THE UNIVERSITY OF ARIZONA
Applied Mathematics
Graduate Interdisciplinary Program

Applied Mathematics Newsletter

Number XXIV, January 2024

Greetings from Misha Chertkov the Chair, Program in Applied Mathematics

Michael (Misha) Chertkov, Chair

Dear Students, Colleagues, Alumni, and Friends,

Admittedly, I hesitated to pen this year's annual letter, caught in a whirlwind of formidable challenges and uplifting breakthroughs. Ultimately, I opted to share a chronicle of our experiences, detailing what we confronted, celebrated, overcame, and enthusiastically welcomed since last spring (of 2023).

Following the high spirits of our recruitment weekend and the now customary Los Alamos – Arizona days, not to mention the culmination of finals and qualifying exams for our first-year students, our program maintained stability across the board -- in the innovation of ideas, the launch of initiatives, and financial health.

Our discussions regarding the Accelerated MSc program in Applied Mathematics have finally come to fruition, a milestone we owe to the guidance of Professor Patrick Shipman. The envisioned program, rooted in our Math department yet drawing on the advanced offerings of our AM GIDP courses, will extend its reach beyond math majors to embrace students from a range of STEM fields, such as physics, engineering, and astronomy. This proposal has navigated the channels of approval from the Math Department to the College of Science and most recently at the University level. It's with great anticipation that we await the arrival of our inaugural cohort of the accelerated MSc students next fall.

July's outset brought a sobering update from the graduate college -- an unanticipated and significant funding cut. The rationale, tied to a restructuring within the upper echelons of the University of Arizona, ignores our contribution to research and pivots formally on the tuition revenue.

Yet, July also delivered exhilarating news: our proposal for the NSF grant "Integrating Data Science into the Applied Mathematics PhD: Generalized Skills for Non-Academic Careers" was awarded. This project underscores the program's commitment to validating the viability of training PhD-level professionals for research positions in national and industrial labs, a vital need in the evolving landscape of applied mathematics, including data science and AI.

We were deeply saddened to learn, in late August, of the passing of Professor Vladimir Zakharov, a towering figure in our research community. His legacy is honored in a heartfelt memorial by Professor Alan Newell within this newsletter.

September was highlighted by the Raytheon days, a flurry of recruitment visits from National and Industrial Labs, and a tapestry of success stories from our students returning from their summer internships across various prestigious labs.

In October, I embarked on a reflective journey through the program's last five years, assessing our accomplishments and obstacles. This introspection culminated in a self-report disseminated across campus and shared on our program's website (https://tinyurl.com/AppMathReport).

All this unfolds against the backdrop of the AI revolution, marked by leaps in large language models, image generation breakthroughs, and particularly the burgeoning interplay between AI and the sciences—a symbiosis where applied mathematics plays a pivotal role in both leveraging and understanding these extraordinary AI advancements. This year saw the launch of our first-ever Applied Math Agora, a conclave for exploring the vibrant intersections between Applied Mathematics and AI (https://tinyurl.com/AppMathAI).

In response to the financial challenges, we've sought creative solutions, calling upon our network of affiliates for support. An account has been established within the Math department to facilitate contributions. An especially heartening response emerged from our faculty, who expressed a willingness to appoint our first-year students as research assistants. We resolved to maintain our admissions without cutbacks, harnessing the innovative strategies proposed by our community and the residual funds from my initial startup budget provided by the provost five years ago. Our commitment to this course has enabled us to sustain our recruitment efforts and operational dynamics at the robust levels we enjoyed prior to the fiscal shift last July.

The recruitment campaign has been a resounding success, and we eagerly anticipate finalizing our new student cohort by April 15. The influx of fresh ideas has led to promising collaborations with UA entities like the Center for Semiconductor Manufacturing and Biosphere-2, all keen on incorporating applied mathematical research into their projects. We anticipate that a substantial number of our incoming students will participate as research scholars in semester-long rotations, under the mentorship of our professors affiliated with these centers. Additionally, junior students will be actively involved as NSF/IGE-funded research ambassadors, playing a pivotal role in coordinating and co-leading our growing partnerships with national and industrial labs.

These forward-looking developments fill me with optimism for the vibrant future awaiting us at this distinguished research university. I am confident that together, we will navigate through current adversities and emerge stronger in our academic and research endeavors.

