud.

While in the Applied Math program, I had studied probability and mathematical optimization but never the machine learning I was using in this project. Fortunately, the skills I developed in the program were a great foundation for quickly learning on the job. Those courses, along with work in numerical methods, taught me how to think about the ML methods I was learning, what to expect, and how to dig into them when I saw something I wasn't expecting.

In my career's second stage, I moved into building tools to help my larger team. It started after I thought I could solve a small problem my group was having. The distributed compute systems we had available weren't quite what my team needed to accomplish our modeling work, but I thought I knew a way we could build a solution. Volunteering for this problem became a turning point in my career, and I began to get more machine learning engineering work coming my way. Building internal-use data products became my primary role for several years. I made tools to assist with feature selection, feature engineering, and managing data quality.

I'd like to give an example of one of the more influential products I built. At American Express, we have many machine learning models that get refreshed regularly, and when we retrain these models we want to know what is different within the data. My most-used product specialized in identifying the significant differences between the old and new data sets, highlighting what they are in an understandable way.

Again, this phase of my career was an outgrowth of my time in the Applied Math program. While at UA I developed an interest in computational reproducibility and reliability. These skills, nurtured by learning from The Software Carpentry and working with our Software Interest Group, laid the groundwork for the second stage of my career.

The third and latest stage of my career has been as a team leader. For the last two years I've been part of the natural language modeling team, leading the data science efforts for our chat bot. My team is responsible for building and maintaining important AI components that allow for interacting via natural language, which include:

- Intent detection: reading the text of a customer to determine what they're asking or what they need. This is the most important part of the chat automation process. If this step goes wrong, there's little that can be done to make automation possible for that chat.
- Named Entity Recognition (NER): many chats require customers to give us specific information to answer their question or complete their request, e.g., identifying a specific card, transaction, or merchant. NER is the process of finding those important pieces of information within the text they send us.
- Sentiment analysis: identifying how a person is feeling in text is often tricky! But if someone is having a poor experience, we want to be sure we can fix it, often by moving the chat away from a bot and to a human agent.

But there's still so much more that can be done in language processing! New techniques are being developed all the time and our team is always looking for the best ways to help not only our customers, but our human agents as well. I'm very excited for what new is to come in 2023!

Let's talk about the job search. I'd like to start with something a job candidate can work on right now: set up a good GitHub

page describing your projects. What I like to see in a GitHub page includes:

1. A good readme. This should explain the project and highlight some of the most interesting results. It's always best if you have some diagrams to explain what the project does and highlight a few of the best results with understandable and professional looking plots. I like Plotly, which can create interactive graphics that work in static web pages.
2. I often take a look at the code, so make sure it adheres to good coding standards of the language you're using. We use Python, so I like to see code that follows PEP8, that has well-written doc-strings.
3. The last two points can be combined with a well-written notebook. GitHub will parse and display notebooks nicely, so it's a straightforward way of showing both your communication and coding abilities.

A well put-together page showcasing your research results and some of your actual work really helps you stand out from the crowd.

Your GitHub page will be a constant through many job applications, but you can also tailor your resume to the job you're applying to. I often will go through a few keyword searches on a resume: NLP, Language, BERT, Neural Network. If none of those come up, then XGBoost, Catboost, Python, Scikit Learn.

Outside of academic work, an internship is a nice bonus, but not always required. It shows that you've worked in a non-academic setting, but not having any wouldn't be a deal breaker for me. Finally, as I look back on my career, there are several skills that I learned after I started my job. The first of these is SQL. My academic work never required that I work with any databases, so I learned a bit of SQL as I started the job hunt. But this is a fundamental skill for working with data in any application, and one that's transferable to big data applications as well. I would recommend becoming familiar with how SQL works and how to pull data out of databases as you're starting to look for work in industry.

A second skill I started using more in industry is regular expressions. Regular expressions are ways of defining patterns in text to find them, but they're very helpful in many applications, including cleaning and learning about data, or even learning about code that someone else has written.

For soft skills on the job, you'll need to be presenting to people who aren't technical. Building your communication skills in schools is extremely helpful. Work on visualization, work on controlling the amount of information you put into presentations at any one time and helping your audience to know what they need to be paying attention to at that time. Further, organizations like Toastmasters will give you the opportunity to fine tune your speaking skills with relevant and helpful feedback in a very supportive environment.

I hope everyone is looking forward to an exciting 2023! Since 2020 I've been working fully remote and I'm back in Tucson. Always happy to meet anyone in the program for a chat, or to connect on LinkedIn.

Current Student Profiles

Brian Toner (4th Year Student)

After completing my undergraduate degree at the College of the Holy Cross in Worcester, MA, medical imaging solutions for pre-clinical and clinical drug trials that was co-founded by **Dr. Jack Hoppin**, another alumnus of the Arizona Program in Applied Math. This job was my first exposure to the world of medical imaging and image analysis, and I was immediately drawn to how imaging research could improve both drug development and clinical diagnosis. The research problems that interested me the most combined biology, image science, and mathematics in a way that inspired me to go back to school to open more research opportunities. The University of Arizona Applied Math Program was already on my radar because of co-workers who had obtained PhDs in various fields at the University of Arizona. However, after I attended the recruitment weekend at Arizona and learned about the interdisciplinary research that students were involved with, I knew that I wanted to come here.

