The University of Arizona

Program in Applied Mathematics

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Greetings from the Chair, Program in Applied Mathematics

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Dear Students, Alumni, Professors and Friends of the Applied Math program at UArizona, what a year! While the world continues to struggle with the many challenges of an ongoing pandemic, the past year has marked significant progress for our program. We have introduced a new curriculum, expanded and strengthened our program's external-partnerships, and resumed in-person lectures, seminars, and social activities.

The year has started with the formal approval of the new curriculum for all three of our core classes, first by the Department of Mathematics Graduate Committee, followed by approval from the University Curriculum Committee. The three new courses include: Methods in Applied Mathematics (Math/APPL 581a,b), Theoretical Foundations of Applied Mathematics (Math/APPL 584a,b) and Numerical Analysis and Algorithms of Applied Mathematics (Math/APPL 589 a,b). See https://appliedmath.arizona.edu/students/new-core-courses for details.

We applaud a continued effort (since 2019) of the core curriculum instructors, Prof. Shankar Venkataramani (Math/APPL 584) and Prof. Mikhail Stepanov (Math/APPL 589). Presently, three qualification committees, each run by the core course instructor, and involving 6 professors of the program, are preparing and grading the six exams. We are happy with the core curriculum progress, as the majority of our first-year students have passed their examinations, and we are happy to observe that many of these students have completed internships during the summer. The core classes continue to evolve. We are planning rotation of the core instructors – Prof. Laura Miller, Prof. Chris Henderson and Prof. Leonid Kunyansky will be teaching Math/APPL 584a, Math/APPL 584a,b and Math/APPL 589a, respectively, in 2022-23, while Math/APPL 581b and Math/APPL 689b will be taught for one extra year by yours truly and Prof. Mikhail Stepanov. With the help of Dr. Colin Clark and Craig Thompson (super-TA) I am finalizing the course notes for Math/APPL 581 and we plan to publish it shortly. Colin continues to run the inter-core recitations which have proven to be extremely useful for coordination between the courses.

The updated curriculum has allowed our students to start testing and exploring their research desires earlier than before. Last summer 8 of our students interned at the National Labs (NL) or government agencies, 5 worked in the tech industry and 2 took a summer RA position with our program professors. Furthermore, the updated curriculum has resulted in earlier M.Sc. certification – now during the third semester in the program. Nearly all of our students are now on RA and fellowship positions starting in their 3rd year, and sometimes as early as their first-or-second year of the program. We continue to work with our NL and Industry partners on creating interaction triangles (a student co-advised by a program professor and a staff member from a partner institution). The RTG/NSF program (lead by Prof. Kevin Lin) and CMMBS/NIH program (lead by Prof. Tim Secomb) continue to provide very much appreciated support (4 + 4 students of the program were funded in 2021). It also gives me an opportunity to mention, in lieu of the fellowship, the extraordinary successes of our students. Three (!!) students of the program, including, Alex Christensen (2nd year), Adrienne Kinney (3rd year) and Patricia Puente (3rd year), have received 2021 NSF Graduate Research Fellowship (the five-year fellowship including three years of financial support including an annual stipend and cost of education allowance to the institution, is the highest NSF award a graduate student can receive). Michael Woodward (4th year) is the recipient of 2021 DOE SCGSR award (one year fully funded GRA position at DOE/LANL). Kevin Luna (6th year) is the recipient of a DOD SMART Scholarship award 2020-23.

Our UArizona footprint continues to grow, mainly via students working with program affiliates (seasoned and new) across campus. Eight new program affiliates (two of them are industrial affiliates from LANL) have joined the program in 2021, in many cases the arrangements were initiated by students. After a 5-year break, the partnered hiring initiative has been revived and we are delighted to welcome our newest partnered-hire colleague, Assistant Prof. Marat Latypov. He was jointly hired by the Department of Material Science and Engineering (College of Engineering) and the Applied Math program. Marat has joined UArizona in 2021 and is preparing a new graduate course to be cross-listed between MSE and AM. We are hopeful to have another partnership hire in 2022 with the School of Sociology and School of Information (both in College of Social and Behavioral Sciences). A partnership hiring with the Department of Mathematics is planned for 2023.

Our colloquium and seminar series continue to flourish. Presently, nearly all of our events are run in a dual operational mode (zoom and in person). With the permission of our speakers, we post recordings online (see, e.g., https://appliedmath.arizona.edu/events/seminar-videos-fall-2021). It also has become a tradition to host, as a part of AM colloquium and of the student-run brown bag seminar series , presentations from National Labs and Industry in the fall. In Fall 2021, we have just had LBNL-, NREL-, LANL- and Raytheon- day. The tradition of Arizona-Los Alamos days continues. After two years of zoom, we are planning to travel to Los Alamos in May of 2022 (tentatively May 16-17, please check our website for updates). We continue to discuss with our NL and Industry partners, as well as with the UArizona leadership, various options which would streamline collaborations via students, creating scientifically sound but also fiscally stable arrangements and helping our partners to meet their ever growing demand in Ph.D. level work-force in contemporary applied mathematics.

Looking into the future, we plan to focus on designing new special courses and series of lectures in the disciplines which are in high demand (by graduate students seeking a degree in Applied Math, major or minor) but which are presently under-represented in the UArizona curriculum, e.g., in Statistical Applied Mathematics, Optimization, Decision Science, Fluid Mechanics and Information Theory. I encourage interested program affiliates, students and alumni to contribute to these ongoing discussions.

Finally, two of the program professors have moved to the emeritus status in 2021. Prof. Jim Cushing has been with the program since its foundation in 1974, and Prof. Vladimir Zakharov, who has joined the program and UArizona in 1990. Both Jim and Vladimir have contributed their expertise, experience and efforts to the program--for which we are eternally grateful. We sincerely hope that we can continue to rely on their advice, wisdom and vision. In honor of Prof. Zakharov's many contributions to the program and with support from the Department of Mathematics, the Data Science Institute, the Department of Hydrology & Atmospheric Sciences, and the College of Science, the program has established the annual "Zakharov Lectureship". I am happy to announce that the first lecture series will be given by Prof. Gregory Falkovich (Weizmann Institute) on "Physical Nature of Information – How to Receive, Send and Forget Information". Five hour-long lectures are scheduled for Jan 31-Feb 28. (See https://appliedmath.arizona.edu/events/1398-zakharov-lectureship-2022 for details.)

Memories of Hermann Flaschka: The Best of Colleagues

By Michael Tabor, Professor Emeritus, Program in Applied Mathematics Program Head, 1992 – 2014

Hermann was a pillar of the Applied Mathematics Program. It was his vision and that of the other founding members that made it what it is today: a highly successful interdisciplinary program with a national and international reputation to match.

When I first arrived at the University to become Head of the Program there was the opportunity to try new things, but new things built on the foundation built by Hermann and the other founders. At the time of my arrival in 1992, I met with all the students to learn about their experiences: what they liked, what they didn't like, what they thought of the courses they were required to take, and what courses they would like to take. A common answer was: "I'll take any course taught by Dr. Flaschka." And that simple reply captured his influence on the Program and his standing with the students.

At the time, the three core courses were: analysis, methods, and numerics.

The only one with an established curriculum was Hermann's already famous Principles of Analysis course with its remarkable set of class notes that to this day needs to converted into a text book and would be a guaranteed best-seller.

The contents of the other two courses were at the whim of the instructor and this sometimes led to (justified) dissatisfaction among the students. In trying to develop a new methods course I was greatly supported by Hermann who made many contributions and improvements to the material (as did other colleagues) and over time I like to think we developed a good course. Of course, times change—as they should—and new approaches are now being considered.

In trying out new ideas and practices for the students Hermann's advice and support was essential for their success. One such innovation was the introduction of term papers in which the students would carry out, in their second semester, a small research project under the supervision of a willing faculty member. Some faculty initially saw this as (unwelcome) extra work, but Hermann saw their benefit. He had the ability to bring the best out of students who were lucky enough to have him as their project advisor. Performance in these projects was often a useful indication of a student's research potential—something that could not always be captured by their performance in the qualifying exams. An endorsement by Hermann carried a great deal of weight.

Ah, yes, the qualifying exams: the bane of the students' existence, and a considerable challenge for the faculty, too! Constructing, year after year, exams with original questions (that could be answered in a finite time), and preparing the final manuscript free of errors, was a challenge and a grind. Preparing the exams was the time when I learned who my true friends were— and none were truer than Hermann. We spent many a winter and summer break endlessly checking, refining, and proofreading the exams. It was a testament to both his commitment to the Program and his genuine concern for the well being of the students. But, again, times change and that fearsome dragon has been slain much to the relief of the students and faculty.

Hermann was the best of colleagues and the best of human beings.

Remembering Hermann Flaschka

By Shankar Venkataramani, Professor, Mathematics

Hermann Flaschka was a faculty member in the Mathematics department at the University of Arizona from 1972 until his retirement in 2018. Hermann was at the forefront of research in integrable systems, nonlinear waves, and solitons. His fundamental contributions to this area were recognized by the Norbert Wiener Prize in 1995 [1]. As very nicely described in the website commemorating Hermann, he worked to advance interdisciplinary research throughout his career, and he played a key role in establishing "nonlinear science" as an interdisciplinary endeavor [2,3].

Hermann was an integral part of the program in Applied Mathematics and was associated with it for over 40 years. He was a member of the GIDP since its inception. Hermann taught extensively in the Applied Math program, and the students who took his classes remember him with great fondness. He also mentored several Applied Math Ph.D. students. Through his teaching and mentoring, Hermann played a key role in developing our unique approach to applied math training here at Arizona. Hermann had great intellectual integrity and was dedicated to everything that the AM program stands for. His contributions remain an integral part of the program to this day. For example, his exquisitely crafted graduate text, "Principles of Analysis", is one of the central pillars in our approach to training graduate students in the Applied math GIDP. The text achieves a remarkable balance — without sacrificing mathematical rigor, it gives an intuitive exposition of modern applied analysis in a manner that is accessible to all of our students, some of whom are taking a proofs-based class for the very first time.

Hermann was unfailingly kind, warm, and approachable. I was in my 3rd year here in Arizona when I first taught the Applied Math core class in analysis from his text. I thoroughly enjoyed teaching the class and Hermann's text was unlike anything I'd ever seen before. Hermann was teaching the methods core class at the same time. He made a lot of time to talk to me, to answer my questions about his book, and to coordinate our teaching so that the methods and analysis classes reinforced each other. My own views on applied analysis, on teaching in the GIDP, on mentoring students working on applied problems, and many other things have been deeply influenced by my interactions with him, and from teaching from his text. Over the years, we've had many conversations about mathematics, ranging from non-standard Poisson structures to Matlab implementations of Empirical Mode Decomposition, and every single time I came away with more insight and a deeper understanding of the question at hand. My experiences were by no means unique, and Hermann similarly enriched the lives of his many colleagues and students. He will be deeply missed.

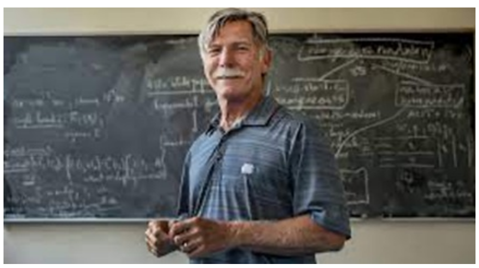
[1] https://www.ams.org/notices/199504/prize-wiener.pdf

[2] https://sites.google.com/math.arizona.edu/flaschka-memorial

[3] Editorial, Physica D: Nonlinear Phenomena, Volume 1, Issue 1, 1980, Pages v-vi, https://doi.org/10.1016/0167-2789(80)90002-0.

[4] https://sites.google.com/math.arizona.edu/flaschka-memorial/memorial-gathering-video

Fond Memories of Hermann Flaschka



By Gregory Forest (PhD 1979)

Dave McLaughlin was my PhD advisor, Hermann was my co-advisor.

We were at a family reunion when the service was held for Hermann last year. It was a disappointment to not be able to join, since I have so many fond memories. I wanted to share some thoughts about Hermann with the Program in Applied Mathematics family, which Keri Oligmueller graciously encouraged me to do. Hermann came to the U of A before me; I arrived in January of 1974 and (I believe) Hermann joined the faculty in the fall of 1972. My first "encounter" with Hermann (Professor Flaschka, that is) was a foreshadowing of his persona. Hermann and I got on the elevator together, just the two of us. I had just arrived from New Orleans, interested (as always) in meeting people. I assumed, and asked directly, "Hi, I'm Greg, are you also a graduate student?" His voluminous response was "no". Efficient, I thought along with other reactions. I am confident Hermann laughed when I got off the elevator on the 6th floor, as I would much later come to understand his sharp, dry humor.