Grand Canyon hike, winding trail

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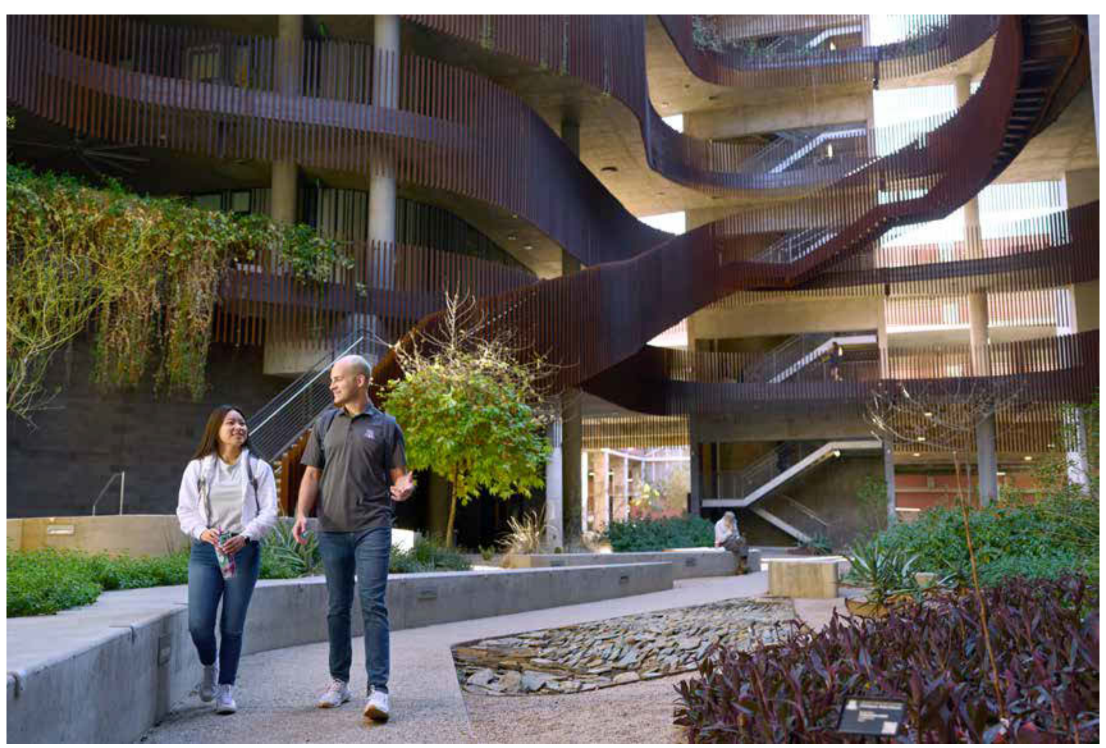


ENR2 Building Courtyard – Math offices on 3rd Floor

VOLODJA ZAKHAROV: THE SCIENTIST, THE POET AND THE MAN.

by Alan Newell, Regents Professor, Department of Mathematics

It is no accident that mathematics and poetry rhyme. Each, using its own language, seeks to strip away the superfluous from some underlying notion or set of ideas and, in doing so, reveal universal truths. And if the truth can also strike the chord of beauty, then so much the better. It becomes a joy forever.

Vladimir (Volodja) Zakharov with Dirac Medal

Volodja Zakharov was a man who excelled at both. But he was so much more. He was an honorable man of enormous integrity who stood up to bullies and demagogues and purveyors of pseudoscience nonsense and spoke truth to power, stands that often cost him great personal freedoms.

He was a good friend for more than forty years. In this short essay, I hope to be able to pass on to you an appreciation of this remarkable individual, his contributions to science, his love of literature and his rock solid integrity. There were four landmark developments in the nonlinear sciences in the latter half of the twentieth century, wave turbulence, solitons and integrable systems, collapse singularities and chaotic dynamics. **Volodja Zakharov** played a central role in breakthroughs in three of them.

WAVE TURBULENCE

Turbulence is about understanding the long time statistics of irregular flows and in particular about being able to calculate transport. The lack of progress on this challenge comes down to the fact that so far there has been no consistent closure of the moment equations. In contrast to the absence of a consistent closure of fully developed homogeneous turbulence, wave turbulence, the longtime behavior of a sea of weakly nonlinear, dispersive, random waves has a natural asymptotic closure. The reasons are fairly simple. In any patch of the sea surface, linear propagation carries waves from distances at which the surface elevations are uncorrelated so that, via the central limit theorem and mathematically by the application of the Riemann-Lebesgue lemma, the sea surface in that patch relaxes to a joint Gaussian distribution. But, because the equations are weakly nonlinear, on longer time scales the third order and higher order cumulants, which have relaxed to zero under the linear propagation, are regenerated. The secret of the natural closure is that, in this regeneration which involves the higher order moments and cumulants, it is the products of the lower order moments that dominate the dynamics. For example, in the regeneration of the third order cumulant by a fourth order moment by, say, a quadratic nonlinearity, the decomposition consists of two parts, a fourth order cumulant and a product of two second order ones. The latter dominate the long time dynamics. Closure is achieved and leads to a kinetic equation for the spectral particle density n(k,t), the Fourier transform of the two point correlation representing energy divided by the frequency ω. For ocean gravity waves, one has to proceed to a higher order and, in the decomposition of sixth order moments, it is the product of three second order cumulants that dominate. The result is a kinetic equation for the Fourier transform n(k), the waveaction (particle) density, of the two point function.