My first two years in the program were spent persevering through rigorous coursework with the help of classmates in my cohort and gaining valuable teaching experience as a TA and instructor in various courses. When I was not working on problem sets or lesson plans, I carved out time to do RTG projects with several

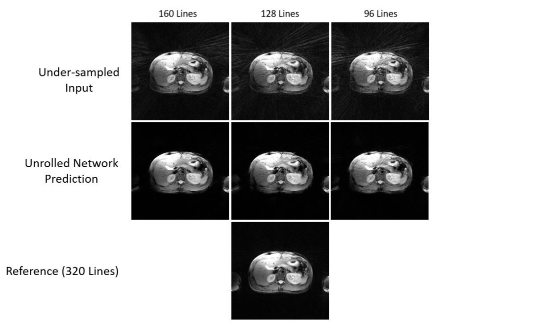


Figure 1: Results of using unrolled networks with data consistency to make predictions (middle row) of highly sampled targets (bottom row) from under-sampled inputs (top row). The number of lines refers to the amount of data used in the reconstruction.

Figure 1

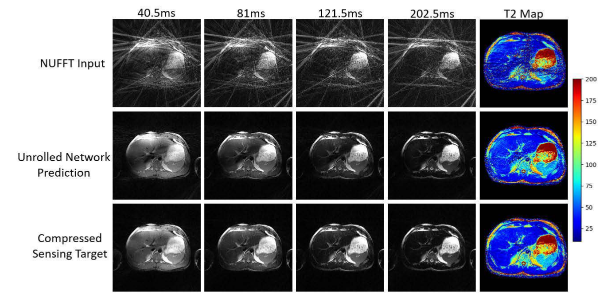


Figure 2: Results of using unrolled networks with data consistency to make predictions (middle row) of compressed sensing reconstructions (bottom row) from inputs that used non-uniform FFT reconstructions (top row). Columns represent different TE contrasts with a T2 parameter on the right-most column.

Figure 2

professors that worked in bioinformatics and medical imaging. When not in Tucson, I spent two summers interning with the Food and Drug Administration on projects that focused on applying machine learning techniques to tasks relevant to mammography imaging. In the Summer of 2020, I trained a convolutional neural network (CNN) classifier to distinguish solid masses from cysts in breast images (Makeev, Toner, et al https://doi.org/10.1002/mp.15005). This was the first project I worked on using CNNs for medical imaging tasks. The Summer of 2021 I returned to explore the use of generative adversarial networks to predict full angle CT reconstructions from limited angle digital breast tomosynthesis images. These internships allowed me the opportunity to explore machine learning applications to medical imaging and gave me valuable experience working alongside the FDA's Division of Imaging, Diagnostics, and Software Reliability. Both these projects also gave me the opportunity to present my work at the SPIE Conference in Medical Imaging.

At the beginning of my third year at Arizona, I officially joined the research group co-led by **Dr. Maria Altbach** and **Dr. Ali Bilgin**. With this group, my research focuses on abdominal MRI. MRI is an extremely powerful imaging modality that is especially useful at producing high resolution, high contrast images of soft tissue. The major drawback is that it is relatively slow and sensitive to motion, a combination of which is problematic when imaging the abdomen, as subjects unfortunately (but understandably) like to breathe during the acquisition. The long-term goal of our group is to be able to produce a high-quality image of the entire abdomen from data acquired during a single breath hold. We approach this goal from two directions: pulse sequence development to more efficiently sample data and image reconstruction to create higher quality images from imperfect data.

One of the projects I have been working on involves using deep learning methods to reconstruct radial T2 weighted MR images. As mentioned above, in most cases in MRI, images must be reconstructed from under-sampled data, and thus require a special reconstruction algorithm. In many research settings, people use iterative compressed sensing techniques, which have been shown to produce high quality images, but are often slow and therefore not desirable in clinical settings. Recently, many researchers have been exploring the use of deep learning methods to predict high quality images more quickly. A common criticism of neural networks is their black box nature, and CNNs for image reconstruction are no exception. To address this, we are studying unrolled networks that incorporate data consistency layers. These layers project the reconstructed image output from a CNN block back to data space, and then takes a convex combination between the reconstructed data and the originally acquired data, before projecting back to image space and proceeding to the next CNN block. This method can be seen as analogous to an iterative compressed sensing method, except that instead of regularizing with a prior that promotes sparsity in a certain basis, we regularize with a prior that enforces similarity to the output of the CNN. In this way we can utilize the powerful deep learning methods that are becoming very popular in medical imaging while also promoting fidelity to the original data.

My research funding is through an academic industrial partnership where I work directly with Siemens Healthineers collaborators, which allows me to gain insight into working in industry. In addition, working with Siemens has been very rewarding because my research results have the possibility of being applied to real life applications. For instance, my research in pulse sequence development could potentially be available worldwide on Siemens scanners. This has been one of many great opportunities that the Arizona Program in Applied Math has given me, and I look forward to seeing my research progress and evolve throughout my graduate program.

Current Student Profiles *(continued)*

Patricia Puente (4th Year Student)

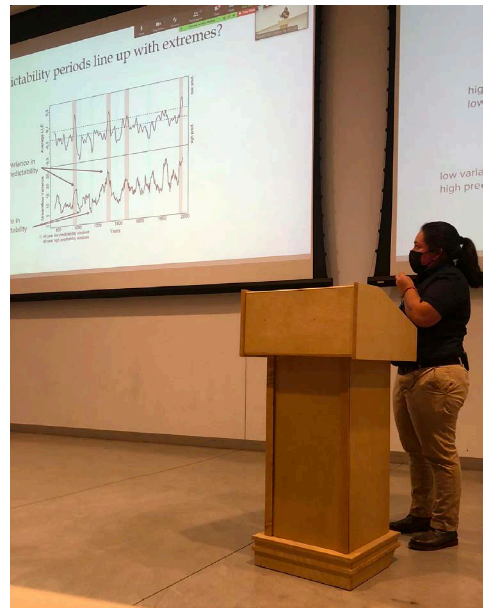
Growing up in North Texas I always fit in. I grew up in an area full of underrepresented minorities. I graduated with a mathematics degree from an institution that was majority women, both student body and faculty. It's even in the name – Texas Woman's University. Prior to grad school I always had a community. I was never the only one in the classroom who identified as a first- generation Latina. But once I moved to Arizona for grad school in applied math, being the only one really took a toll on my confidence and sense of self. I started questioning whether I had made the right decision in pursuing grad school. I write this today with great confidence in myself, in what I do, and why I am here to share my story.