I jump forward to another, more dramatic, illustration. I believe it was 1976 when Martin Kruskal visited Tucson; Martin (Princeton famous, Professor Kruskal) was buzzing around the top floors of the Mathematics Building. Many super famous folks were constantly visiting U of A Mathematics during my graduate school days; only later did I realize "we" must be, or becoming, famous too. Martin was indeed famous, one of the seminal figures in the booming field of solitons, for his numerical discovery of "recurrence", both in Fermi-Pasta-Ulam lattice simulations and with simulations of the KdV equation with Norm Zabusky, and for his theoretical work on integrable systems in the Gardner-Green-Kruskal-Miura powerhouse. Martin was child-like; those who knew him will know what I mean, such as doing origami in the middle of the front row of lectures during an entire conference. I would later come to know Martin quite well, as we attended week-long soliton meetings every other summer throughout the 80s at waterfront resorts in southern Europe. But I digress.....only to underscore how many famous folks I met through Hermann and Dave and the amazing faculty of my era, and how important those relationships would be in my future. During Martin's visit in '76, he was telling everyone about his new discovery ..... that Hermann Flaschka had never made a mistake! He had walked into Hermann's office, where Hermann was doing calculations with a pen. Martin asked: "what do you do when you make a mistake?" Hermann replied: "I don't know, I have never made a mistake." Martin knew that Hermann was the heralded protege of Gil Strang, who still says (as recently as 2017 when we were at a SIAM meeting) Hermann was the smartest student he had ever encountered at MIT. Martin was beside himself, like a kid who just met Santa Claus. I am confident Hermann laughed as soon as Martin left his office.

Perhaps it was 1976 when I took a 6-week summer course from Hermann, during which "we" went through Whitham's Linear and Nonlinear Waves book. In reality, Hermann went through the book, and we basically held on for dear life. He was an incredibly fast and deep consumer of mathematics, including physical mathematics. There was one calculation in the book where Whitham simply announced that the 3x3 system of modulation equations for the elliptic function periodic solution of the KdV equation possessed Riemann invariants, and thus the nonlinear modulations of this exact solution were themselves exactly integrable. There was no explanation of how Whitham arrived at this result. Hermann and Dave gave me a project to recover the result. It took me weeks to confirm rather than derive the result. Eventually, years later in fact after much learning by all of us about functions and differentials on Riemann surfaces, the paper that settled this question for all multiphase periodic solutions of KdV was published by Flaschka, Forest, and McLaughlin. Hermann would later tell Dave, who shared with me, that this was one of his favorite results. That paper, and chapter of my dissertation, remains my favorite, not just because of the beauty of the mathematics, but because it was the first and only paper I wrote with both of my advisers. A graduate student of Willis Lamb in Physics at UA (of the Lamb shift, a Nobel discovery) remarked back then how fortunate I was to land in Tucson and work with Dave and Hermann. You think?

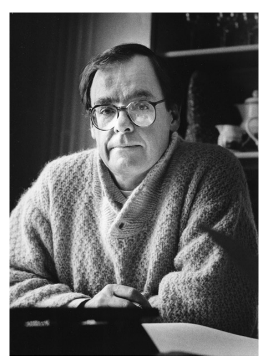
Every other summer in Europe at the soliton meetings during the 1980s, it was a mixture of the Western and Eastern bloc soliton communities. Hermann and Dave never went to those meetings, and it never failed that I, their perceived protege, was interrogated to learn what they could about what Hermann and Dave were working on. I learned quickly to only lecture on, or discuss, already published work. Whatever was going on in Tucson, stayed in Tucson. After I left Tucson in 1979, I maintained a close relationship with many of my mentors back in Tucson and visited regularly for the first few years. Marty Greenlee, George Lamb, Jim Cushing, John Bownds, Paul Fife, Bob O'Malley, Bill Faris, Al Scott, Rabi Bhattacharya, ... were all fantastic, and dedicated, teachers like Hermann and Dave were. Alan Newell arrived as I was leaving, and has been a driving force of the Program since. My new collaborator at Ohio State in 1980, Nick Ercolani, who brought new tools of algebraic geometry to integrable systems, eventually would move to Tucson to join the Tucson nonlinearity brigade. Nick and Hermann worked together until Hermann's untimely passing.

During one of my and Nick's visits to Tucson, I was uplifted to tell Hermann something he had not already thought of and worked out better than I could. It had to do with how to generalize KdV integrability results with respect to action-angle variables. For KdV due to self-adjointness of the Lax operator pair, the angle variables oscillated within intervals on the real line bounded by the invariant periodic spectrum of the Hill operator. Nick and I showed how the complex-valued angle variables for the sine-Gordon equation were topologically, but not analytically, constrained on the Riemann surface of an N-phase solution. Hermann smiled, probably like he did after I got off the elevator in January of 1973, but in real time, sharing his approval and joy of a cool result. It is difficult to convey how much that smile meant. What an impact Hermann had on all of us who were touched by his brilliance and humanity. To this day, he is exactly what Gil Strang said....the smartest son-of-a-gun most humans have ever known. May he rest in peace, and his family and colleagues take pride knowing Hermann's brilliant contributions will forever be recognized and admired.

Al Scott Lecture: Jess Pillow (PhD 2021)

Jess Pillow (PhD 2021) was selected as the winner of the annual Al Scott Prize and Lecture in May 2021. The title of their talk was "Bayesian Spatially Varying Multi-Regularization Image Deblurring" and the abstract follows:

Many scientific experiments such as those found in astronomy, geology, microbiology, and X-ray radiography require the use of high-energy instruments to capture images. Due to the imaging system, blur and added noise are inevitably present. Oftentimes the captured images must be deblurred to extract valuable information. In the presence of noise, image deblurring is an ill-posed inverse problem in which regularization is required to obtain useful reconstructions. Choosing the appropriate strength of the regularization, however, is difficult. Moreover, many images contain some mixture of smooth features and edges which requires the use of multi-regularization, i.e., the type of regularization (total variation or Tikhonov) varies across the image. We address these two issues by formulating the image deblurring problem within a hierarchical Bayesian framework, varying both the strength of the regularization, as well as the regularization type across the image. In this way, both the image and the strength of the regularization, which varies across the image, are described by



a hierarchical posterior distribution which we can sample by Markov chain Monte Carlo (MCMC), in particular Gibbs samplers that make use of conditional distributions for efficient sampling. We compute the means of the image and parameter samples for simulated test images, and we compare our results with existing non-spatially-varying Bayesian methods to show that our new method both increases the quality and decreases the error of the image reconstruction.

New Program Affiliate Members

Sudha Ram, Anheuser-Busch Chair in MIS, Entrepreneurship and Innovation, Eller College of Management

I direct an interdisciplinary research center at the Eller college called he INSITE center for Business Intelligence and Analytics (www.insiteua.org). The objective of the center is to foster research and development in the area of big data analytics. Specifically, my research focuses on developing, implementing, and evaluating, quantitative methods based on machine learning and network science. These address interesting and important research questions in areas including health care, education, smart cities, and identification of hate speech and fake news. My research addresses research grand challenges that have a societal impact, in collaboration with many local and international colleagues, post docs, graduate, and undergraduate students, and organizations. Typically, my research involves developing machine learning models and algorithms to solve problems, and then empirically evaluating them using real world datasets. I also focus on developing methods to make deep learning methods explainable, transparent, and trustworthy.

In the area of health care analytics, I have developed network and machine learning methods to (a) predict emergency room visits for people impacted by chronic conditions such as Asthma (https://uanews.arizona.edu/story/how-twitter-can-help-predict-emergency-room-visits);

(b) identify high-cost patients at the point of admission using disease interaction networks; (c) understand the relationship between environment and stress using IoT and wearable devices; and (d) identify threat of vector borne diseases using via surveillance of social media data sources. In the area of prediction modeling for education, I have developed network science based methods to glean social interaction patterns and campus integration behavior to proactively predict freshman retention in large public universities by leveraging spatiotemporal data from smart cards (see http://arizonaalumni.com/article/big-data). In the area of smart cities, I have established an international collaboration to leverage big data, extract human mobility patterns by developing deep learning methods, and smart transportation solutions in the city of Fortaleza in Brazil (https://uanews.arizona.edu/story/ua-uses-big-data-solve-bus-woes-brazil. This work was awarded the Gobernarte Award by the Inter-American development bank in 2016. Our work is now being explored for use as a model for other Latin American cities including Bogota, Colombia, and Buenos Aires. Some of the recent research projects are summarized below.

We are developing a collaborative filtering framework for explainable short-term predictions of multiple disease risk in critical care. Patients in intensive care units (ICU) are in dire health conditions and often diagnosed with subsequent diseases during treatment. However, predicting multiple disease risks with limited patient history is a challenging problem. Furthermore, most existing methods for disease prediction do not guarantee transparency and accountability. Relations between patients and diseases after admission are analogous to collaborative purchase patterns among users in e-commerce platforms such as Amazon.com (e.g., "customers who bought x also bought y"). In this project we adapt and extend state-of-the-art methods in graph representation learning and natural language processing to model collaborative relationships between patients and diseases. We extensively evaluate the performance of our method using very large real-world patient datasets and demonstrate that it outperforms widely used methods in recommender systems and graph representation learning. Furthermore, dataset-level and instance-level explanations generated using our framework enhance patient safety and support clinical decision-making.

A recent interdisciplinary project, funded by NSF for $1.9 Million the Nepaccess system (https://www.nepaccess.org/) is developing new machine learning methods to support and enhance environmental decision-making. The National Environmental Policy Act (NEPA) has fostered public awareness of environmental consequences of large-scale Federal actions, however, there are many controversies over its effectiveness. In this project we are developing novel design artifacts using data science to address grand challenges related to environmental impact assessments (EIA) mandated by NEPA. We propose a data-driven framework for predicting the time to complete EIA, which is a complex process at the heart of NEPA. It is repeatedly suggested that unnecessary and unexpected delays occur during EIA, causing bottlenecks and inefficiencies in other related projects. Hence, accurately predicting how long an assessment may take can benefit many stakeholders. For instance, government agencies can better allocate available resources and simultaneously manage multiple EIA projects. We adapt graph representation learning, which is an ideal method to represent and leverage diverse relationships among different parts of a complex system. However, there are challenges in adapting graph representation learning for our specific prediction task, including the need to consider heterogeneous relations between entities/nodes as well as node-level information. We address these challenges in our proposed framework, which incorporates a role-theoretical perspective into the EIA process.

In another research project we are developing tools and models to manage the COVID-19 pandemic. To accomplish this, we have developed a privacy preserving web-based platform called TIMES-

CAPE using anonymized wifi logs to (a) Identify movement of people across a large area and analyze person-density in buildings and locations in real-time, and build computational models to support both institutional action decisions and individual decision making and conduct scenario analysis at various times and locations; (b) Provide a near real-time congestion tracker to help identify traffic patterns, locations and routes for the logistics and facilities team for streamlining traffic flow; (c) develop a Memory Jogger as a Contact path-tracing aid: to provide individuals with a view of their spatial and temporal movements to help them "jog" their memory by either creating a visualization of their on-campus movement (fast-forward over specified time period) OR flagging locations where they were for either an extended amount of time or during time of dense traffic. This is being utilized for enhancing manual contact tracing efforts by the SAFER team at the University of Arizona (see https://radio.azpm.org/s/86652-episode-278-using-data-analysis-to-counter-covid-19/).

We are also conducting an empirical comparison of Manual and Digital app-based contact tracing methods to understand how they work in tandem to contain COVID on campus.

Contact tracing involves monitoring people who have been exposed to a person with a confirmed infection, such as COVID-19 infections and quarantining them until they are known to be infection-free. The standard practice of manual contact tracing entails an individual being contacted by a public health official after diagnosis by a clinician. This is a process that has multiple challenges, including 1) faulty recall, and 2) timeliness of notifications. Two digital strategies i.e., Bluetooth enabled contact tracing via a mobile app and prompted mobility paths for enhancing recall, can be used to extend and enhance contact tracing. Bluetooth enabled technology allow individuals to download an app on their mobile phones that leverages the

Google/ Apple api. The prompted mobility pathways strategy takes advantage of the location information generated from catcard and wifi logs to provide a tailored mobility path to student, staff, and faculty contacts on campus which can then be leveraged to help enhance recall of potential contacts during manual contact tracing. A robust manual contact tracing protocol has been set up in the Epidemiology and Biostatistics Department in coordination with Pima County Health Department, we partnered with COVID-Watch to be the initial pilot center for Bluetooth contact tracing, and we have an effort on campus that is leveraging an extensive network of geo-located wifi/ catcard system that allows for mobility paths to be constructed.

In this research we answer the following research questions: (a) How do the three contact tracing approaches differ in their outcomes such as timeliness and coverage of contacts and other metrics? (b) How do these methods complement each other and what are their relative strengths and weaknesses? (c) How do these methods perform overall in preserving privacy while allowing for comprehensive contact tracing? What are the tradeoffs? (d) How acceptable are these three strategies to the community and what is an effective path to deploying comprehensive contact tracing?

I like to use social science theories to both improve and enhance machine learning methods and conduct experiments to evaluate how these methods can work with humans-in-loop and learn from them as well as support human decision making. In today's world, where online information is proliferating in an unprecedented way, a big challenge is to determine whether or not to believe the information we encounter. We are developing a novel, social science theory-motivated deep learning (DL) framework for identify fake information. We base our framework on the structural balance theory (SBT) that helps examine the consistency between claims (whose veracity needs to be verified) and corresponding evidence (which contains true information) text. Specifically, we build a word network from claim and evidence text reflecting its syntax and convert it into a signed word network using word semantics. Then, we measure the level of the network's structural balance and use it as an important source of information for verifying claim veracity and explaining the model's decision making. We conducted real world experiments to test the performance and explainability of our framework. Our SBT-based explanation shows a strong positive impact on human content moderators in terms of their task performance, trust in algorithms, and confidence in decision making. In an extension of this work, we propose a novel deep-learning framework for detecting online fake news by incorporating theories of deceptive intention. Specifically, we first develop a transfer-learning model that identifies deceptive intention reflected in text using semantic and deceptive cues derived from multiple deep learning and natural language processing techniques. We apply this model to distinguish two subclasses of fake news: deceptive and non-deceptive fake news. Then, these two classes of fake news, along with an observed class of non-fake news (i.e., true news), are used to train deep bidirectional transformers whose goal is to determine news veracity.