For ocean waves this was originally developed by Hasselmann who used a Stosszahlenstatz argument to omit certain terms. Very shortly after, Benney, Saffman and myself established that such assumptions were not in fact necessary. The nature of the transfer term captures the mechanism for transfer, namely, in the case of ocean gravity waves, four wave resonances by which energy and number density shared throughout the wave-vector spectrum.

As I recall, when it came to understanding the various solutions of the kinetic equation that might be of interest, most of us in the West focused on the equipartition spectra of isolated systems. But Zakharov, mindful of the role that Kolmogorov spectrum plays in hydronamic turbulence transferring energy from the injection to dissipative scales, asked the question if there were similar solutions, each connected with a flux of conserved density, of the wave turbulence kinetic equation. He found them. For ocean waves where both energy and waveaction are conserved densities, there is a constant energy flux solution nk=cP^1/3k^-4 from large to small scales and an inverse flux nk=cQ*k^-23/6 of waveaction from small to large scales. They are now called KZ spectra and are central to understanding behavior of measured spectra in oceans, in optics, and in plasmas. For this work and in particular for showing the existence of inverse fluxes from small to large scales, he and Kraichnan shared the 2003 Dirac Medal.

SOLITONS AND INTEGRABLE SYSTEMS

The first time I recall registering Zakharov's name was at the Potsdam NY conference on Nonlinear Waves in 1972 sponsored by AMS and SIAM, the two Mathematics Societies. We had brought a stellar line up of principal speakers together, Brooke Benjamin, Dave Benney, Martin Kruskal, Gerry Whitham and we had left the afternoons free for serendipitous informal sessions. During one of these, Fred Tappert told us about a new paper by two Russians, Zakharov and Shabat, purporting to solve what Tappert then called the Benney-Newell equation (that moment of fame was fleeting) but which became known later as the nonlinear Schrodinger (NLS) equation. The solution method followed the same prescription, later called the inverse scattering transform or IST, as Gardner, Greene, Kruskal and Miura (GGKM) had used to solve the Korteweg-deVries equation. Namely they had found a "Lax" pair, L and B, such that the NLS equation could be written as dL/dt=[B,L] with antisymmetric B which guaranteed that the spectrum of the operator L, which depended on the solution u(x,t) of the NLS, remained invariant as one of its coefficients, u(x,t), evolved (deformed) according the NLS equation. Associated with the operator L is a scattering problem where waves from x=+inf are partially reflected from and also transmitted to x=-inf by the intervening potential u(x,t). There is thereby a map, called the Inverse Scattering Transform (IST) from the solution of the nonlinear equation to the scattering data and any associated bound states. The scattering data evolves via linear equations. Very soon thereafter, AKNS showed that there was a whole class of nonlinear equations of KdV and NLS type important many physical contexts which also had all the hidden symmetries and when properly transformed into new coordinates, the scattering data, were really linear. (The Colonel's lady and Judy O'Grady are sisters under the skin!)

COLLAPSE AND SINGULARITY FORMATION

At about the same time, Zakharov introduced another idea, the notion that certain equations of NLS type in dimensions greater than one, can have localized, "soliton" like solutions that become infinite, "collapsed", in finite time. Indeed in the context of light physics, a linear subject until the advent of the laser which allowed for intensities sufficiently large that nonlinear effects were measurable, a light wavepacket envelope evolves according to the NLS equation in materials where the refractive index is intensity dependent. The equation can also be recast into hydrodynamic form with the intensity playing the part of a fluid density and the gradient of the phase its velocity. The resulting Bernoulli equation shows an effective pressure that increases as the density decreases which may turn out to have much value as a paradigm for some of the mysteries of dark energy.

THE MAN

I first met Zakharov in 1979 in a meeting in Kiev that the two Academies, Russian and American, had organized. The line-up was stellar in that almost all of the leading scientists in Russia at the time were present. He was genuinely delighted to meet the AKNS four as we all had been friendly rivals for the preceding decade. I registered the impression he made on me in a book on Solitons that I wrote shortly thereafter.

Vladimir (Volodja) Zakharov

'Before I leave this section, I want to tell you a bit about a giant in the field, V.E. Zakharov. He has contributed in so many areas: the Zakharov equations of plasma physics, his papers with Shabat outlining for the first time a general prescription for handling Lax pairs in both one and higher spatial dimensions, his work on the self-focusing singularity, and his papers on the dressing method for building hierarchies of solutions. He seems to have the knack for being the first at getting to all the good problems. He is a genius, brilliant and intuitive. A wild bull of a man of great good humor and appetites, he has a deep and abiding love for poetry and literature as well as physics. On one of our meetings in the hotel Ukraina bar, he recited and acted out with great relish the opening scene ("when shall we three meet again...") from Macbeth. You will often come across his name.'