I was an incoming junior when I did my first math/biology summer Research Experiences for Undergraduates (REU) at Arizona State University (ASU) and I learned what a PhD was. My family and I always thought I would end up being a math teacher because that is all I knew math majors could do. Little did I know the REU experience at ASU would open the door to plenty of opportunities such as conferences, panels, another REU, and eventually grad school.

Having mentors has always been essential for me. My very first mentor, Dr. Alicia Machuca mentioned REU's in class and I was so interested when she mentioned that they funded travel and paid you to do math. My younger self found this mind blowing because up to this point in my life I had never been on a plane and had only spent my summers working at a car wash to make money. So when I heard of these perks I applied. She helped me through my application process and nominated me to be in the Math Alliance which would later grant me a grad school application mentor through their F-Gap program and while in grad school would grant me participation in the Internship Network in the Mathematical Sciences (INMAS) program. After my first REU I was even more curious as to how math could be applied and I am so thankful that Dr. Ellina Grigorieva was one of the few professors at Texas Woman's University who taught her classes with qualitative rigor and pushed me in her classes to ask all the "hard" questions. Along with my advisors from my REU's Dr. Karen Rios-Soto from the University of Puerto Rico – Mayaguez and Dr. Hala Nelson from James Madison University I applied to grad school with their help with recommendations and guidance through the process.

Once I made it to grad school, I thought I was on my own. My mentality at the time was, I finally made it, now I am supposed to find my own path. However, after my first semester I realized I needed to find a mentor and potential PhD advisor, someone who I could open up to and rely on to give me advice on how to navigate grad school as a first-generation, queer Latina. I credit the Applied Mathematics PhD program structure for this because they encourage their students to seek advisors outside the mathematics department. Additionally, the program does not require their students to have a defined research area which was really helpful for someone like me who didn't have any research questions in mind. I came into grad school with a research background in biological modeling and material science but my priority was to find my ideal mentor in the earth sciences knowing that my research interests would come soon after. It was terrifying at first to approach professors who are complete strangers but looking back at it, it was through this uncomfortable moment that I found my mentor/advisor and her amazing research group who values community, communication, and impact.

My advisor, **Dr. Laura Condon** is very supportive, caring, patient, and very



well established in the field of hydrology. With her guidance I was granted the National Science Foundation Graduate Research Fellowship. This fellowship is very prestigious in the academic community and it has granted me the opportunity to fully focus on my research work. My current work is being concluded in my first paper where I explored the connections between low frequency streamflow extremes and nonlinear dynamics in the Upper Colorado River Basin. Through the application of nonlinear methods such as wavelet transform, dimension embedding, time lag, and calculation of predictability through the Lyapunov exponent we asked ourselves if we could extract some relationship when comparing it to streamflow attributes such as the rolling average and rolling variance. I think the beauty about mathematics is that we can use theoretically based methods such as wavelet transforms and Lyapunov exponents to extract information that reach a physically sound conclusion. My results include that we are entering a period of low predictability where the variability of extremes is much higher which is apparent by the current droughts we are seeing in the West. I have presented iterations of this work both locally and nationally. I presented at the American Geophysical Union (AGU) Fall Meetings in 2021 and 2020. I most recently presented at El Día del Agua y la Atmósfera in March 2022 [pictured above] where I received best oral presentation award from the Pima County Flood Control.

It was Fall 2021 when I started thinking about what my next summer [2022] was going to look like. Up until then, I had only done research experiences during my summers in undergrad and had spent my grad school summers continuing my research with my advisor. I knew my goal was to eventually have a government or industry position post grad school and therefore decided I needed to think about internship positions. I applied to the INMAS program where I received Python training on data visualization, statistics, and machine learning and professional development. The program's goal is to get grad students prepared for the interview process with one of their industry partners. I finished the program and actually did not have to go through the interview process, thanks to networking. I ran into one of my hydrology professors at the DFW airport and mentioned to him that I was coming back from a training workshop with the INMAS program and hoping to get an internship in the summer. Little did I know he is a consultant for Transcend Engineering in Vermont and weeks later I receive an email where he recommended me to be their intern for the summer on a project using machine learning (ML) to predict subsurface water flux. I gained so much insight on what it takes to use physics-based models to generate data to then train an ML model. Data processing tasks and hyperparameter optimization took most of my time in the duration of the internship. This experience was a special one, I learned a lot about myself and how to manage my time, communicate with my supervisor(s), learn technical skills, and develop an interest in data science to guide my next research project/long term career.

If I were to meet my younger self and tell her where she would be today, I would not believe it. I took a risk on myself every time an opportunity presented itself. "You won't know until you try" has gotten me through all the pivotal moments in life. Grad school has been a period so far where I have grown into a version of myself I am proud of; overcoming the mental toll the beginning of COVID-19 had on me; coming out to my parents as queer at the end of my first year; cutting my hair short recently; realizing that the goal of grad school is not to be all-knowing but to know a substantial amount about one thing in a subject of many things and be an effective communicator about my work/findings. Lastly, taking care of my mental health because unexpected events happen that are out of my control – overall being kind to myself. I hope my story serves as a testimony that putting yourself out there and being your authentic self will attract people and experiences that will encourage you to grow and who knows, it might even be life changing.