Our experiments reveal that, when used to assist humans in the loop of the fake news detection process, the proposed design showed some synergistic effects including increased accuracy, trust, and confidence. Finally, we are extending these approaches to identify online hate speech using deep learning and personality theory. Our approach uses important findings from many studies in psychology investigating the relationship between one's personality and his/her tendency to write hate speech. We develop a text-mining approach which fully automates the process of personality inference. Using the automated approach, we learn that findings from the literature on the relationship between personality and offline hate behavior also hold true in an online setting. Based on this analysis, we develop a personality-based deep learning model, called PERSONA, for detecting online hate speech. We evaluate our model with two large real-world datasets. First, we apply the model to detect hate speech on Wikipedia. The results show that our model significantly outperforms state-of-the-art baselines including the closed-source system proposed by Google. Then, we further test PERSONA on a new dataset collected from Yahoo. In comparison with the baselines, our model produces the best results confirming its strong generalizability.

I teach a doctoral course (MIS615) on Network Science: Theory and Applications which is popular with students across campus in multiple disciplines. This course introduces doctoral students to quantitative methods in network science used to model, analyze, and understand various complex systems and the unique interactions among their components. Students in this class acquire knowledge to analyze complex systems by modeling interactions among the components as a network. They also learn to analyze these networks by implementing and using various algorithms and visualizing the results of the algorithms and ultimately integrating networks with prediction models and machine learning methods. Topics covered include the mathematics of networks (graph theory), data analysis, graph representation learning, and applications to technology, business, biology, medicine/healthcare, and other relevant fields.

I am very passionate about interdisciplinary research to address societal grand challenges and hope to continue my many collaborations with people in different disciplines as articulated in this recent paper titled, "Focusing on Programmatic High Impact Information Systems Research, Not Theory, to Address Grand Challenges", published in MISQ, 2021.

Tonatiuh Sánchez-Vizuet, Assistant Professor, Mathematics

My research journey began quite early in my life. As a child I always felt attracted to puzzles and would spend countless hours going over any puzzle book that I could get my hands on. However, at that time I did not really consider mathematics as a profession, but rather as a fun past-time; in fact I felt more attracted to history and music. The definitive moment came when I was twelve when I took my first middle school classes on physics and chemistry. My teachers were incredibly good at communicating their passion for nature and encouraging scientific though and, perhaps most importantly, curiosity. Around that time a copy of Stephen Hawking's "A brief history of time" fell in my hands. I got fascinated by the book's description of the beginning of the universe, the creation of stars, the idea of black holes, curved space-time... I could not stop thinking about all these things and I decided that I would become a theoretical physicist.

Somehow, I managed to stick to my childhood decision and, when the time came, I enrolled in the National Autonomous University of Mexico where I earned a "Licenciatura" (roughly equivalent to a masters degree) in Physics. However, during my studies I realized that a deeper understanding of the mathematical properties of the equations from theoretical physics is necessary in order to tackle problems from physics, engineering and other applied sciences. I then switched gears and earned a masters in mathematics from the same University before moving to the US to start my doctoral studies in applied mathematics, which I completed in 2016 at the University of Delaware. After graduation, I accepted a position as postdoctoral associate at New York University's Courant Institute of Mathematical Sciences.

My research interests have always been deeply tied to my early fascination with the interaction between physics and mathematics: as an undergraduate student I was mentored by a group doing research in computational general relativity, during my masters studies I worked on developing a computational solvers for the equations of gas dynamics, during my doctoral studies I studied integral equation formulations for the simulation of wave propagation in unbounded domains and in the development of coupled algorithms for multi-physics problems, and as a postdoc I worked in a projects related to efficient and accurate computational methods for the computation of magnetic equilibrium in fusion reactors; this project has lately been expanded into the exploration of surrogate methods for quantification of the uncertainty introduced by the stochasticity of certain physical parameters in the reactor.

I recently received support from the National Science Foundation to develop methods and algorithms for accurate simulation of a problem arising in plasma physics that involves integrodifferential equations and a so-called "free boundary problem". In a fusion reactor, strong electromagnetic fields are used to confine an extremely hot ionized mixture of deuterium and tritium. At such high temperatures, the nucleii of these gases oscillate so violently that they may overcome the electromagnetic repulsion and get close enough to each other to allow for the strong nuclear force (a short-range, attractive force) to fuse them together. The Helium nucleus resulting from the merger has in fact less mass than the two original nuclei had when they were independent. This "mass defect" is turned into energy according to Einstein's famous relation E = mc^2. The conversion factor in this relation is the square of the speed of light, which means that even if only a minuscule amount of mass is converted in the process, the energy yield will be huge. Moreover, as opposed to nuclear fission, no radioactive waste is created, making nuclear fusion a very promising source of energy.

One of the many, many challenges to harness the power of fusion, is the determination of the equilibrium configuration of the plasma within a reactor. The nucleii in the plasma are subject to the effect of magnetic forces and can only remain confined in the regions of space where the steam lines of the magnetic field are closed. Reactors are designed with many coils that produce a confining magnetic field. The difficulty stems from the fact that the plasma, being a soup of charged nucleii flowing inside of the reactor, acts itself as a coil and thus affects the total magnetic field modifying the streamlines. As a result, the location of the confinement region cannot be known a priori and must be determined as an additional problem unknown. Mathematically, the equilibrium condition can be stated as a non-linear partial differential equation or integro-differential equation (depending on the parameters specified by the physicists) posed in a domain whose boundary is unknown (the interior of the plasma). The goal of the project is to produce highly accurate computational tools that will allow the physicists to simulate and predict the location of the plasma within the reactor.

Despite the fact that most of my research interests stem from physical applications and involve the development of computer solvers, I consider myself an applied mathematician. My work mostly revolves around the understanding of the equations involved and the rigorous mathematical study of the approximation properties of the schemes developed. As a numerical analyst, I lean heavily on tools from the theory of partial differential equations, boundary integral equations, functional analysis, approximation theory, probability and statistics. I am happy to be part of a program that values the interaction between mathematics and other sciences and that recruits top students with a similar interdisciplinary vocation. I am convinced that this environment is ideal for my research career to blossom, and I am looking forward to what the future might bring.

Alumni Profiles

Katie Williams Young (PhD 2016)
Director, Business Development,
Applied BioMath

I was fortunate to develop two types of mathematical knowledge during my time at the University of Arizona. The first is a strong foundation in mathematical concepts: key theorems and approaches to solving or approximating particular types of differential equations. The second, oft underappreciated, is quantitative reasoning: an understanding of how to gather and use data to make informed decisions. The former was the result of working through homework sets and exams my first two years while the latter came while working on my dissertation; taking courses in the Department of Physiology, Pharmacology, and Biomedical Engineering; and interning at Takeda Pharmaceuticals. While a student, I primarily focused on perfecting my understanding of mathematical concepts and didn't fully appreciate the quantitative reasoning I was acquiring. However, as I think back to my time in Tucson and its influence on my subsequent career trajectory, it is quantitative reasoning that has had a dominant impact on my professional success.

I started in the Graduate Program in Applied Math in fall of 2011 with a mathematical biology background and a passion for using mathematics to work on biomedical problems. I chose Arizona because of the balance of theory and applications outlined in the course requirements and the approach to research. My committee included Ardith El-Kareh, Tim Secomb, Michael Tabor, and Joe Watkins, and my dissertation explored the impact of cell cycle stage on cancer cell sensitivity to radiation and chemotherapy. Much of my work involved trying to understand (1) what must be happening intracellularly to drive the observed treat-

ment exposure-response relationship and (2) how one would represent that behavior mathematically. It turns out that similar models are commonly developed as part of drug research and development in the pharmaceutical industry. By the time I graduated in 2016, my coursework, research experience, and internship had taught me everything I needed to know to begin a career as a quantitative systems pharmacology (QSP) modeling scientist.

The field of QSP has developed substantially over the last two decades, and today most large companies have teams of scientists building ODE, PDE, and statistical models to help optimize the time-consuming and costly process of making a drug. My first job was as a modeling scientist at Applied BioMath, a start-up that provides quantitative consulting services for pharmaceutical and biotechnology clients. Our interdisciplinary teams build mathematical models that integrate data from many sources and advise companies on key decisions such as which drug doses are expected to be both safe and efficacious, which drug candidate properties are predicted to be optimal based on its mechanism of action, and how we expect preclinical experimental results to translate to clinical outcomes. In my role as a scientist, I developed mathematical models for novel therapeutics across a variety of disease areas and drug modalities. The quantitative reasoning I developed at Arizona enabled me to determine not only what equations might represent observed data but also what biological network would result in those equations and what could be gleaned from the resulting model simulations.

After several years as a modeler, I joined the business development team to spend more time sharing the value of math modeling with potential new clients, determining how our math modeling approaches might solve particular client challenges, and learning how to grow our company. Today I am Director of Business Development, and my work includes attending conferences to present our scientific work and build relationships with potential clients, fostering collaborations with our existing clients by learning about their technology and recommending services, building and managing a team of sales and inside sales professionals to expand our business, and analyzing our internal operations and market data to provide growth strategy recommendations. My experience in the Program and as a scientist building math models and presenting the results to broad audiences has helped me quickly adapt and thrive on the business side of my organization.

Lastly, outside of work I volunteer with Women In Bio, an international non-profit organization that promotes gender parity in the life sciences. I have held both local and national leadership positions, and I am currently the National President and Chair of the Board of Directors. I have helped the organization navigate the pandemic but perhaps more importantly have instigated more data-driven decision-making through carrying out staff time studies to optimize our staff resources, gathering data on our fundraising efforts to make more robust future budget predictions, and identifying membership growth potential in key life science cities. Again, I rely on mathematical sense gained in the Program to help me guide our growth and serve the life sciences community.

As I look at all the exciting science I've had the privilege of working on in the last ten years, I am continually reminded of the ways in which the Graduate Program in Applied Mathematics at the University of Arizona launched my career. Learning to approach complex problems by understanding what underlying networks may drive observed behavior has been invaluable to my work across roles.

I'm grateful for the professional and personal ties I made at Arizona, and I'll close here with a few bits of advice for current and future graduate students:

- Time-permitting, take coursework in other departments to complement your mathematical knowledge and help you see how applied math fits into neighboring fields.
- Get used to talking about mathematical results and their impact in the context of the problems you are solving – be able to answer the question "so what?"
- If you have opportunities to present your work (especially in other departments or to non-mathematical audiences) take them.
- Think about what you like to spend your time doing and what excites you intellectually. I have always loved biology, chemistry, and physics in addition to math. I also enjoy both building mathematical models and educating people on how math modeling might help develop better therapeutics. I am now able to work in all these areas.
- Spend a summer at an internship. Even if you don't end up working in the same field as your internship, you'll have experience to add to your resume and will get exposed to how applied math is used in an industry setting. Many large companies have internship programs, and you can always reach out to Program alumni or search on

LinkedIn to find open opportunities.

- Engage with Program alumni to learn about their careers and what decisions they made along the way – many jobs are filled by word of mouth and fellow alums are great advocates.

Here's to an exciting 2022, and I'm always happy to connect on LinkedIn. Bear down!

I married fellow Applied Math 2011 cohort member Alex Young on August 24, 2019 in Columbus, Ohio. We celebrated with the following friends from Tucson, including a number of Program alumni (from L): Andrew Leach, Amy Veprauskas, Luke Edwards, Logan Gantner, Susan Borowski, Kerensa Gimre, Rohan Chaudhary, Candice Clark, Katie Williams, Alex Young, Michael Borghese, Ben Holman, Colin Clark, and Georgia Pfeiffer.

Our son, Malcolm, was born on November 29, 2021, in Cambridge, MA

Amy Veprauskas (PhD 2016), Assistant Professor, Applied Mathematics, University of Louisiana at Lafayette

I have my undergraduate mathematics professor, Victor Donnay at Bryn Mawr College, to thank for my decision to attend the UA program in applied mathematics. In my senior year I decided to go to graduate school for applied math. Since the Bryn Mawr mathematics department at the time focused almost exclusively on pure mathematics, I asked Victor for advice on where to apply. After a quick internet search, he suggested the University of Arizona. I had lived in the Northeast my entire life and had not intended to move that far from home, but given the recommendation, I decided to include UA in my applications.

A few months later, I received an invitation to participate in the graduate student weekend. Even before returning home, I had decided to attend Arizona for graduate school. The beauty of Tucson and the surrounding area surprised me. I had also received the impression that the program promoted a good sense of community, that the students worked together rather than competing, and that my peers would be people with whom I could both spend hours working through problem sets during the week and join for a hike on the weekend.