I met him again in 1983 at the Kiev conference at which all the Soviet luminaries were present, Zeldovich, Gelfand, Sagdeev, Zakharov, Arnold, Sinai, but which was poorly attended by Western colleagues because of the rather fraught relations brought about by the downing of the Korean airplane which had strayed over or close to Soviet territory. There was initially much tension in the air but it rapidly dissolved under the joint influences of the science, the drink and the brotherhood that developed. I got to spend a lot of time with Volodja at that meeting and, on several occasions, when we took long walks, caused considerable consternation among the minders (KGB guys who were attending as participants). I learned then of his many scrapes with the controlling regime. Because of his stand against the invasion of Czechoslovakia in '68, he had been denied permission to visit countries outside the Soviet block and enjoyed very few visits even within the block. How small were the minds of the authorities! Volodja was a man of enormous integrity who would never betray his beloved Russia. He was Russian to the core. He treasured its many good qualities, the science, the arts, the companionship of close friends but he was never shy about speaking truth to power. And for that he paid a price. In addition, through many vivid descriptions, I learned of his great love for the outdoors and for the mountains of central Asia.

Vladimir (Volodja) Zakharov

I also began to understand why our Russian friends treasured their science and their arts, the company of close and trusted friends with whom they would spend many hours around the kitchen tables sipping vodka and simply talking without fear. It was a way to escape the oppressive and stifling atmosphere of the political system.

Finally, in the mid to late eighties, a more enlightened regime ruled Russia but it wasn't to last. Sadly, after a decade of personal freedoms and instability caused by an inability to deal with the new freedoms and the ensuing chaos, the period of personal freedoms ended. Putin came to power. Recent developments were to be a great disappointment to Volodja as they have been to many of our Russian colleagues. "Plus ca change, plus c'est la meme chose."

He finally made his first trip to the West to visit along with a Soviet delegation the Santa Fe Institute in 1987. I recall Khalatnikov, his boss in the Landau Institute in Chernogolovka at the time, wagging his finger at me in warning to be careful when we took off one day to explore the wonderful desert landscapes of New Mexico. Volodja liked the open spaces. We enjoyed ourselves and stayed out of trouble.

After the fall of the Soviet Empire, he came again to America, to Chicago, at the invitation of Leo Kadanov. Shortly thereafter, he accepted a half time Professorship at Arizona and brought with him a team of student colleagues, Sasha Dyachenko, Andrei Pushkarev, Vladimir Shvets and later Sasha Balk and Sergey Nazarenko. They had an enormous impact on the intellectual life of the department. He became a full time Professor at Arizona after he stepped down from the Directorship of the Landau in about 2000. He became a Regents Professor in 2007. He finally retired from the University of Arizona in 2021 and then was invited to take up a post at the new Institute, Skoltech, in Moscow. The Russian invasion of Ukraine has led to his resignation from that position.

Volodja and his family, Sveta, Alexei, Dima (Ilya was already married with a son and lived in Moscow) became active Arizonans and eventually took American citizenship along with their Russian citizenship. Sveta and Volodja bought their present house in the lower foothills in part because of the wonderful friendship they developed with Brendan Phibbs and his wife Leana. Brendan was a great man, a pioneer heart surgeon and expert, a prize winning author of considerable stature and a wannabe Irishman who was one of the dominant and larger than life figures in the medical and literary worlds of Tucson.

In recent years, Volodja took great delight in his grandchildren and enjoyed sharing with each of them the joys of childhood. In many ways, he himself was a grown-up child.

There are many other stories I could tell, involving long generously lubricated dinners in our respective houses, Volodja was a dab hand at lamb stew, adventures in Denmark, to broken legs in Tucson due to a collision with a car on 5th Street after which Fortov suggested, tongue in cheek, that its location would be an ideal place for a memorial statue. I remember so many adventures in Tucson and in Moscow and Chernogolovka and in particular a trip in 1991 to Georgia and the Caucuses mountains, full of feasts, friends and Kindzmarauli wine. I also remember a dead of night, pitch dark drive back to Chernogolovka from their house on the Volga without any headlights through bible black, narrow roads, clinging to the wakes of large trucks for light and guidance. Several times we lost power and were restarted with a push from local bandits. And to cap it all, the gear stick came adrift from its moorings just as we entered the parking lot of their apartment building. But these are stories the details of which are best suited for another day and well lubricated and less critical audiences.

POETRY

Volodja loved his poetry and indeed could recite thousands of poems, often without any prompts and/or encouragement from his audience. Once in poetic mode, his voice (he was not a natural singer) would take on a wonderful cadence, rising and falling in theatrical fashion. His lifelong muse was Sveta who matched him and sometimes even bettered him in recalling certain poems and certainly in recalling any musical works. Volodja was not into music. Sveta also helped him with his science. Many works would have remained unpublished but for her contributions. He published a book of poems which was translated into English as “Paradise of Clouds” and his and Sveta’s great work was their anthology of six volumes on ancient Russian poetry. His photograph on the front of Volume Number Four was taken in Ireland. His poems were often quite simple but contained deep truths.