News from Members and Affiliates

Bredas, Jean-Luc (Chemistry and Bio-Chemistry) was confirmed Regents Professor in April 2022 (UA News Article). As defined by ABOR, "The designation of Regents Professor is an honored position reserved for faculty scholars of exceptional ability who have achieved national and international distinction. The title Regents Professor serves as recognition of the highest academic merit and is awarded to faculty members who have made a unique contribution to the quality of the University through distinguished accomplishments in teaching scholarship, research or creative work." Read more

Chan, Chi-kwan (Astronomy & Steward Observatory) In May 2022, the Event Horizon Telescope (EHT) Collaboration published the first ever event-horizon resolution images of the supermassive black hole at the center of the Milky Way. The image was produced by a global research team of more than 300 members using observations from a worldwide network of radio telescopes. It helps us understand the accretion flows around supermassive black holes, constraints the plasma physics around these extreme objects, and test Einstein's general theory of relativity in the strong field regime. Applied Mathematics affiliated member Dr. Chi-kwan "CK" Chan led the theoretical modeling and interoperation of this work, developed the data processing pipelines, and contributed machine learning algorithms to image the interferometry data. The results were published in a series of six papers:

https://doi.org/10.3847/2041-8213/ac6674
https://doi.org/10.3847/2041-8213/ac6675
https://doi.org/10.3847/2041-8213/ac6429
https://doi.org/10.3847/2041-8213/ac6736
https://doi.org/10.3847/2041-8213/ac6672
https://doi.org/10.3847/2041-8213/ac6756

Cheng, Jianqiang (Systems & Industrial Engineering) I would like to share with you that I received the NSF Career Award last year (https://www.nsf.gov/awardsearch/showAward?AWD_ID=2143679&HistoricalAwards=false).

Cushing, Jim (Mathematics) Well, if you're hard up for news, all I can report is that I've signed two book contracts. One is with the AMS for a book in their Student Library Series on matrix models in structured population dynamics. The other is with Springer and is co-authored with ecologist James Hayward and mathematician/biologist Shandelle Henson (a former postdoc here). It reports on a 15+ year field ecology and mathematical modeling project on marine vertebrate population dynamics carried out on Protection Island National Wildlife Refuge managed by the US Fish & Wildlife Service.

Guo, Bo (Hydrology & Atmospheric Sciences) has received the National Science Foundation CAREER Award to study thin water films and develop mathematical models to represent their control on the transport of surface-active emerging contaminants (e.g., PFAS and colloidal particles) in soil and groundwater. CAREER is NSF's most prestigious award in support of early- career faculty who have the potential to serve as academic role models in research and education and to lead advances in the mission of their department or organization.

Piegorsch, Walter (Mathematics) Published 2 papers in 2022. Titled: "Adjusting statistical benchmark risk analysis to account for non-spatial autocorrelation, with application to natural hazard risk assessment" and "Computational Statistics in Data Science": 1.) Liu, J., Piegorsch, W.W., Schissler, A.G., McCaster, R.R., and Cutter, S.L. (2022). Adjusting statistical benchmark risk analysis to account for non-spatial autocorrelation, with application to natural hazard risk assessment. Journal of Applied Statistics 49, 2349-2369. doi:10.1080/02664763.2021.1904385. 2.) Piegorsch, W.W., Levine, R.A., Zhang, H.H., and Lee, T.C.M., eds. (2022). Computational Statistics in Data Science. Chichester: John Wiley & Sons.

Rafelski, John (Physics) In May 2022 I have been elected honorary member of the Hungarian Academy of Science. I attach a video screen-shot from the presentation of the diploma. The other older person in the picture is Norbert Kroo.

Stepanov, Misha (Mathematics) Publication: Embedded (4, 5) pairs of explicit 7-stage Runge–Kutta methods with FSAL property. The general case of embedded (4, 5) pairs of explicit 7-stage Runge–Kutta methods with FSAL property ($a_{7j}=b_j$, $1\leq j\leq 7$, $c_7=1$) is considered. Besides exceptional cases, the pairs form five 4-dimensional families. The pairs within two (already known) families satisfy the simplifying assumption $\sum_j a_{ij}c_j=c_i^2/2$, $i\geq 3$. https://link.springer.com/article/10.1007/s10092-022-00486-1

Subbian, Vignesh (Systems & Industrial Engineering and Biomedical Engineering) Here's one item from my end for the newsletter: https://news.engineering.arizona.edu/news/undergraduate-research-program-will-take-community-based-approach-arizona-health-challenges

Zhang, Chicheng (Computer Science) had the following conference papers accepted this year: On Efficient Online Imitation Learning via Classification. Yichen Li and Chicheng Zhang. NeurIPS 2022. PopArt: Efficient Sparse Regression and Experimental Design for Optimal Sparse Linear Bandits. Kyoungseok Jang, Chicheng Zhang, Kwang-Sung Jun. NeurIPS 2022. Active Fairness Auditing. Tom Yan and Chicheng Zhang. ICML 2022. Thompson Sampling for Robust Transfer in Multi-Task Bandits. Zhi Wang, Chicheng Zhang, and Kamalika Chaudhuri. ICML 2022. Margin-distancing for safe model explanation. Tom Yan and Chicheng Zhang. AISTATS 2022. The "Active Fairness Auditing" is one of the outstanding paper runner-ups for ICML 2022 - the CS department also has an article on this.

News from Alumni

Aceves, Alejandro (PhD 1988) As of January 1st of this year I began a 2-year term as SIAM Vice President for Science Policy. My role as VP is to Chair the SIAM SP committee whose chart is to provide timely information to its membership regarding science policy and funding. SIAM also provides information to policy makers regarding issues of interest to its members when SIAM member's expertise offers something to contribute to the discussions"

Alvarez, Oliverio (PhD 2005) Overall 2022 was a year of realizing prototypes and/or performing rigorous testing. However, it was a year with six conferences, from which I presented in five. The topics varied from testing microwave technologies to cool results when you heat a shale rock really fast up to 1000 degrees.