The transition to the applied math program from a small liberal arts school with a pure mathematics focus was difficult. In the very first assignment for Numerical Analysis, we were asked to program a summation (I think it was the sum from n=1 to 100 of n^2) and I remember being shocked when I was told to write ⟦x=x+ n⟧^2 in the for-loop. How can x be equal to ⟦x+ n⟧^2? However, after getting through the core courses and the qualifying exam, things improved. In my second year I took my favorite mathematics course during grad school, Perturbation Methods taught by Michael Tabor. I also worked with Jim Cushing for the second-year research project and decided that I would like to continue working with him for my dissertation.

My dissertation focused on understanding how incorporating stage structure in a model, such as distinguishing between distinct developmental stages, influences population dynamics. In particular, I used bifurcation analysis to establish the dynamics of discrete-time population and evolutionary models with imprimitive projection matrices which may lead to more complicated dynamics. I really enjoyed working with Jim and learned a lot from him. I appreciated his approach to advising where he never seemed disappointed by the amount of progress, or lack thereof, that I had made and had a tactful way of telling me that I had made an error, usually something along the lines of "well that would be interesting, why don't you double check it to make sure?".

I am appreciative of all that I learned during my time in the applied math program and found that the program structure truly helped in my mathematical training. I enjoyed the early introduction to the process of doing research. This experience was invaluable in its introduction to both the research process and the practice of explaining and presenting research in a clear and coherent manner. I also liked the out-of-department course requirement. Though I was initially intimidated to take a graduate-level ecology courses (I had never taken any as an undergrad), I feel that the experience made me a better researcher. I especially enjoyed Peter Chesson's courses where I learned how to better link mathematics modeling with ecological theory.

Ski Trip to Whistler, BC
(Sadly not my dogs)

After graduating in 2016, I accepted a two-year postdoctoral research position at the University of Louisiana at Lafayette. My post-doc advisor was Azmy Ackleh and I was funded through a grant whose overall goal was to gain a better understanding of how the Deepwater Horizon oil spill, and disturbances in general, may affect marine mammals. During this time, I worked on a number of projects aimed at understanding and quantifying both the long- and short-term impacts of disturbances on biological populations. In my second year, a tenure-track position in mathematical biology at UL opened to which I applied and was offered the position.

Beautiful Swamps of Louisana – Lake Martin in Breaux Bridge

I am now in the fourth year of this position. My current research focuses on understanding how population stage-structure (e.g., distinct developmental stages), environmental disturbances (both natural and man-made such as hurricanes and pesticides), and evolutionary changes in a population (such as the evolution of pesticide resistance) affect the dynamics of a species and the species with which it interacts. For me, an ideal research project is one having not only an interesting biological question to address but also some challenging mathematics problems. With my current research focus, I am able to explore topics such as nonautonomous and stochastic matrix equations, persistence, and global dynamics while also collaborating with biologists at other universities on interdisciplinary projects. One of my current projects focuses on modeling the invasion and establishment of new tick populations and their associated pathogens. The aim of this project is to gain a better understanding of how host availability, host movement, and variability in the abiotic environment drive these processes in order to better inform management efforts and risk assessments.

I enjoy working at UL and have the opportunity teach a variety of interesting classes, including a two-semester biomathematics course where I can present topics which are directly related to my research interests. I also recently started working with my first graduate student which is both exciting and a little intimidating. I hope that I am able to emulate Jim's approach to advising my own students.

I miss living in Tucson and will extoll its virtues whenever the opportunity arises. I love the outdoors in and around Tucson and all the great activities – hiking, cycling, climbing, and even skiing! – that it provides. I also love the fact that you can do things outdoors all year round, even if that may mean waking at the crack of dawn in summer. Although I certainly prefer dry heat over wet heat, Louisiana has its own charms including many beautiful waterways and swamps. To take advantage of this, I have added paddling to my pastimes, both kayak and stand-up paddleboard. The phrase "beautiful swamps" may sound a bit strange to some, but you have to see it to believe it. And, so far, I have not had any alligators try to eat me.

Finally, for those of you who were wondering, Modi is doing great.

Alejandro Aceves (PhD 1988)
Professor, Mathematics, Southern Methodist University

This story is about nonlinear optics, climate, (of course) covid-19, Sapienza University, Rome and the 2021 Noble Prize in Physics. All converging to one place in space (Aula Magna, Sapienza, Rome) and time (December 6, 2021, 18:00 CET).

Late July this year marked the end of a 6-year term as Department Chair and the start of a 1-year sabbatical. At the time, with some hope for better conditions, I began to make plans to travel and visit friends and colleagues. In particular, there was a proposed visit to a friend and colleague of many years: **Stefan Wabnitz**, a Professor of EE at Sapienza University. Recently his group had performed beautiful experiments on optical filaments, including effects such as orbital angular momentum (spiral filaments) and propagation at interfaces which brought me back to my dissertation work with **Alan Newell** and **Jerry Moloney**. With an air of optimism, we pinned the visit for December 6-17. Fall arrived with indications that covid-19 perhaps was winding down. It was also a time where the conversation on climate change was front and center; in part from the latest (6th) IPCC report, and the Glasgow Climate Change conference, but also in no small measure, scientific papers on the climate driving engine for Europe: the Atlantic Meridional Overturning Circulation (AMOC), currently showing signs of its weakening. The studies prompted "frightening" articles in the WP, NYT, The Guardian and other outlets. All of this drove me to invest time on reading recent literature on AMOC research (a topic that a former student of mine worked for her dissertation), and on the policy side, I co-authored an article which appeared in SIAM News, October 2021. Then came the announcement of the 2021 Nobel Prizes. In Physics, with perhaps a hint of the Nobel committee trying to make a point about climate, the award was shared by Syukuro Manabe, Klaus Hasselmann and Giorgio Parisi, who is in the Faculty at Sapienza. For those interested in the Nobel Lectures, they can be found at https://www.nobelprize.org/. A brief pause on, and detour from the main story: in my opinion this could have easily been called the year of the 2021 Noble prize in Applied Mathematics. All of the research recognized has a strong AM flavor; furthermore the UA/AM community should take pride in that if you were to walk in the corridors of the ancient Math building (and if so, as you go from one floor to another, please avoid the elevator), you could knock on a few doors and have faculty tell you of important contributions they have made to the fields represented by the Laureates. For brevity I only mention Hasselmann who is known for his work on the kinetic equation and wave turbulence, with a formulation using Feynman diagrams; on this we know of the seminal contributions on WT by **Zakharov** and **Newell**. The same can be said on studies from UA Math/ApplMath faculty on spin glasses, disorder, and computational studies for ocean dynamics.

Back to serendipity: When I looked at work by Parisi, he did have a short (1982) and a long (1983) paper on stochastic resonance and Climate (the 1983 paper was published in SIAM which supports my previous observation). While I was not aware of this work, it turns out our paper on AMOC (SIAM 2014) faithfully followed his approach, with our theoretical outcomes specific to a Climate (AMOC) model eerie similar to Parisi's 1983 paper. All of this prompted me to create a presentation on climate focusing on these recent events and reports. This was presented as an in person invited talk at the SIAM TX/LA annual conference in early November (it was great to reconnect with many friends including Misha Chertkov).

The Italian Physics community is naturally proud and happy to see Parisi co-sharing the award. At a recent photonics workshop at the SIMONS Foundation (first in person event I attended in the covid-19 era), during one lunch, two young Italian physicists told me that (notwithstanding the pandemic) 2021 was a great year for Italy for 2 reasons: Parisi's Nobel prize and that the national soccer team won the European Championship. I can't disagree with where their priorities stand. It also made me think of my planned visit to Sapienza. After a nice Thanksgiving and myself getting a vaccine booster, it was decision time about my upcoming trip. Omicron arrived, making this more challenging. Took the required covid-19 test. Departure is scheduled for noon Sunday, December 5 and twelve hours earlier, results on my test have not arrived. Midnight, they finally come (negative), I insert all

Parisi with his Nobel

information to the airline system and midday Sunday get in the plane. A connection at JFK gives me time to check on the Sapienza website and see announcement of talks, concerts,… which might be of interest. There I learned that because of covid-19, this year, except for the Peace prize, all other Nobel prize ceremonies were going to take place at different locations and times lined to where the Laureates live. Some (like in Washington DC) included a group from different disciplines. Then I read that for Parisi, the ceremony was going to be held in Aula Magna at La Sapienza the next day (Monday 18:00hrs CET) and that it would be live. To find the link you would need to login to a University account. Since at that moment (Sunday afternoon) I could not find this link, I emailed the organizer, told them I was arriving Monday morning to spend time in Sapienza as a visiting faculty and I was hoping they could email me the link. Closed my laptop, board my plane and arrive in Rome Monday, Dec 6, 10AM; after a surprisingly fast and easy passport control process. I exit the terminal and turn on my cellphone (yes it can be a convenient gadget). First, sent a message home with news that I arrived safely; then I let Stefano know where I was for him to pick me up. Lastly, time to check other emails; jetlag had made me forget about my request, but an email thread in Italian reminded me of it. I open the email and instead of the link, I find an invitation to attend in person with instructions on what needs to be done to enter the Aula. Once I settled in my room at the Sapienza guesthouse, I got a guest email account which I needed to process my entrance requirements. First, one must register to enter campus and which building to visit; this was approved. Second one would turn out to be a permanent challenge throughout my stay: need to show my "green pass". This is a QRcode with vaccination records (the European version of our vaccination white card). Of course, I didn't have a green pass; it is only for European citizens. So, there I go to the ceremony, not knowing if I would be able to get in. First step: get on campus went well, I had the right form. At the Aula I saw everyone with their cellphones showing their green pass, all except me. With my basic Italian, I try to explain why I only have a white card… tense seconds, but they accept my story, so there I was, ready to see the ceremony live.

The Ceremony: Because of the unique situation due to covid-19, at the introduction they more of less explained the ceremony (which only took 1hr) was in two parts: Part one, the hosts (in this case Sapienza) had full discretion on who would give speeches: We heard the Rector, the Director of Research and the Mayor of Rome, who asked Parisi to solve a practical problem with a high level of disorder: Traffic in Rome. Part 2, lead by the Swedish Ambassador would follow as close as possible the usual protocol (including it being in English, though Parisi gave his acknowledgement in Italian): this consisted in a brief history of Alfred Nobel, a vague explanation on the principle that awards reflect important contributions that stand the test of time. Then came the actual recognition: giving the medal and diploma on behalf of the King of Sweden, a long applause, and a time for the media to take pictures followed. The ceremony ended with Parisi's acceptance. In the words of someone who was sitting close to me, the event was "sobrio".

So, the story ends, all paths leading to this event, pure serendipity. As I write this, still in Rome, my attention has returned to conversations with Stefano's team on their nonlinear optics research, testing every time I try to dine in if my American vaccination white card is a credible piece of information. Trying to stay healthy and avoid crowds and soon will start preparing my return which now requires a negative outcome for a covid-19 test within 24hrs from departure. I hope all goes well; if I get stuck in Italy, rest assured Rocio will make sure to keep me in permanent exile.

Current Student Profiles

Alexa Aucoin (4th Year Student)

My decision to join the Program in Applied Math at the University of Arizona for my PhD can be summed up into one word: possibilities. After graduating with my Master's in Pure and Applied Math from Montclair State University in NJ, I had no idea where my research focus would take me. I had experience in dynamic epidemics modelling and computational fluid dynamics (both of which I would have happily continued) but I still had a ton of curiosity regarding where I could take mathematics research. From the beginning of my time here, the department has encouraged research exploration through the semester RTG projects and their willingness to allow novel collaborations with different departments on campus. It is precisely this research freedom that pulled me to Tucson. I knew choosing U of A meant my research path was wide open. It excited me and petrified me, which usually means it's the right choice to make.

As a fourth year in the program, I can spoil the ending and say all that exploration led me to computational neuroscience, the current focus of my dissertation research. More specifically, my research focuses on modifying data-driven modelling techniques for experimental neural data. Our goal is to uncover spatio-temporal interactions between brain regions that are meaningful to emotional regulation and behavior. This research is done with my advisor Kevin Lin and using data from our collaborators Kati Gothard and Anne Martin at the Gothard Lab. This work merges my interest in dynamics and computation with my newfound fascination of the brain and I owe it to my early days in the program for given me the freedom and encouragement to discover this new research area for myself.

Just like I could have never predicted my search for a research direction would lead to computational neuroscience, I would never have predicted working toward my PhD in a global pandemic. Navigating a new modality for teaching, learning and research during COVID was certainly not without its struggles, but I've adapted and tried to make the most of these new challenges. Moving my classes and teaching online midsemester taught me how to balance the demands of virtual teaching, set boundaries to prioritize my own research, and challenge me to more thoughtfully curate my lectures to engage students online. Under the support of the RTG and CMMBS training grants during my third and fourth years respectively, I have also developed and gained new skills as a researcher. I cultivated my mentoring skills by guiding undergraduate research students with their summer projects and learned how to guide students more effectively in their remote research. I created and led online and in-person modules on a variety of topics in Machine Learning, and this semester I was awarded the Galileo Circle Scholarship from the College of Science. Although online conferences and Zoom study sessions weren't quite what I imagined my time in graduate school to look like, I am thankful for the opportunities and support I have had throughout, and I look forward to making the most of the time I have left in the program.