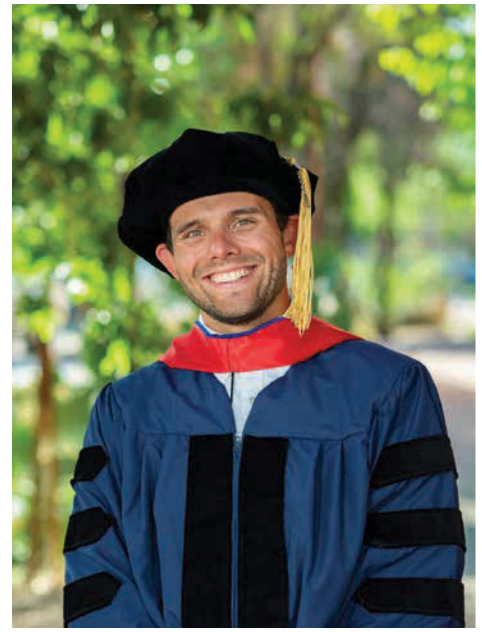
We salute you, Volodja, for reminding us of that truth and for all the other truths you have taught us. Goodnight old friend. Although greatly missed, you will be also greatly remembered.

Grand Canyon hike current students from right to left: Brian Toner, Ben Stilin, Teddy Meissner and Teddy’s partner

Grand Canyon hike current students Sheila Whitman and Woody March-Steinman

Grand Canyon Hike 2023

Al Scott Lecture: Bill Fries (PhD 2023)



William (Bill) Fries

In Spring of 2023, the Program in Applied Math gave me the honor of presenting the Al Scott memorial lecture. I never had the pleasure of meeting **Dr. Scott** but have come to learn that we shared similar motivations for interdisciplinary research. As with Dr. Scott's research, much of mine has been focused on nonlinear modeling: specifically, how simple nonlinear models can be used to understand non-mathematical phenomena.

I focused my lecture on a specific example of how exploring a simple nonlinear system can bring a novel perspective to mathematical biology and social sciences. Specifically, I investigated how social behaviors and events impact the spread of epidemics. While Dr. Scott's interdisciplinary work focused primarily on solitons, biological systems and, later, neuroscience, my interests lay in understanding and modeling human behavior. The approach of using nonlinear dynamical systems or PDEs in physics and mathematical biology is not as readily employed in the social sciences. Most modeling is agent-based, where an individual's behaviors can be tracked, modified and quantified. Analogously, in physics, this would amount to tracking individual atomic interactions. While this research is informative, it does not show the whole picture. In social science, it can be helpful to understand the impact of collective behaviors. I wanted to develop a model that would quantify collective behaviors and measure their impact on epidemic spread. As Dr. Scott emphasized the use of nonlinear modeling, we considered epidemic spread in its simplest terms: the interaction between infectious and susceptible individuals. The specific model we considered is the Susceptible-Infectious-Removed (SIR) model which considers how diseases spread in fully-mixed, homogeneous populations. Statistical analysis of this model allowed us to measure social and epidemic severity in two terms: infectiousness and number of people interacting with the disease. We can then track how these parameters change during an outbreak and, with the help of social scientists and public health researchers, how these might correlate to specific events.

Working with the experts from these fields made my tenure in the Applied Math Program incredibly worthwhile. As Dr. Scott emphasized exploring how math can be applied to various areas, I sought to learn from and work with non-mathematical experts when possible. I obtained my Graduate Certificates in Science Communication and Computational Social Science while finishing my PhD. These classes allowed me to meet students and professors outside of the math department. Through a social science class, taught by Dr. Charles Gomez, I researched the correlation between state-level political alignment and COVID-19 government policies. Without this class and guidance of Dr. Gomez, I would not have been able to produce the meaningful research which ultimately became a chapter in my dissertation. This and many other experiences with individuals outside of the math department have left a lasting impression. The importance of interdisciplinary research cannot be understated. Working with experts from other fields helped make me the researcher that I am today and without the groundwork that Dr. Scott helped lay in the Applied Math GIDP, I would not have the same experience or knowledge that I do now.

Upon graduation, I decided to stay in Tucson and take a position at Raytheon Technologies, just down the street from UA. Since starting there, I have had the opportunity to work with many individuals from various fields. Relying on other experts' knowledge to help solve complex problems has made my time there very enjoyable. I have also been able to keep in touch with both Joceline and others in the GIDP to keep researching collective behaviors and how understanding nonlinear phenomena can offer a more nuanced perspective to existing problems. I hope to continue to work with academic experts in the social sciences to understand how nonlinear dynamics can offer a new perspective to their research.

The Lowell-Stevens Football Facility, Arizona Stadium, and the Highland District dorms at dusk

New Program Affiliate Members

Afrooz Jalilzadeh, Asst. Professor

Afrooz Jalilzadeh
Assistant Professor,
Systems & Industrial Engineering

I am an assistant professor in the Department of Systems and Industrial Engineering at the University of Arizona, and I am also a member of the Applied Mathematics-GIDP and Statistics-GIDP. My academic journey began with a bachelor's degree in mathematics from the University of Tehran, followed by a Ph.D. in Industrial Engineering and Operations Research from Pennsylvania State University.