Brazier, Richard (PhD 1997) As senior associate dean for faculty and research in the Office of the Vice President for Commonwealth Campuses, I have been named interim dean of Penn State's 14-campus University College.

Goshy, John, (MS 1996) I am now working at Zemax LLC as a Computational Physicist. I'm glad to hear and read about the program in your newsletter.

Hottovy, Scott (PhD 2013) In April of 2021 I was promoted to Associate Professor at the United States Naval Academy. Professionally I love

teaching the midshipmen and including them in my research. In my research I

study reduced order models of the tropical atmosphere as well as the diffusion problems I started at UofA.

Personally, my wife Anna and I have three girls Ivy (3 years old), Victoria (5), and Ella (7). Here is a picture from the tenure ceremony with my family and I along with our Dean of Students Samara Firebaugh and the Superintendent Vice Admiral Sean Buck.

Johnson, William (PhD 1978) My consulting work with Sandia National Laboratories has ended due to government rules, so I am really slowing down. I think this will be my last note to you. I have been involved in a few conference presentations: J. Rivero, F. Vipiana, D. R. Wilton, W. A. Johnson, "Novel Test Integral Quadrature Scheme for the Method of Moments" for EuCAP 2023, March 26-31 2023, Florence Italy. D. R. Wilton, M. A. Khayat, W. A. Johnson, J. Rivero, F. Vipiana, "Using the dimensionality reduction approach to treat near- singular source and test integrals on triangles for moment methods", IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting, July10- 15,2022, Denver, Colorado. J. Rivero, F. Vipiana, D. R. Wilton, W. A. Johnson, "A radial- angular testing scheme to accelerate the numerical evaluation of surface test integrals", IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting, July10-15, 2022, Denver, Colorado.

I also am writing a book chapter with D. R. Wilton on the fundamentals of solving electromagnetic problems with integral equations.

Lane, Emily (PhD 2004) In the last year I have been promoted to Principal Scientist: Natural Hazards and Hydrodynamics. I have been very busy with the tsunami caused by the eruption of the Hunga Tonga Hunga Ha'apai volcano. From giving advice to the National emergency management agency in the day as part of New Zealand's tsunami expert panel through to looking at the source mechanisms of the volcano and especially the pyroclastic density currents. I am also leading a 5 year programme to consistently map the flood hazard around New Zealand. We are currently just beginning year 3.

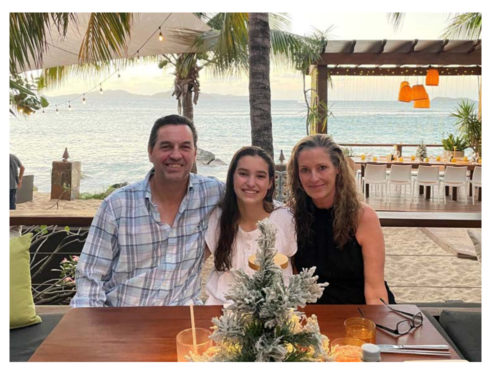
McLaren, Sam (PhD 2021) This past year, I was hired as a permanent staff scientist within the National Ignition Facility and Photon Science Directorate at Lawrence Livermore National Laboratory. I also made the Physics Lead for Virtual Beamline++, the modeling software that is poised to take over responsibilities for predicting laser performance at the NIF. The NIF had a big result on December 5th, 2022, when we achieved ignition, producing more energy from a nuclear fusion reaction than was put into it. It has been an exciting year here! Missing beautiful Tucson and all its amazing people.

Miller, Peter (PhD 1994) I spent the fall semester visiting the UK as a Leverhulme Visiting Professor based at Bristol University. Here is a picture of me at Loughborough University with an actual cutting from Newton's apple tree.

Park, Subok (PhD 2004) recently started in a position as Senior Director of Regulatory Affairs at medical diagnostics company RapidAI.

Shelley, Michael (PhD 1985) has been elected to the National Academy of Sciences for outstanding contributions to scientific computing, biophysics, and fluid dynamics. On my work these days: I work mostly on self- organization in cell biology and active matter systems.

How do structures form in the cell from the interactions of many molecular constituents; How do these subcellular structures do important things like move and position genetic material during cell division, etc. This involves development of numerical methods for many-body interactions, coarse-graining methods for such problems, mathematical analysis, and large-scale simulation and inference.



Soares, Edward (PhD 1994) is currently serving as chair of the Department of Mathematics and Computer Science for AY 2022-23 through 2023-24. I recently published a paper titled "Event Studies Without Market Expectations" with Bryan

Engelhardt (U Wisconsin Osh Kosh), Vol. 2, 1, 2022. ,Journal of Econometrics and Statistics. I attach a family pic from our recent trip to the British Virgin Islands!

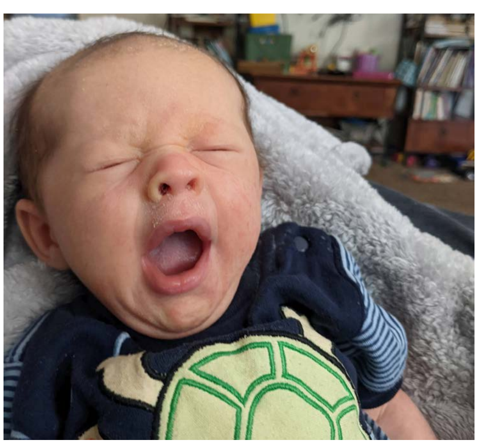
Soterwood, Jeanine, (PhD 2005) started a new job as a team lead with Thoughtbot, a Ruby on Rails software consulting company. She is enjoying having teammates and paid vacation after having run her own software company for 9 years. She and her wife and two kids had a great time white water rafting on the Rogue River in Oregon this past summer.