Beyond my school life, Tucson has really become like my second home. When I'm not burying myself in math, I love exploring the city with my partner Kevin and our Rhodesian Ridgeback, PJ. I never imagined the desert could be so beautiful. Some of our favorite activities include scenic drives through Mt. Lemmon and swimming in Patagonia Lake, but most often you can find me trying out one of the many great restaurants and breweries in town. No matter where my journey takes me next, I will certainly always be drawn to Tucson for the food, mountain views and gorgeous weather (5/6ths of the year).

Caleb Dahlke (4th Year Student)

In 2018, I was finishing my undergraduate degree in Math and Physics at UNC (University of Northern Colorado... not the real UNC). I was in Russia for the Math in Moscow (MiM) program, and I needed to decide not only which graduate program to attend, but whether I wanted to focus my studies on math or physics. While my experience in the MiM program convinced me to pursue a Mathematics degree, I also wanted to attend a program that would allow me to explore different avenues for research. The interdisciplinary emphasis at the University of Arizona's Applied Math program was just what I was looking for and I chose to attend the University of Arizona while I was still in Russia. Fortunately, this seems to be one of the better long-term decisions I have made. In hindsight, however, moving directly from Russian winters to Tucson summers may have not been my most brilliant idea ever!

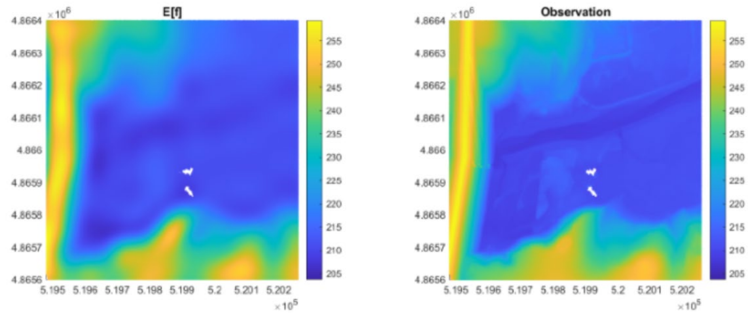


Figure 1: (Left) is a NSGP approximation to a dense surface (Right) is true observations of a lake bed

My first year at the University of Arizona was the hardest I have ever academically been challenged. Luckily, the students and professors in the program are truly amazing and encouraged everyone to work to the best of their abilities, pushing me forward through the first year and by the grace of some higher power, allowing me to pass my qualifying exam. The qualifying exam was possibly the most infuriating portion of my degree, not necessarily because of the stakes attached to it, but because I was part of the final year to take the Quals in their traditional format. It is for the better that we have moved past the Qual, but the small portion of me that struggled through it is jealous of every year after that doesn't need to experience it!

I spent the next few years jumping between advisors and research projects, from pure mathematics, to aerospace, to applied math, and finally settling on applied math in computer science with my advisor Dr. Jason Pacheco. I believe that this is one of the strongest aspects of the University of Arizona Applied Math Program. I didn't know exactly what I was interested in coming off to grad school but due to the structure of the program, I was encouraged to explore all my opportunities and ended up with an ideal project and advisor!

I am currently working on a handful of projects with Dr. Pacheco. The first project that I started working on, which is now one of my main focuses for my PhD, is Variation Bayesian Optimal Experimental Design. In the field of Optimal Experimental Design, one wants to quantify which decision in an experiment will lead to the best output. In the Bayesian setting of optimal experimental design, this is done via finding the action/decision that will lead to the largest expected information gain. Information gain is found through the change of entropy in the system before and after an expected observation. The major issue with this approach is that the distributions that define the system and observations are often intractable so computing the entropy change is infeasible.

This is where variational methods come into play. The idea is to approximate the intractable distribution with a tractable one, often from the Exponential Family (for example, a Gaussian). This variational approximation creates a bound on the expected information gain that can actually be computed and current methods are looking for ways to minimize this bound. In my research, we take the tradeoff of losing the nice property of having a lower (or upper) bound on the Expected Information Gain in place of an approximation that ideally will give a better approximation in absolute value.

Along with this research, I am working out at the Nevada National Security Site with Dr. Dan Champion (an alumni of UoA) on a photogrammetry project with hopes of making tunnel predictions. When tunnels are built, the ground above them settles creating a dip in the surface, called subsidence. In this project, we are given dense spatial observations but sparse temporal observations of a target surface. The goal is to simplify the dense data into a size that is feasible to work with, detect subsidence between each of the temporal observations, and then use the subsidence to predict the location of tunnels underneath the surface.

To address the dense spatial observations, a current approach is to learn a Non-Stationary Gaussian Process Kernel to "encode" the surface. With this learned surface, the goal is then to use regression to learn the most likely location of the Tunnel.

I am very fortunate to have chosen the University of Arizona as it has allowed me to explore so many fields that I previously never would have considered. The program has given me opportunities to work with collaborators in various departments and national labs allowing me to finally find my passion and direction within mathematics.

Bill Fries (4th Year Student)

Over my career in the Program in Applied Math, I've come to appreciate the power of a simple mathematical model. Not only can simple models offer analytic potential, but the methods used in their analysis can be applied to a variety of research fields. In my research, I have found that these reduced models can offer two interesting advantages: both in streamlining analysis of and speeding up their complex counterparts.

My interest in mathematical models started at Wake Forest University in a nonlinear dynamical systems and chaos class taught by John Gemmer ('12). While the models we investigated were relatively simple, he highlighted the insight that could be gained from them and the various applications that can arise from the same dynamical system. Continuing my academic career at the University of Arizona has offered an incredible opportunity to further this knowledge. Working with my advisor, Joceline Lega, I extended my knowledge of the fundamental epidemic models to complex heterogeneous networks of varying scales. We also began to explore SINDy, a system identification algorithm developed at the University of Washington. While these two may initially appear disjointed, we soon found an useful intersection: developing simpler models. SINDy provides a tool to discover the fundamental features of complex nonlinear systems, allowing us to uncover intrinsic dynamics hidden within the complexity.

With the onset of COVID-19, I sought to use my understanding of dynamical systems and mathematical epidemiology to help me process the current state of the world. With the increase and subsequent decrease of lock-downs, I began to study how human behavior can be modeled and included within existing epidemic models. While many dynamical systems have been proposed, each attempts to quantify a specific behavior and investigates its impact on the epidemic spread. However, it is not clear how to quantitatively compare behaviors and mitigation strategies. For example, it can be difficult to measure the impact of social distancing when compared to business closures.

To address this, we have begun to develop a method that quantitatively captures the impact of behavior on the epidemic spread. By understanding how behaviors modify the mean-field epidemic models, we create a space for directly comparing various, potentially unrelated, behaviors. Previously, each attempt to quantify specific behavioral impacts in models seems to uncover one piece of a puzzle. Placing each of these pieces together naturally makes a very complex and potentially cumbersome model. Rather, preliminary research shows that slight modifications to the SIR model can capture much of the puzzle pieces in one.

This simple approach is bolstered by our perspective shift on epidemic analysis: the incidence v. cumulative cases (ICC) curve. By plotting incidence (new cases) against cumulative cases, SIR trajectories become nearly parabolic in this new phase-plane. This offers a powerful extension

when considering stochastic models and even real-world data. Using the Gillespie algorithm, we simulated a multitude of epidemic outbreaks which, in the ICC phase plane, are found to be normally distributed about the SIR ICC curve. This allows for fast and accurate predictions by avoiding the need for computational expensive methods, such as Markov Chain Monte Carlo (MCMC). Using SINDy to identify a dynamical systems representation, we hope to combine both the ICC analysis and behaviorally-extended epidemic models to develop a simple method for quickly quantifying and comparing the influence of various behavioral adjustments to epidemic model.

Through my time in the program, I also had the opportunity to intern at Lawrence Livermore National Lab under Youngsoo Choi. This past summer, I worked with the reduced order model (ROM) team to develop a method for accelerating physics-based partial differential equation (PDE) simulations through exploiting a simpler model representation. Traditionally, ROMs rely on lowdimensional representations of the more complex PDE dynamics. Working with the team, we have found methods to extract meaningful information from this latent-space representation. This relies on extracting the core features of the latent-space representation through a method similar to SINDy. Using these, in conjunction with the low-dimensional representation, we are able to generate accurate simulations at a fraction of the time. While this does not make the more complex physics models obsolete, the low-dimensional representation of the simulations offers potential that the more complex model could not.

While these two projects appear disjoint on first inspection, they both rely on finding the fundamental dynamic features to create potentially simple and generalizable models. With an understanding of the core dynamics within the complex nonlinear systems, we can create simpler models, ask to what extent these core dynamics capture the complexity, and which aspects of the original dynamics of the system are present in the new model. The projects highlight the versatility in math that I first discovered in my nonlinear dynamical systems class. Without the interdisciplinary nature of the GIDP, I would not have the opportunity to explore the impact math could have in both of these fields. I feel very fortunate to be able investigate various applications of reduced order model with the knowledge that sometimes the simpler perspectives can offer powerful potential.

Adrienne Kinney (3rd Year Student)

My interest in studying biological phenomena through a mathematical lens was sparked during my college experience when I had exposure to research projects modeling dermal diffusion and Alzheimer's Disease. I loved working with interdisciplinary teams and using techniques I learned in my classes to study pressing health issues. These early experiences were incredibly formative for my career goals; I wanted to pursue a career that balanced mathematics and biology, that challenged me, and that provided solutions to issues I was passionate about. I was initially drawn to Arizona's Program in Applied Mathematics because of its interdisciplinary nature. I appreciated both the diversity of the affiliated faculty's research interests and the flexibility to create a program of study that fit my specific interests.

The transition to graduate school was tough, but incredibly rewarding. I am

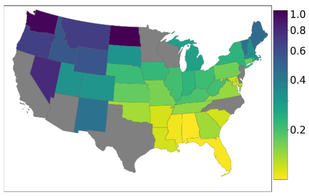


Figure 1a. States are colored according to model combined score in their capital city. Lower scores indicate better model performance. Grayed out states are omitted.

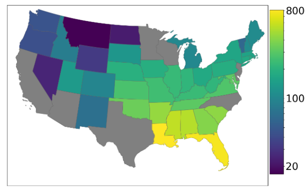


Figure 2b. States are colored according to the average number of mosquitoes in their capital city. Grayed out states are omitted.

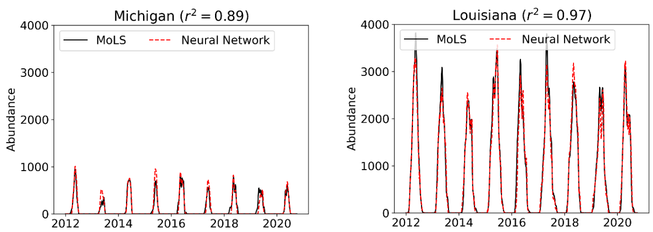


Figure 1. Model predictions compared to MoLS in capital cities of low (Michigan) and high (Louisiana) mosquito abundance.

VERY grateful both for a cohort who supported me through the qualifying process, and for faculty and postdocs who helped me think about my research priorities and connect with my advisor, Dr. Joceline Lega. Dr. Lega has helped me create a project that combines developing modeling techniques for infectious diseases and studying machine learning interpretability.

Vectors are organisms (mosquitoes, ticks, etc.) that spread infectious diseases (malaria, dengue, etc.); the mosquitoes I study prefer a warm, humid climate, thrive near dense human populations, and have started multiple disease outbreaks in the past few decades. In 2017 Dr. Lega developed an agent-based computer simulation, the Mosquito Landscape Model (MoLS), that accurately captures trends in mosquito populations. But MoLS is computationally expensive and is not set up for interactive use. Thus, it is inaccessible to many vector control specialists interested in either deploying the model or studying how the global distribution of mosquitoes will shift with our changing climate.

The goals of my dissertation are twofold: 1) assess the ability of equation-free, neural network models to learn the dynamics of the mechanistic MoLS, and ultimately, replace MoLS with a viable model for studying mosquito populations, and 2) advance neural network interpretability methods, specifically in the context of the neural network models used as MoLS replacements.

Thus far, I have worked primarily on model development with Dr. Lega and a collaborator (Sean Current, graduate student at Ohio State University). We developed neural network models designed to learn the mosquito abundance dynamics of MoLS from local weather data. Our models use the last three months of temperature, precipitation, and humidity data to predict the corresponding MoLS abundance. Our base neural network model utilized convolutional layers, and we studied the impact of 1) adding recurrent layers, and 2) overrepresenting certain abundance patterns in our training samples. We developed a robust evaluation method to assess the neural network models; our 'combined score' rates our model's ability to capture abundance trend, magnitude, and the timing of season onset, offset, and peak.