My research is motivated by the intricate challenges posed by optimization problems compounded by uncertainty. I concentrate on two primary areas: addressing continuous stochastic optimization problems and delving into game theory and variational inequalities (VI). The rapid advancement of machine learning (ML) and artificial intelligence (AI) has significantly influenced various domains such as power systems, wireless communications, and sensor networks. This progress owes much to enhancements in storage, computational capabilities, data representation, and algorithms, facilitating the exploitation of increasingly complex datasets.

The efficacy of optimization algorithms has been pivotal in the success of modern ML and AI applications, as these tasks are often formulated as optimization problems. However, existing algorithms may exhibit suboptimal performance when confronted with ill-conditioned problems typical in large-scale ML scenarios. Consequently, my research objective is to devise robust and efficient optimization algorithms capable of handling intricate problem structures, including nonsmooth and nonconvex objective functions, and nonlinear constraints, ensuring convergence to satisfactory solutions. My research received support from the National Science Foundation (NSF), University of Arizona Research, Innovation & Impact (RII) Funding, and the Arizona Technology and Research Initiative Fund (TRIF) for Innovative Technologies for the Fourth Industrial Revolution initiatives.

Beyond research, my overarching career aspiration is to excel as both an educator and researcher. I seamlessly integrate my research findings into course instruction, providing students with firsthand exposure to cutting-edge developments and guiding them in addressing real-world challenges. In today's data-centric era, proficiency in optimization is indispensable for unleashing the full potential of machine learning models. To this end, I have developed and teach a new course, "SIE496/596: Optimization for Machine Learning," designed to equip students with a deep understanding of optimization algorithms and the ability to implement them using popular programming languages such as MATLAB and Python. This course caters to both undergraduate students seeking to bridge theory with practical application and graduate students aiming to push the boundaries of optimization in machine learning.

In alignment with my research and teaching responsibilities, I have prioritized active engagement in initiatives aimed at promoting inclusivity, fostering diversity, and cultivating an environment supportive of underrepresented groups. I firmly believe that a diverse and inclusive STEM community is not only crucial for innovation and excellence but also for social progress. Since joining University of Arizona, I have implemented various strategies to bolster minority representation in STEM. Through collaborations with local schools, community organizations, and underrepresented student groups, my aim has been to inspire and encourage students from diverse backgrounds to pursue careers in STEM fields. These programs have included mentorship, workshops, and hands-on activities designed to foster interest and confidence in STEM subjects.

Finally, I am thrilled to be a part of the Applied Mathematics program and eagerly anticipate getting to know the students and initiating collaborations. I hope this brief snapshot of my work serves as an introduction to my research interests and inspires future collaboration opportunities within our community.

Liliana Salvador
Assistant Professor, Animal & Comparative Biomedical Sciences


Liliana Salvador, Asst. Professor

Who thought that I would ever be interested in bacterial genomes? I have a background in computer science and my first research interest focused on Kolmogorov complexity and Information theory. However, after I wrote an essay on the "complexity of biological systems" I knew that I wanted to use my quantitative skills to understand biological processes. I was fascinated by the possibility of measuring biological complexity, and with that in mind, I enrolled in a PhD in Biology. I now call myself a computational disease ecologist and molecular epidemiologist. As such, I develop mathematical and computational models to understand the ecology and evolution of zoonotic diseases at the animal-human-environment interface (One Health paradigm) to understand what pathogen threats develop in parallel of the current media focus.