Swierczek, Stan (PhD 2021) started as a Model Risk Analyst for M&T Bank in March of 2022. In April, he and his brother welcomed a second dog, Moosh, into their family. She is a rescue from Mexico.

Moosh

Uribe, Guilleremo (PhD 1993) retired from The University of Arizona on June 30, 2020 after over 30 years of service. He lives in Albuquerque NM where he enjoys his grandchild and the benign weather of this city.

Washburn, Ammon (PhD 2018) We have some news. We had our fifth baby this last April. A boy named Kai. He and Mom are doing well.



Recent Graduates

Ruby Abrams (PhD, Spring 2023) is currently a Postdoctoral Research Fellow at Critical Path Institute

Brian Bollen (PhD, Summer 2022) is currently a Data Analyst at Gravy Analytics

Alyssa Burritt (MS, 2021) is currently a Research Scientist at PING, Inc.

Hannah Kravitz (PhD, Summer 2022) is currently an Assistant Professor, Computational Mathematics at Portland State University

Grace Lee (PhD, Summer 2022) is currently a Quantitative Medicine Postdoctoral Fellow at Critical Path Institute

Dan Li (PhD, Fall, 2022) is currently an ORISE Fellow at the Food & Drug Admin

Erica Papke (MS, 2021) is currently an Associate Decision Scientist at Ibotta, Inc. Craig Thompson, (PhD, Fall 2022) is currently a Systems Engineer at Raytheon

Current Student Achievements

Riding the ferry to the island

Bormanis, Ari (2nd Year Student) attended a one week summer school and workshop for topics in surface theory at the beginning of the semester. The airfare was covered by my advisor's grant and the lodging was courtesy of the Jochim Herz Foundation and Chemnitz University of Technology. I've attached some of the pictures I took. The venue was crazy! It was hosted in Bavaria, Germany, (close to Munich) in an active abbey on an island in a lake. It was one of the greatest trips I've ever been on :)!

The name of the workshop is Surfaces22 and their website can be found here: https://www.tu-chemnitz.de/mathematik/harmonische_analysis/events/surfaces22/

Broeren, Teddy (4th Year Student) attended and presented a poster at the AGU fall conference this December in Chicago titled "Demonstrating HelioSwarm's Ability to Characterize Space Plasma Waves Using the Wave-Telescope Technique". I also virtually attended the 2022 Machine Learning in Heliophysics conference this year. Over the summer I received a URA Summer Graduate Research Fellowship and worked at Sandia National Laboratory in the Radiation Electrical & High Energy Density Science Research Foundation.

Riding the ferry to the island

Fernandez, Dunia (3rd Year Student) This summer I worked at a part-time internship focused on data analytics with Genesis Research in Hoboken, NJ. Genesis Research is an international real-world evidence (RWE) and health economics and outcomes research (HEOR) organization that delivers scientifically rigorous, tech-enabled solutions to pharmaceutical, biotech, and medical device clients across the product lifecycle.

Ferrando, Robert (3rd Year Student) Misha Chertkov, Laurent Pangier, Yury Dvorkin (Johns Hopkins), and I submitted a paper "Machine Learning for Electricity Market Clearing" which was accepted to the IREP Power Systems Dynamics & Control Symposium in July 2022. I presented a poster based on the above conference paper at the NREL Autonomous Energy Systems workshop in July 2022, and a talk by the same title at Los Alamos-Arizona Days in August 2022.

Kinney, Adrienne (4th Year Student) won the Beder Prize for a great video she submitted about her research to the #ElevatingMath competition and received the following comments: CONGRATULATIONS! We loved your submission and are so excited to award you the $1000 Beder Prize for #ElevatingMath.

Hyett, Criston (4th Year Student) Presented "Applicability of Machine Learning Methodologies to Model the Statistical Evolution of the Coarse-Grained Velocity Gradient Tensor" at American Physical Society's Division of Fluid Dynamics Conference in November. Received GPSC Travel Grant to attend Physics-Informed Machine Learning Conference hosted by Los Alamos National Labs Center for Nonlinear Studies, and UA-LANL Days, attended three conferences: CNLS PIML, University of Arizona/Los Alamos National Lab Days, and APS DFD. - Summer Internship at CCS-2 at LANL