Our results are presented in Aedes-AI: Neural network models of mosquito abundance (Kinney, Current, Lega, PLoS Comp. Bio. 2021, https://doi.org/10.1371/journal.pcbi.1009467). We tested our neural network on the capital cities in the contiguous United States, and the results are shown in Figure 1a. Model performance is highly correlated to abundance (Figure 1b) with a log scale Pearson correlation r=-0.913; we perform well in states that have high average mosquito abundance and are less successful in states with low average abundance. Figure 2 shows examples of our model compared to the corresponding MoLS abundance curves in locations of low (Wisconsin) and high (Louisiana) average abundance. Even in areas of low abundance, the neural network captures the major trends in abundance quite well. Figures 1 and 2 are adapted from S8 Appendix in Aedes-AI: Neural network models of mosquito abundance (http://journals.plos.org/ploscompbiol/article/asset?unique&id=info:doi/10.1371/journal.pcbi.1009467.s008)). The work we have done suggests that our equation-free models can map weather data directly to mosquito abundance and will provide the foundation for my dissertation.

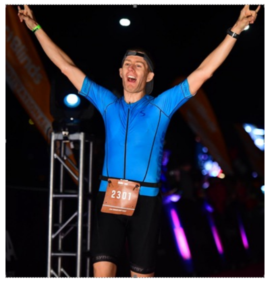
In 2021 I received an NSF Graduate Research Fellowship (GRFP) to support my work developing neural networks that can serve as vector models. I am currently advancing my work on both the public health front and the applied mathematics front. On the public health side, Dr. Lega and I are partnering with a vector-borne disease specialist from the CDC to develop a methodology for using the neural network model to forecast future mosquito abundance. On the applied mathematics side, my goal is to develop a method of model interpretability in which the neural network jointly learns abundance regression prediction and a human-interpretable explanation for the prediction. My initial studies have revealed behavioral differences in how the networks process samples from varying geographical locations and have suggested that the neural network learned known entomological features of the mosquitoes, but I have a long way to go before achieving my goal of an interpretable model. Wish me luck!

News from Members and Affiliates

Bredas, Jean-Luc (Chemistry & Biochemisty) Three publications I like best from 2021: 1) "A Unified Description of Non-Radiative Voltage Losses in Organic Solar Cells", X.K. Chen, D. Qian, Y. Wang, T. Kirchartz, W. Tress, H. Yao, J. Yuan, M. Hülsbeck, M. Zhang, Y. Zou, Y. Sun, Y.F. Li, J.H. Hou, O. Inganäs, V. Coropceanu, J.L. Brédas, and F. Gao, Nature Energy, 6, 799-806 (2021). 2) "Organic Photovoltaics: Understanding the Preaggregation of Polymer Donors in Solution and Its Morphological Impact", T. Wang and J.L. Brédas, Journal of the American Chemical Society, 143, 1822-1835 (2021). 3) "Thermally Conductive Ultra-low-k Dielectric Layers Based on Two-dimensional Covalent Organic Frameworks", A.M. Evans, A. Giri, V.K. Sangwan, S. Xun, M. Bartnof, C.G. Torres-Castanedo, H.B. Balch, M.S. Rahn, N.P. Bradshaw, E. Vitaku, D.W. Burke, H. Li, M.J. Bedzyk, F. Wang, J.L. Brédas, J.A. Malen, A.J.H. McGaughey, M.C. Hersam, W.R. Dichtel, and P.E. Hopkins, Nature Materials, https://doi.org/10.1038/s41563-021-00934-3 (2021)

A grant of note: A collaborative UArizona team from Chemistry & Biochemistry and Wyant OpSci (Jean-Luc Bredas, Jeff Pyun, Dennis Lichtenberger, Jon Njardarson, and Bob Norwood) was granted a $1.8 M NSF DMREF award (with a start date of 10/01/2021). The DMREF program is a directed toward the use of computation and simulations to accelerate materials discovery. The current project is aimed at the discovery of new long wave infrared polymers for infra-red thermal imaging, which if successful would be the first development of plastic optics for IR imaging, which would be a major advance in the field. See https://nsf.gov/awardsearch/showAward?AWD_ID=2118578&HistoricalAwards=false

Ditzler, Gregory (ECE): Here are a few highlights: I am Co-PI on both the NSF-CAT Vehicle ($415,000) and PACT REUs ($3,000,000). We hosted 12 students between the two programs in the summer of 2021. You can find the official UA news here: Hands-On Research Experiences Sets Undergraduates Up for Success, Electrical and Computer Engineering, The University of Arizona. Publications: 1) W. Zhang, M. Krunz, and G. Ditzler, Intelligent Jamming of Deep Neural Network Based Signal Classification for Shared Spectrum, Military Communications Conference (MILCOM), 2021. 2) S. Shao, P. Satam, S. Satam, K. AI-Awady, G. Ditzler, S. Hariri, and C. Tunc, Multi-Layer Mapping of Cyberspace for Intrusion Detection, ACS/IEEE International Conference on Computer Systems and Applications, 2021. 3) A. Berian, K. Staab, G. Ditzler, T. Bose, and R. Tandon, Adversarial Filters for Secure Modulation Classification Asilomar Conference on Signals, Systems and Computers, 2021. 4) D. Schwartz and G. Ditzler, Bolstering Adversarial Robustness with Latent Disparity Regularization, IEEE/INNS International Joint Conference on Neural Networks, 2021. 5) S. Hess and G. Ditzler, OrderNet: Sorting High Dimensional Low Sample Data with Few-Shot Learning, IEEE/INNS International Joint Conference on Neural Networks, 2021. 6) S. Gupta, R. Golota and G. Ditzler, Attack Transferability Against Information-Theoretic Feature Selection, IEEE Access, 2021, vol. 9, pp. 115885-115894. 7) H. Liu and G. Ditzler, Data Poisoning Against Information-Theoretic Feature Selection, Information Sciences, 2021, vol. 573, pp. 396-411.



Gupta, Hoshin (Hydrology and Atmospheric Sciences) Activities: continued to guide and develop the international (informal) Information Theory in the Geosciences (ITG) Group (see website and YouTube channel listed below). https://geoinfotheory.org *Top 3 Learning and Information Theory related papers published i n 2021:*

1) Moghaddam M, Ferre T, Klakovich J, Gupta HV and Ehsani MR (2021), Can Deep Learning Extract Useful Information about Energy Dissipation and Effective Hydraulic Conductivity from Gridded Conductivity Fields? Water, 13, 1668, doi:10.3390/w13121668. 2) Gupta HV, RM Ehsani, T Roy, MA Sans-Fuentes, U Ehret and A Behrangi (2021), Computing Accurate Probabilistic Estimates of One-D Entropy from Equiprobable Random Samples, Section on Information Theory, Probability and Statistics, Entropy, 23(6), 740, doi.org/10.3390/e23060740 3) Gharari S, HV Gupta, MP Clark, P Matgen, M Hrachowitz, F Fenicia, and HHG. Savenije (2021), Understanding the information content in the hierarchy of model development decisions, Water Resources Research, doi.org/10.1029/2020WR027948

Other Math-related papers published in 2021: 1) Razavi S, A Jakeman, A Saltelli, C Prieur, B Iooss, E Borgonovo, E Plischke, S Lo Piano, W Becker, S Tarantola, J Guillaume, J Jakeman, H Gupta, T Iwanaga, N Melillo, G Rabitti, V Chabridon, Q Duan, X Sun, R Sheikholeslami, M Asadzadeh, S Kucherenko (2021), The Future of Sensitivity Analysis: An Essential Discipline for Systems Modelling and Policy Making, Environmental Modelling and Software, doi.org/10.1016/j.envsoft.2020.104954. 2) Ruddell BL, M Clark, JM Driscoll, D Gochis, H Gupta, J Harvey, D Huntzinger, JW Kirchner, L Larsen, HW Loescher, Y Luo, R Maxwell, E Moges, Z Xu, M Donatelli, F Hoffman (2021 in review), Calling for a National Model Benchmarking Facility, AGU Advances.

Gutenkunst, Ryan (Ecology and Evolutionary Biology) Professional highlights included publishing a key paper for our group that introduces a new way of understanding natural selection in multiple populations: https://doi.org/10.1093/molbev/msab162 . Other adventures include completing my first full-distance 140.6 mile triathlon at Ironman Arizona. Finish line pic attached…

Imbert-Gerard, Lise-Marie (Mathematics) Lise-Marie Imbert-Gerard signed a contract with SIAM for the publication of a book entitled An introduction to stellarators: From magnetic fields to symmetries and optimization. Stellarator refers to a type of Magnetic Confinement Fusion device, which could lead to real-world fusion power. This project is a collaboration with two plasma physicists, Elizabeth Paul and Adelle Wright, and presents introductory material for an audience of non-specialists. The main goal of the project is to build a common language in order to stimulate more collaborations between plasma physicists and mathematicians in the field of stellarator design, in particular for the optimization of both equilibrium fields and electromagnetic coils to produce these fields.

Kobourov, Stephen (Computer Science) Inaugural recipient of the Distinguished Student Mentoring Award established by College of Science Dean Garzione. Comments by David Lowenthal, PhD, Professor and Interim Department Head, Computer Science:"Probably the best attribute of Stephen's advising is outcomes. Stephen is regularly placing our undergraduates in top-10 PhD programs. For example, Ben Jacbosen, this year's recipient of the College of Science Excellence in Undergraduate Research Award, is attending Wisconsin's PhD program this Fall. Other students have attended Berkeley, Stanford, Harvard, Washington, and Cambridge. In addition, Stephen's previous undergraduate who won the College-level award is Daniel Fried, who is graduating from Berkeley with his PhD this summer and will be an assistant professor at Carnegie Mellon. In summary, Stephen has an uncanny ability to take undergraduates and transform them from the classroom to the research lab in incredibly short order."

Kunyansky, Leonid (Mathematics) Supervised a student from Cornell during the summer school for the RTG "Data drive discovery". Published the following: M. Eller and L. Kunyansky, Parametrix for the inverse source problem of thermoacoustic tomography with reduced data Inverse Problems 37(4), 2021, 045003.

Pacheco, Jason (Computer Science) Received an Air Force Office of Science Research (AFOSR) Young Investigator Program (YIP) grant for project titled "Robust Maximum Entropy Planning, Learning and Control in Uncertain Environments." The objective of this program is to foster creative basic research in science and engineering, enhance early career development of outstanding young investigators, and increase opportunities for the young investigators to recognize the Air Force mission and the related challenges in science and engineering.

Piegorsch, Walter (Mathematics) Publications: 1) Piegorsch, W.W., McCaster, R.R., and Cutter, S.L. (2021). From terrorism to flooding: how vulnerable is your city? Significance 18, 20-25. doi:10.1111/1740-9713.01487. 2) Sans-Fuentes, M.A. and Piegorsch, W.W. (2021). Benchmark dose risk analysis with mixed-factor quantal data in environmental risk assessment. Environmetrics 32, Article No. e2677. doi:10.1002/env.2677. 3) Aberasturi, D., Pouladi, N., Zaim, S.R., Kenost, C., Berghout, J., Piegorsch, W.W. and Lussier, Y.A. (2021). 'Single-subject studies'-derived analyses unveil altered biomechanisms between very small cohorts: implications for rare diseases. Bioinformatics 37, i67-i75. doi:10.1093/bioinformatics/btab290. 4) Piegorsch, W.W. and Young, L.J. (2021). Casella, George [biography]. Wiley StatsRef: Statistics Reference Online. Davidian, M., Kenett, R.S., Longford, N.T., Molenberghs, G., Piegorsch, W.W., and Ruggeri, F., eds. Chichester: John Wiley & Sons. Article No. stat08218. doi:10.1002/9781118445112.stat08218.

Rafelski, Johann (Physics) Elected in June 2021 to be foreign member of the Academia Europaea. I completed my Fulbright Award at the Wigner institute in Budapest this Summer (interrupted by COVID). A farewell Photo is attached:

My Modern Special Relativity book to appear in a few days - maybe a week or two, you can see the book, my certificates and more pictures on my website at: http://www.physics.arizona.edu/~rafelski/RafelskiForAll.html

I am the old man on left near to the two other older people who are Fulbright Hungary officials, and all the young people are US students

Raza, Taqi (Management Information Systems) Sole-PI NSF Grant SaTC: CORE: Small: Automatic Exploits Detection and Mitigation for Industrial Control System Protocols". Published 3 Papers: 1) Muhammad Taqi Raza, and Fatima Muhammad Anwar, "On Key Reinstallation Attacks over 4G/5G LTE Networks: Feasibility and Negative Impact", ACM Annual Computer Security Applications Conference (ACSAC), 2021. 2) Muhammad Taqi Raza, Fatima Muhammad Anwar, Dongho Kim, and Kyu-Han Kim, "Highly Available Service Access Through Proactive Events Execution in LTE NFV", IEEE Transactions on Network and Service Management (TNSM), 2021. 3) Mohammadreza Ebrahimi, Ning Zhang, James Hu, Muhammad Taqi Raza, and Hsinchun Chen, “Binary Black-box Evasion Attacks Against Deep Learning-based Static Malware Detectors with Adversarial Byte-Level Language Model”, AAAI Workshop: Towards Robust, Secure and Efficient Machine Learning (RSEML) 2021.

Secomb, Timothy (Physiology) Won the Prestigious National Award for Microvascular Research: Professor of Physiology at the University of Arizona College of Medicine, Timothy Secomb has been selected to receive the 2022 Eugene M. Landis Award for his outstanding contributions to the field of microvascular research. This award is the highest honor given by the Microcirculatory Society to a member and active investigator who conducts and publishes meritorious research advancing the understanding of the microcirculation.