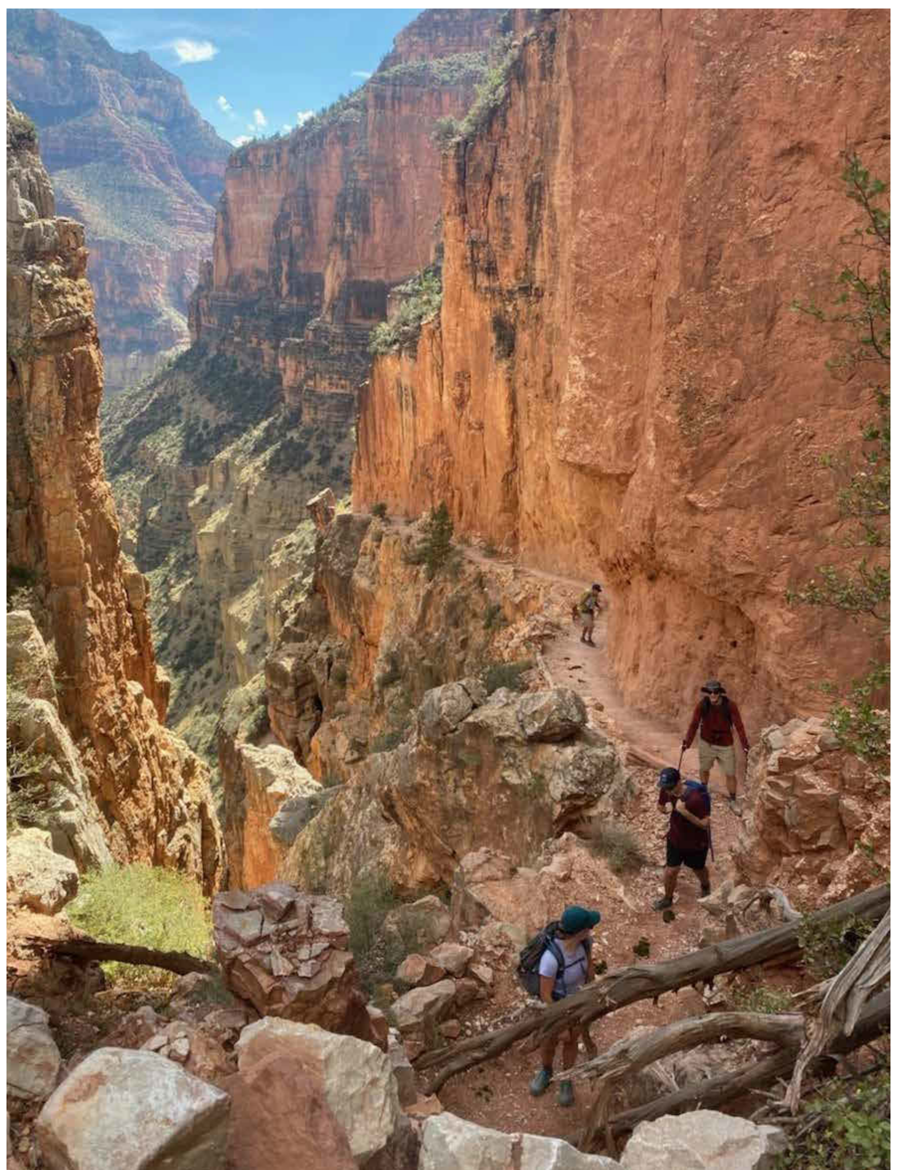
My research program is centered around understanding of how interactions among individual organisms scale up to generate population-level dynamics through both ecological and evolutionary mechanisms. I explore the complex relationships between animals, humans, and the environment to identify the epidemiological, ecological, and evolutionary circumstances involved in pathogen spillover events, amplification, and spread. These circumstances are essential for prioritizing One Health surveillance strategies and predicting future disease emergence risk in vulnerable populations. The systems I work with range from microorganisms to large mammals and these let me engage in diverse collaborations with experimentalists, wildlife biologists, policy makers, veterinarians, and microbiologists. Only through these rich interdisciplinary collaborations we can do the work we do, and an open science type of environment is key to reach progress in advancing our multi-disciplinary research in a collaborative, safe, equal, and reproducible way.

As a computer scientist, I experienced a fascinating and surprising transition when I stepped outside the deterministic world of theoretical computer science to enter the messy and complicated field of biology. Biological systems are heterogeneous, noisy, variable, and this messiness provides the basis for evolutionary adaptations to new challenges and/or environments. Furthermore, observational data are very often incomplete or biased, making it difficult to make sense of, or perform, for example, model fitting or data forecasting. However, I find joy in finding new data integration techniques and improve our understanding of biological processes. It is life we are talking about after all, and each organism on earth produces multitudes of data points.

My multi-disciplinary background has allowed me to apply quantitative approaches effectively to several key questions in ecology and biology. During my graduate and postgraduate time, I worked on combining animal movement and disease ecology. I used statistical, mathematical, and computational techniques to validate animal random search theory, test the resilience of disease surveillance systems, and understand evolutionary disease dynamics in biological systems. I have been fortunate to fly over areas of high-risk for animal diseases, and I could witness how landscape spatial structure can determine contacts between locations and host species. Spatial models and network theory are two examples of methods that we use to study disease spread and estimate the geographical risk of future disease outbreaks.

Our work uses a combination of mathematical modeling, network theory, and comparative genomics that detail pathogen epidemiological, spatial, and genomic data from infected hosts and/or locations to improve both animal and human health. These types of analyses provide valuable insights into the historic and contemporary dynamics of pathogen spread across space and unravel important epidemiological mechanisms of reservoirs versus incidental hosts in endemic areas. However, modelling disease outbreaks often involves incorporating the wealth of data that are gathered during epidemics into complex mathematical or computational models of disease transmission. This task is often difficult and computationally slow; therefore, we use powerful technologies such as Graphic Process Units (GPUs) that efficiently handle (and simulate) large amounts of data to provide enough computational power and speed to the development of such demanding tasks.