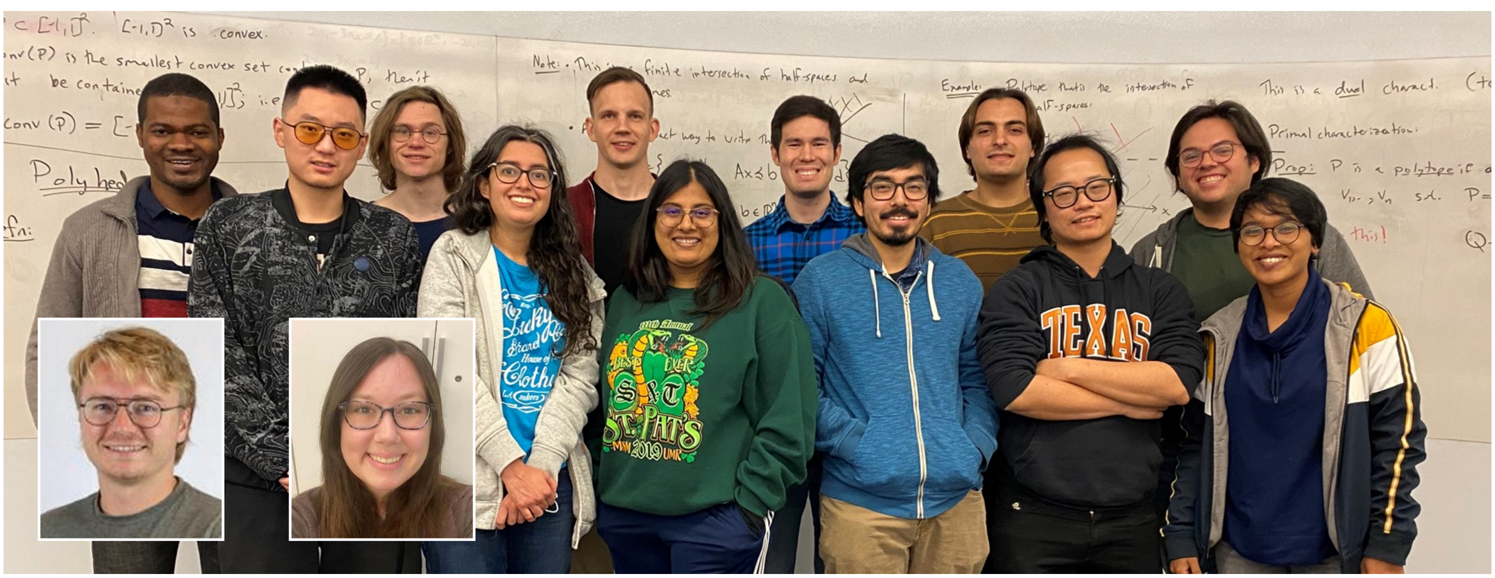
McCann, Fiona (3rd year Student) This past summer, I attended my first conference as a graduate student and presented a poster on my research, "Positioning the tragedy of the commons within density-dependent selection" at the Evolution 2022 conference, in Cleveland, Ohio. It was a wonderful experience, and I am excited for future conferences

Sharma, Akshita (2nd Year Student) Last summer I did an internship in quantitative finance at Abu Dhabi Investment Authority (ADIA) — the sovereign wealth fund of the United Arab Emirates. I worked as a Quantitative Researcher and Developer at the wealth fund.

Thompson, Craig (6th Year Student) Received Outstanding Teaching Assistant honorable mention award. "Craig's performance as the super-TA for both the methods class (Math 581) and the numerics/algorithms class (Math 589) has been extraordinary. Craig is taking the difficult job of super-TA most professionally and seriously." "Through recitations, but also emails, and of course multiple chats, Craig makes himself available to students interested to not only solve HW problems, but to really understand solutions. This task is very hard to accomplish, and Craig helps us (the instructors) a lot by routinely discussing with students not only formally, but also informally..."

Van Boxel, Danielle (3rd Year Student) Published a paper at the TopoInVis 2022 workshop, "Autoencoder-Aided Visualization of Collections of Morse Complexes." with Jixian Li and Josh Levine. She also presented her current machine learning research, "Born in a BARN: Bayesian Additive Regression Networks" to the American Mathematical Society Central Section Meeting in El Paso, TX in September and other venues throughout the year. On a personal level, she was excited to complete a legal name change in November 2022!

New Students Fall 2022

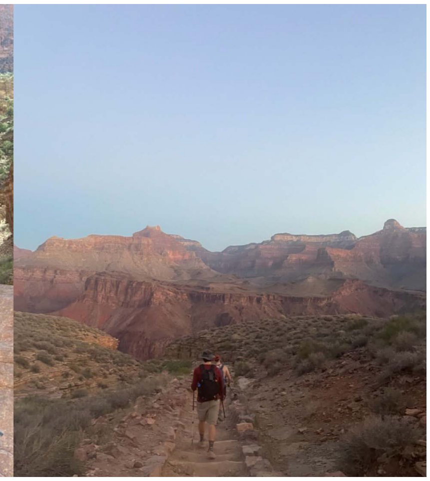


Back row: **Saheed Adisa Ganiyu**, University of Silesia, Poland; **Christian Cooper**, University of Arizona; **Ilya Kuk**, Skoltech, Russia; **Kevin Beck**, Whitworth University; **Ayrton Alamada-Jimenez**, UNAM, Mexico City; **Jacob Quintero**, Arcadia University.

Front row: **Qipeng Qian**, University of Wisconsin, Madison; **Rebekah Saucier**, University of New Mexico; **Marium Yusuf**, University of Arizona; **Rishi Pawar**, University of Wisconsin, Milwaukee; **Edward Huynh**, University of Nevada, Las Vegas; **Asha Barua**, University of Texas, Rio Grande

Inset Photos: **Andrew Arnold**, University of Iowa; **Stephanie Marsh**, University of Nebraska

Student Grand Canyon Trip, October 2022



The 3rd annual Grad Student trip to the Grand Canyon took place on September 30th to October 2nd and was organized by this year's Grad Rep, **Fiona McCann**, and **Woody March-Steinman**. Thirty people went on the trip! There were 24 applied math graduate students, 5 significant others and 1 department head, **Misha Chertkov** (who ran rim-to-rim-rim!!). Everyone in the group split up on different hikes, with some going rim-to-rim and some to the south Kaibab trail to name a few! We mainly camped at the Mather Campground on the south rim, with north rim hikers doing one night at the Demotte Campground. We had a lot of fun gathering around the campfire and hanging out. We saw elk walking through the campsites and heard early morning elk bugling. We also saw some wild burros in the Grand Canyon, and watched beautiful sunrises, with only a few mis-adventures!

The Don Wilson Applied Mathematics Endowed Fund for Excellence

was established to honor the memory of Don Wilson, a University of Arizona Research Professor in the College of Optical Sciences, with the purpose of providing support for the professional development of graduate students in the Program in Applied Mathematics. Dr. Wilson worked very closely with Harry Barrett's renowned medical imaging group and helped train many of the Applied Mathematics students who worked in that group. One of those students, **Jack Hoppin (PhD 2003)**, and his wife Janna Murgia, made a generous gift to the Program that enabled the fund to be established and continue to flourish.