A member of the Microcirculatory Society since 1982, Dr. Secomb will present his Landis Award Lecture on “Microcirculatory Networks” at the Experimental Biology 2022 Annual Meeting in Philadelphia in April. “I am honored and excited to be selected for this Landis award,” he said. Dr. Secomb received his bachelor’s and master’s degrees in Mathematics from the University of Melbourne, Australia, and his PhD in Applied Mathematics from the University of Cambridge, U.K. It was while at Cambridge that he began working in the field of physiological fluid mechanics, and saw a need for applied mathematicians to work more closely with experimental physiologists in research on the circulatory system. This led him to take a postdoctoral position with an interdisciplinary group at Columbia University and then to join the faculty of the Department of Physiology at the University of Arizona in 1981.

Zeng, Xubin (Hydrology and Atmospheric Science) Elected as Fellow of American Geophysical Union in 2021 and selected to lead a major international program on climate and environment-the Global Energy and Water Exchanges (GEWEX) project.

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!

Recent Graduates

Sam McLaren (PhD, Summer 2021) is currently a Laser Modeling Physicist Postdoctoral Researcher at Lawrence Livermore National Lab

Dwight Nwaigwe (PhD, Summer 2021) is currently a Postdoc at INRIA in Grenoble, France

Jess Pillow (PhD, Spring 2021) is currently a Postdoctoral Researcher at the Nevada National Security Site

Nikki Plackowski (PhD, Summer 2021) is currently a Senior Software Engineer at Sandia National Labs,

Stan Swierczek (PhD, Summer 2021) is currently an ASEE Postdoc Fellow at the Naval Research Laboratory

Nick Bagley (MS, Fall 2021)

Sheldon Deeny (MS, Fall 2021)

The Don Wilson Applied Mathematics Endowed Fund for Excellence

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

News From Alumni

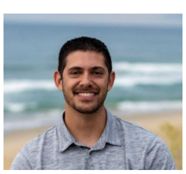
Aceves, Alejandro (PhD 1988) After 6 years as Department Chair at SMU, I now returned to the faculty ranks. I am trying to make best use of a Sabbatical year and hope to do some travel in the Spring. This year I was recognized as one of four SMU 2021 Ford Fellows as well as a 2021 SIAM Fellow. Beyond advancing my own research projects, leading our NSF-RTG program keeps me busy (please send us students to our RTG program!). As the country reopens, Rocio (MS 1991) and I enjoy spending time with family, including 3 grandchildren. This past June we were fortunate to have a full family gathering in San Diego to celebrate our son Adrian's completion of his Medical Internship".

Alvarez-Sierra, Oliverio (PhD 2005) Was made Senior member of the Antenna Measurement and Technique Association (AMTA). Built and tested a prototype from a previously granted patent.

Beauregard, Matthew (PhD 2008) Became the Interim Chair of Computer Science at Stephen F. Austin State University. I am also interim Chair for the Department of Physics, Engineering and Astronomy Department at Austin state University, Nacogdoches, TX. Since I now have two interim chair positions, I now make a "loveseat".

Borghese, Michael (PhD 2017) Started a new job as a Research Scientist at Amazon in September 2021.

Burton, Jackson (PhD 2016) Accepted a



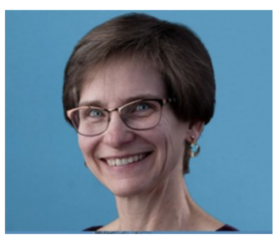
new position at Biogen (biotechnology company in Cambridge MA, although I'm fully remote). My new title is Director, Clinical Pharmacology and Pharmacometrics, Ophthalmology lead. My wife and I adopted our son Isaac in October, 2020.

Clark, Colin (PhD 2019) is a Postdoctoral research associate with the Program in Applied Mathematics at the University of Arizona where he is continuing to work with Misha Chertkov on modernizing the core-course curriculum.

Diniega, Serina (PhD 2010) Serina Diniega's family grew in 2021, with a kind and beautiful 9yr old girl joining hers and Abraham's home. Serina's Mom is also moving in, and we look forward to the multi-generational support and sharing. Serina has also done well with research grants, getting two selected for funding for the next 3 years (through JPL and NASA) to characterize the present-day Mars seasonal surface frost cycles and their geomorphic effects. She's also planning two workshops to foster mission concept development for in situ studies of planetary surface and atmosphere interactions, and is hoping that in-person travel in 2022 is a safer endeavor.

Fry, Brendan (PhD 2013) Promoted to Associate Professor at Metropolitan State University of Denver.

Henscheid, Nick (PhD 2018) Started a new job as an AI/ML Scientist in Quantitative Medicine at the Critical Path Institute, Tucson, AZ in July 2021.



Hunke, Elizabeth (PhD 1994) Named a Los Alamos National Laboratory Fellow in 2021; appointed by the Laboratory Director in recognition of their extraordinary career contributions, Fellows serve as advisors and mentors at all Laboratory levels. CICE sea ice modeling team won two awards from R&D World: a listing among the top 100 R&D innovations for the year, and their Gold Medal for Corporate Social Responsibility, which honors organizational efforts to be a greater corporate member of society, from a local to global level.

Johnson, William A. (PhD 1978) I have been working part time mentoring new employees at Sandia National Laboratories and am involved with some research with my friends from the University of Houston and Politechnico di iTorino, which have resulted in two publications and a number of conference papers.

B. A. Freno, Neil Matula, Justin I Owen, William A Johnson, "Code-Verification Techniques for the Method-of-Moments Implementation of the Electric Field Integral Equation", has been accepted for the Journal of Computational Physics.

J. Rivero, F. Vipiana, D. R. Wilton, W. A. Johnson, "Evaluation of 6-D Reaction Integrals via Double Application of the Divergence Theorem", accepted for publication in IEEE Transactions on Ant. And Propagat.

Two of our conference papers are:

Eurocap, March 2022, Madrid Spain paper accepted

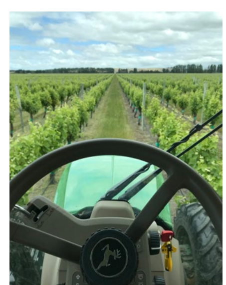
D. R. Wilton, M. A. Khayat, W. A. Johnson, J. Rivero, F. Vipiana

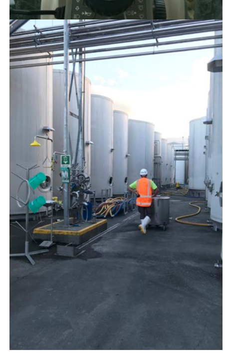
Evaluation of (Near-) Singular Integrals for Computational Electromagnetics by Dimensionality Reduction

APS- URSI, Dec 2021, Singapore, paper accepted

F. Rivero, F. Vipiana, D. R. Wilton, W. A. Johnson,"Acceleration of the Surface Test Integral Using Vertex Functions"

My sons: Richard is a mechanical engineer at Los Alamos National Laboratories, Jeremiah is a resident in radiation oncology at the University of Kentucky, Benjamin is a resident in ent at Case Western University. I have worked very hard and it seems my sons have followed in that respect.





Marsden, David (PhD 2002) Greetings to all from the mostly-Covid-free South Island of New Zealand. When you last heard from me, I was probably in Sydney, working as STEM Curriculum specialist for an international education program - and tripping around a few interesting countries (China, Mexico) talking to ESL STEM teachers about how to teach Mathematics and Science. Have now passed all of that in for a career change: after returning to NZ in late 2017, I studied for a year at Lincoln University's Winemaking school to start fresh in the world of wine.

It's been an interesting journey. I bought a house and moved to the little town of Seddon, in the heart of Marlborough Sauvignon Blanc country, at the start of 2020. Began my first vintage just as lockdown hit New Zealand (and the world). Got through that, and have been working my way up in the local industry ever since. Every day is a new learning experience: if you'd told me 20 years ago that one day I'd be driving a tractor professionally...

Anyway, if you find anywhere a bottle of either Vavasour 2020, or Kim Crawford 2021 (both labels do export to the US, so you never know), I will have had a hand in making that! I'm working with Kim Crawford again this season, and have high hopes of doing a vintage in Europe later in 2022, assuming international travel becomes possible again.

Find attached a few photos: two entries for the entirely made-up and completely unofficial "UA Applied Math Alum Best Office View", and one of me at the Kim Crawford winery at the end of vintage this year.

McLaren, Samuel (PhD 2021) I started a new job this year as a Computational Laser Physicist Postdoctoral Researcher at Lawrence Livermore National Laboratory and moved out to California with my new wife Emily Mason, soon to be McLaren. We got married on May 24, 2021 at Manzanita Vista up on Catalina Highway. We also got a new dog, Pippin, from Pima Animal Care Center in Tucson. Attached is a photo from our wedding day.

Meissen, Emily (PhD 2017) Began a new job in November 2021, working for Legal Zoom as a Principal Data Scientist, this job is 100% remote.

Nwaigwe, Dwight (PhD 2021) Published a paper titled "On the Convergence of WKB Approximations of the Damped Mathieu Equation", Journal of Mathematical Physics. Also a preprint titled "Convergence Rates for Multi-class Logistic Regression Near Minimum" that has been submitted for publication. Now in a postdoc position with INRIA in Grenoble, France.

Ragsdale, Aaron (PhD 2016) In 2020, finished my postdoc at McGill University and before starting at UW-Madison, I did a short one-year postoc in central Mexico at Langebio (the National Laboratory for genomics and biodiversity). I worked on projects focusing on demographic history and genetic variation within Mexico and how that relates to health outcomes, such as Covid-19. It was also great to be able to live down the road from my wife Sathya's family for the year we were in Mexico! At Wisconsin, my research will focus on population genetics and human evolutionary history, and I'll be teaching courses on evolution and genetics. Attached is a photo of Sathya and me on a lab hiking trip to a lake near Guanajuato, Mexico last fall.

Sritharan, Sivaguru (PhD 1982) Exciting experience serving as the Vice Chancellor at a private University in India. During late 2018 the governing board of Ramaiah University of Applied Sciences at Bengaluru selected me through an international search as the Vice Chancellor (U. S. equivalent of university president) of the institution. At that time, I was holding the position of Provost and Vice Chancellor at the U. S. Air Force Institute of Technology in Dayton Ohio. This was an exciting career move given the fact that I never worked in far east since I left Sri Lanka back in 1978 for graduate study in United States.

This university was started in 2013 and has eight faculties (colleges) – engineering and technology, physical sciences, dental, pharmacy, management, hotel management, art and design, and allied health sciences. In addition, the governing board wanted me to start two other schools – a law college and the school of social sciences. This exciting portfolio of the university presented a diverse set of opportunities and challenges that I thoroughly enjoyed, in addition to experiencing the local culture and food along with my wife who accompanied with me to Bengaluru.

Ramaiah University faculty members are smart, hardworking, ambitious, and collegial. Collaborating with them I set a vision consisting of ten thrust areas to shape the university as a twenty first century academic institution. Our vision and priorities were: 1. University level and department level strategic planning where I utilized my experience in U.S. universities leading institutional level strategic planning. 2.Streamlined hiring process to model American university system of faculty committees and transparent decision making. 3. Streamlined promotion process following and structuring the promotion and tenure process like the guidelines of American Association of University Professors. 4. Encouraging sponsored research across all faculty members across all departments of the university. 5.Initiated several innovative new degree programs to increase the enrolment BTech undergraduate engineering degree programs in artificial intelligence, robotics, mathematics and computation and information sciences. In addition, "innovation" was indoctrinated as a credit bearing undergraduate core course. 6. Taken the necessary steps and national controlling body approvals, faculty hirings and infrastructure acquisition to launch two new faculties/colleges -law and social science. 7. Energize the university to prepare for institutional and programmatic accreditations. 8. Enhancing transparency and communication utilizing frequent town-hall meetings. 9 Initiated and signed several partnership MOUs with international universities including U.S. and Europe. Enlisted several international distinguished academic scholars as permanent advisors to individual departments and at university level. 10.Distinguished seminars by international scholars from U.S, U.K and Australia in innovative areas such as artificial intelligence and robotics.

These initiatives gave the university an excellent start and impetus to grow as a progressive modern university and gave me enormous satisfaction as I returned to U.S. due to the pandemic. The university community and the management board were deeply appreciative to my contributions and the farewell ceremony and felicitation (photo attached) was an enjoyable and touching event as well.

Stover, Joseph (PhD 2008) Promoted to Associate Professor of Mathematics at Gonzaga University, starting at rank in Fall 2020. Excited that I was able to create an undergraduate Stochastic Processes course here and have run the course once. I have a 4-year-old son now, who tells me in the morning: "go get some mathematics!" Recently got back to following up on my dissertation topic after a roughly 10-year hiatus, made some progress and published a paper: https://doi.org/10.1016/j.spl.2020.108763.

Swierczek, Stan (PhD 2021) Published 2 articles in 2021, "The effect of resolution on vertical heat and carbon transports in a regional ocean circulation model of the Argentine Basin" in Journal of Geophysical Research: Oceans, and "Investigating predictability of DIC and SST in the Argentine Basin through wind stress perturbation experiments" in Geophysical Research Letters. Currently an American Society of Engineering Education Postdoctoral Fellow at the Naval Research Laboratory in Stennis Space Center, Mississippi.