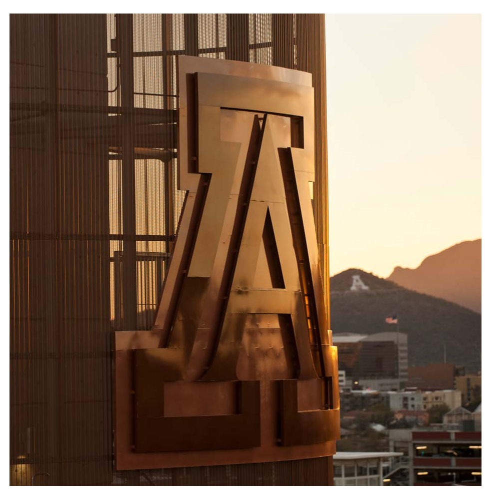
Due to the Covid-19 pandemic, no don Wilson Travel awards have been distributed since 2019 but we hope to give out awards in Spring 2023.

For more information about donating to the Don Wilson fund, the Michael Tabor Fellowship Endowment, or the Applied Mathematics General Fund, please visit http://appliedmath.arizona.edu/program-info/donate

Donor Thank You!

Special Thank Yous to **Jack Hoppin (PhD 2003)** who recently made a donation which will bring the **Tabor** fund up to $25K and make it an endowment; and for replenishing the Don Wilson Fund. And to **Arthur Lo (PhD 2004)** for his annual contributions to the Applied Mathematics General Fund.

Thank you both for your generosity! Please note: we are not always directly notified of donations made to the Program from Alumni and would like to thank everyone who has contributed to the Program that we are not aware of. Your support is very appreciated!



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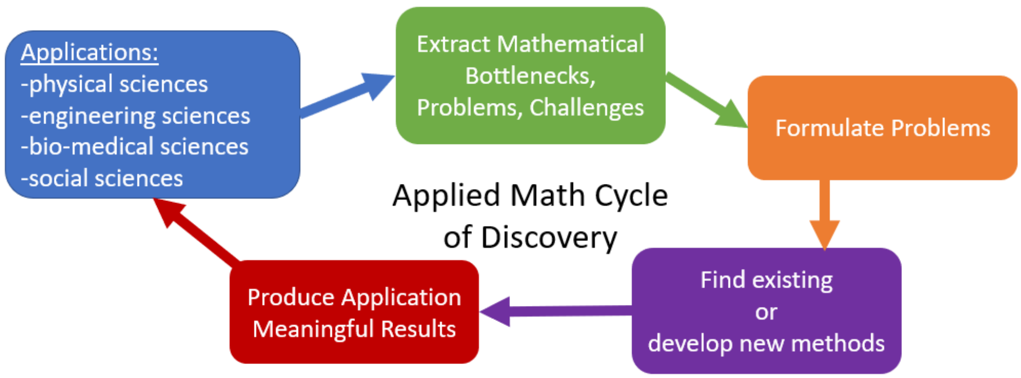
Applied Mathematics

Graduate Interdisciplinary Program

Apply by January 6th to start in the Fall Semester
https://appliedmath.arizona.edu/admissions

Interdisciplinary means students can choose from any professor on campus. Currently, we have over 100 professors/ 26 departments/ 8 colleges across the UA campus that are affiliated with our program.

How does Mathematics work with Applications @ UArizona?



Core courses provide hands on teaching of the AM-cycle methodology

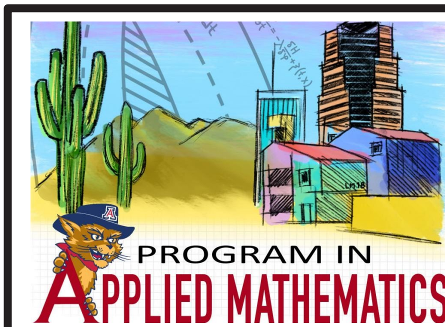
- Training in **methods** (Math/APPL **581**), **theory** (Math/APPL **584**), **algorithms** (Math/APPL **589**)
- Math (quantitative) and Application-specific (qualitative) intuition

"The students that have worked in applied mathematics have both a deep knowledge of mathematical, computational and theoretical approaches, but also really know their subject area – in this case biology and physiology. We have found that these kinds of students are very much in demand in academic institutions, industry and government. "

Tim Secomb
Dept. of Physiology

All students admitted to the Program are offered a comprehensive and long-term package of financial support, which includes health insurance and tuition remission. Program students are supported on Teaching Assistantships, Research Assistantships and various training grant fellowships.

SCAN ME



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SCAN ME

Core Courses: In the Fall of 2020, the three Core Courses were modified with new material balancing traditional and contemporary sides of applied mathematics.

CLASS NAME	EARLY FALL	LATE FALL	EARLY SPRING	LATE SPRING
584:Theory	Analysis	Integration	Optimization (Theory)	Statistics & Probability
581: Methods	Applied Analysis	Differential Equations	Optimization (Methods)	Applied Probability & Statistics
589: Algorithms	Numerical Algebra & Analysis	Numerical Differential Equations	Optimization (Algorithms)	Inference & Learning

"Opportunities to do research with the program are many! Applied math is a renaissance science connecting classical mathematics with today's reality of Artificial Intelligence and data, making revolutionary change in how we believe and do science. Come here and join us in this exciting endeavor!"

Misha Chertkov
Chair, Applied Math

"The second semester emphasizes the more contemporary topics of optimization, statistics and probability, and inference and learning, which are addressed from the three viewpoints of algorithms, theory, and methods."

Colin Clark
Postdoc, Applied Math

After completing the Core Courses, students can pursue flexible and individually designed programs of study.

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