Washburn, Ammon (PhD 2018) We are expecting a boy in April 2022. This will be our 5th bundle of joy!

Xiao, Zhuo-Cheng (PhD 2020) I actually planned to come back for the ceremony but had to cancel it due to other schedules...Alas, I still haven't had a chance to take a photo in my PhD uniform. Regarding my updates: I switch my position from Swartz Fellow to Courant Insturctor at NYU (same work, just different form of payment, and need to teach now). I published one paper on Frontiers in Computational Neuroscience in the last academic year (here), and have another two accepted (one on PLoS Computational Biology, and one on Journal of Computational Neuroscience).

Yamamoto, Ken (PhD 2020) I do both research and teaching here at SMU. The NSF RTG opportunities here at SMU have thrust me into new research that has pushed me beyond my PhD work. I've been exposed to new mathematical techniques and applications as well as the flexibility to work on different topics—from modeling electrical double layer dynamics to electrodeformation and transport—with multiple, different colleagues both in the Mathematics and Engineering Departments.

Although I don't work with Alejandro on research directly, he's the PI of the NSF RTG team, so I update him on general research progress as well as get valuable guidance and support from him.

Southern Methodist University. Enjoying visits with alumni!

Current Student Achievements

Abrams, Ruby (5th Year Student) Published 3 papers: 1) "Influenza spread on context-specific networks lifted from interaction-based diary data" The Royal Society, January 2021. 2) I helped publish with a group at Los Alamos National Lab, "Modeling the Effect of Subsurface Structure on Shear Wave Generation: The Case of the Yucca Flat Basin at the Source Physics Experiment Phase II Site" Journal Earth and Space Science, Open Archive (ESSOAr). 3) "Graphical Model of Pandemics" with Misha Chertkov, PLOS ONE (I'm not sure if this has been published yet though). I also landed a sweet new job at the Critical Path Institute, Tucson, AZ. It started as a summer internship, but I've been promoted to part-time work as an Associate Scientist there working for their QuantMed team (Current stuent Grace Lee and Alum Nick Henscheid are there too!). We develop algorithmic validation frameworks for wearable devices to assess progression of Parkinson's Disease.

Broeren, Teddy (3rd Year Student) Published a paper titled, "Magnetic Field Reconstruction for a Realistic Multi-Point, Multi-Scale Spacecraft Observatory". Frontiers in Astronomy and Space Sciences. I will remotely present a poster on the same research titled "Reconstruction of Turbulent Magnetic Fields from a Multi-Point, Multi-Scale Spacecraft Observatory" at the American Geophysical Union's fall meeting in New Orleans on December 14, 2021.

Christensen, Alex (3rd Year Student) Winner of 2021 National Science Foundation (NSF) Graduate Research Fellowship (GRF) competition. This is a five-year fellowship includes three years of financial support and an annual stipend and cost of education allowance to the institution. Being selected as NSF Graduate Research Fellows is a highly significant national accomplishment and places students amongst an elite group of fellows who have gone on to distinguished careers in STEM and STEM education.

Deeny, Sheldon (3rd Year Student) Honorable Mention Outstanding Graduate Teaching Assistant award for Fall 2021: Comments include, "He's made consistent contributions with writing exam questions, asking about content clarifications, and checking in with his students in their progress over the semester. In all his interactions, Sheldon has been very thoughtful, considerate, and detail-oriented." "Each example in class introduces a single new skill in order to not overwhelm students." "He is thoughtful and invested in his students' success." "He sought out help when needed and was always ready to discuss the topic for the meeting. I found meeting with him very informative for me too."

Kinney, Adrienne (3rd Year Student) Winner of 2021 National Science Foundation (NSF) Graduate Research Fellowship (GRF) competition. This is a five-year fellowship includes three years of financial support and an annual stipend and cost of education allowance to the institution. Being selected as NSF Graduate Research Fellows is a highly significant national accomplishment and places students amongst an elite group of fellows who have gone on to distinguished careers in STEM and STEM education.

Kravitz, Hannah (5th Year Student) Paper titled "Spectral solutions of PDEs on networks" was accepted to the peer-reviewed journal Applied Numerical Mathematics to be published in 2022. Awarded the ARCS Foundation Scholarship for the second year in a row.

Li, Dan (4th Year Student) was recently awarded a GIDP Herbert Carter Travel Award to attend the SPIE Medical Imaging conference in San Diego, February, 2022.

Puente, Patricia (3rd Year Student) Winner of 2021 National Science Foundation (NSF) Graduate Research Fellowship (GRF) competition. This is a five-year fellowship includes three years of financial support and an annual stipend and cost of education allowance to the institution. Being selected as NSF Graduate Research Fellows is a highly significant national accomplishment and places students amongst an elite group of fellows who have gone on to distinguished careers in STEM and STEM education.

I was accepted to the Internship Network in Mathematical Sciences (INMAS) training program. The goal is to prepare students for internships through computational and professional skills training over the course of several months. For the first training, I traveled to Johns Hopkins University in Baltimore, MD on October 22nd - 23rd with the travel support of the program itself.

I recently traveled to the American Geophysical Union (AGU) Fall Meeting on December 12th - 17th in New Orleans, LA with the travel support of my advisor Dr. Laura Condon and the Graduate College Travel Grant. I presented my poster titled "Exploring the Role of Nonlinear Dynamics on Low Frequency Extreme Streamflow Events". Picture provided below of me at my designated poster board.

Toner, Brian (3rd Year Student) In February 2021, I presented at the SPIE Medical Imaging Conference. a digital poster titled "Classification of round lesions in dual-energy FFDM using a convolutional neural network. Simulation study." I did this work during my Summer 2020 internship with the FDA. That same internship project led to a publication in the Medical Physics Journal for which I was a co-author. The full citation is: Makeev A, Toner B, Qian M, Badal A, Glick SJ. Using convolutional neural networks to discriminate between cysts and masses in Monte Carlo-simulated dual-energy mammography. Med Phys. 2021 Aug;48(8):4648-4655. doi: 10.1002/mp.15005. Epub 2021 Jul 5. PMID: 34050965. Over the summer, 2021 I returned to the FDA for another internship. This time, I worked on a project titled: "Towards improved lesion quantification and volume estimation with contrast-enhanced digital breast tomosynthesis using convolutional neural networks: a simulation study." I will present a poster on this work at the 2022 SPIE Medical Imaging Conference that will be held in February 2022 in San Diego; I was recently awarded a GIDP-Herbert Carter Travel Award to help fund this trip.

Woodward, Michael (4th Year Student) In January 2021, published a conference paper titled "Direct Numerical Simulations of Laminar-Turbulent Transi-tion for Transonic Boundary Layers" at the AIAA (American Institute of Aeronautics and Astronautics). Interned in the summer for Los Alamos National Laboratory at the CCS-2 Division, mentor: Daniel Livescu. In May, presented at the virtual Los-Alamos Days on Physics informed machine learning of Smoothed Particle Hydrodynamics (SPH). Was awarded the **DOE SCGSR fellowship**, and on October 1st moved to Los Alamos as a student guest at LANL. In November, presented a talk at the APS-DFD titled "Physics Informed Machine Learning of Smooth Particle Hydrodynamics: Validation of the Lagrangian Turbulence Approach". Published a preprint article on arxiv titled "Physics Informed Machine Learning of SPH: Machine Learning Lagrangian Turbulence."

Student Grand Canyon Trip October 2021

The 2021 Applied Mathematics Grand Canyon trip was a huge success; we doubled the number of participants compared to the previous trip! (The tradition started in 2019, and after a hiatus in 2020 due to the pandemic, we were able to safely resume the tradition this year.) We had 35 participants, 20 of whom chose to camp both nights at the south rim. This group spent their time hiking along the south rim and cooking on campfires.

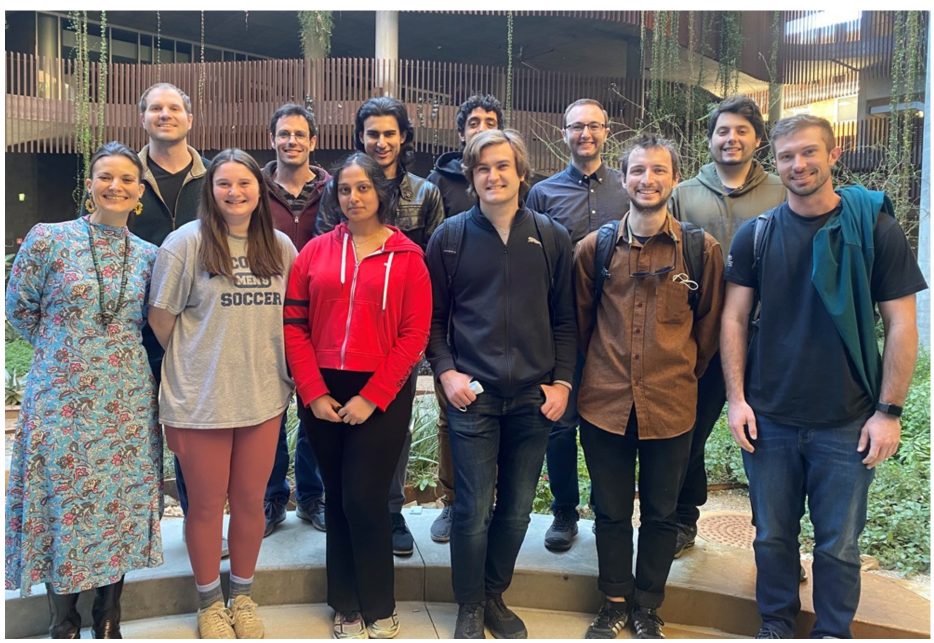
The rest of the participants elected to hike the rim-to-rim trail – a 24-ish mile trek from the north rim through the canyon to the south rim. This group camped the first night in the frigid cold at the north rim. Up bright and early, the hike started at 4am and took until late afternoon. We saw incredible sights: hiking down the north rim in the pitch dark, watching the sunrise over the canyon, following the Colorado River through the canyon, and ending with the tough climb out at the south rim. The hike was so invigorating (and left our feet very sore!).

We hope to continue this tradition in the future! We had students of different cohorts hiking together, and really prioritized meeting new people and appreciating the beauty of Arizona.

New Students Fall 2021

Back row: **Edward McDugald** (University of Washington); **Woody March-Steinman** (CUNY Hunter College); **Sam Nasreldine** (UC Santa Barbara); **Riyaaz Ray Vachani** (NY University); **Aaron Larsen** (Brigham Young University); **Jackson Zariski** (University of Washington)

Front row: **Ana Fernandez-Sirgo** (University of Washington); **Shelia Whitman** (Lycoming College, PA); **Akshita Sharma** (UC Davis); **Ari Bormanis** (University of Arizona); **Ben Stilin** (University of Washington); **Theodore Meissner** (Rollins College)



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Graduate Interdisciplinary Program

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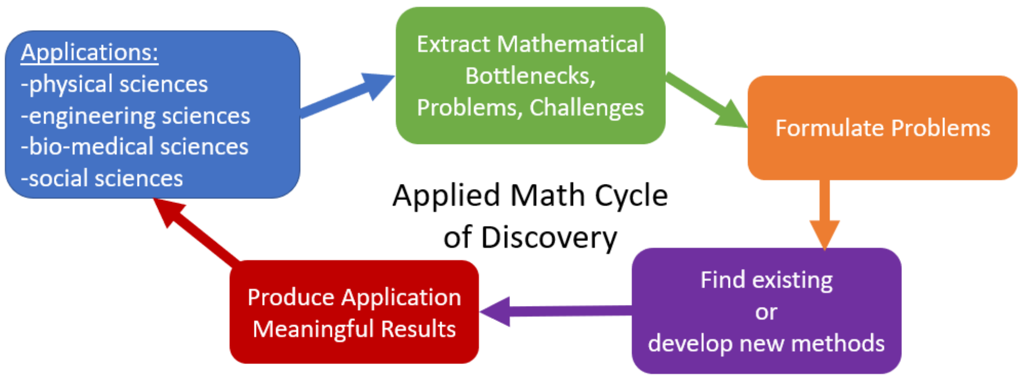
https://appliedmath.arizona.edu/admissions

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

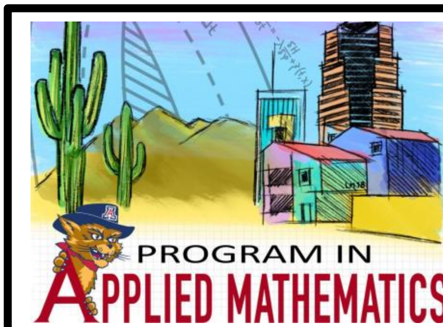
- Training in **methods** (Math/APPL **581**), **theory** (Math/APPL **584**), **algorithms** (Math/APPL **589**)
- Math (quantitative) and Application-specific (qualitative) intuition

"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

New 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 have the opportunity to pursue flexible and individually designed programs of study.

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The University of Arizona
PO Box 210089
Tucson, AZ 85721-0089
appliedmath.arizona.edu
Phone: 520-621-2016

Michael (Misha) Chertkov
Chair

Stacey LaBorde
Program Coordinator, Sr.

Keri Oligmueller
Graduate Coordinator

To submit articles or
news items, contact:
appliedmath@math.arizona.edu

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