I started my position at the School of Animal and Comparative Biomedical Sciences at the University of Arizona in February 2023, and I am very excited to be already a part of the Applied Mathematics Interdisciplinary Graduate Program. I am also excited for the classes that I will be teaching. Currently, I am teaching Clinical and Medical Virology, and next year I will be teaching Ecology of Infectious Diseases, where I will introduce many of the topics mentioned above. This class will be a hands-on research project, which will be very useful for students from any background that are interested in learning more about the ecological and evolutionary mechanisms of infectious diseases (and how to apply quantitative methods to study them). So far, I experience my job as a professor to be very rewarding. Witnessing students' motivation and success, as well as guiding them pursuing their passions has been a highlight in my career. I am very looking forward to interacting with students and colleagues of the Applied Math program.



Grand Canyon Hike, current students on the trail

Alumni Profiles

Joe Dinius (PhD 2014)
Principal Autonomy Software Engineer
AeroVironment

Joe Dinius and Stan Lee

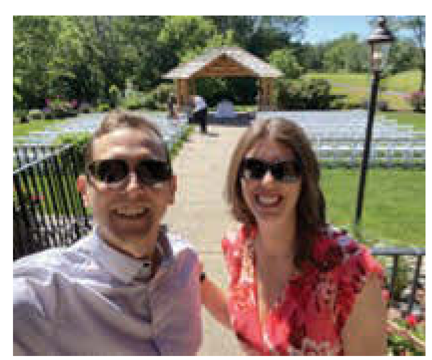
My trip through graduate school was pretty unusual. Instead of doing what any sane person would do - i.e., divesting myself of all professional commitments and, let's be honest, most personal ones, to pursue graduate degrees - I charged forward in both my professional and academic pursuits concurrently. When I started in the program back in 2007, I thought that I could do it all: I worked 40 hours a week as an engineer at Raytheon, I played drums in a band that played gigs regularly, I DJ'd at a bar on 4th Avenue a couple of nights a week, and, oh yeah, I took the Methods and Numerical Analysis core courses. Oh, how I miss that youthful vigor and optimism! Suffice it to say, that first year in the program was pretty ugly.

After I struggled to gain traction that first semester, **Dr. Tabor** sat me down and we had a consequential talk. Around this same time, there were a lot of pulls on my attention - my responsibilities at Raytheon were growing, my bandmates wanted to play more shows, and I had met the woman that I would marry a few years later (at the bar where I was DJ'ing). I was in danger of dropping the balls I was metaphorically juggling when Dr. Tabor, thankfully, asked me how committed I was to pursuing my studies further. This was a real gut-check moment for me. Getting a graduate degree had long been a dream of mine, so I decided to reevaluate my life and refocus my attention so that I could achieve my academic goals.

Once I committed myself to my studies, things got better for a while. My grades improved, I had enough bandwidth to start my research, and I felt more balance in my professional and personal lives. After a while, though, the stress wore me down. Looking back on this time, I regrettably don't have a lot of warm memories of my time in graduate school. I wasn't able to attend many of the colloquia or department talks, nor was I able to attend many recitation sessions for the core courses. It's pretty striking to me that my fondest memories are of the times spent studying for the written qualifying examination. These were the periods where I had the most interaction with other graduate students; where I got to know the people I was in class with. We all had a shared purpose - to pass the exam - which helped us to find common interests more easily. Though I enjoyed these study sessions, I was thankful when I received notification that I had passed the exam on my first attempt and would not need to repeat the exercise the following summer.

Though I didn't know it at the time, the research landscape would change dramatically after I selected my research topic (in dynamical systems). I still find dynamical systems theory to be elegant and powerful with loads of theoretical and practical applications. Part of me does wonder though: If I had it all to do again, would I have chosen the same topic? The nascent fields of data science and machine learning were starting to emerge as processing hardware and data scaled up. Robotics was poised to take major leaps forward as well; thanks in large part to the first release of ROS happening the same year (2007) that I started in the program (more on this to come later in the article). I loved my dissertation topic and am grateful to have had such a conscientious advisor - **Joceline Lega** - and committee members - **Ricardo Sanfelice** and **Hermann Flaschka** - to help me through some tough times. Joceline helped me to become a better researcher and, consequently, a better engineering professional. Dr. Flaschka (I never dared call him "Hermann") helped in these areas as well, though what I remember most are the conversations where we connected more personally about life and ambitions, both personal and professional. I count myself fortunate to have known such a prolific mathematician who was also a very kind and decent person.

After I finished my Ph.D., I decided to switch fields - from aerospace to robotics. I have had the opportunity to work on some amazing projects over the last 8 years, including Ford's early self-driving car prototype and an immersive mixed reality ride concept while at Walt Disney Imagineering R&D. My teams and I have been consistent in advancing the state of what's possible with embodied AI on different robotic platforms, both on the ground and in the air. I don't believe that these professional opportunities would have opened up for me had I not been prepared so well by the Program and its affiliates.


Joe Dinius and his wife

In closing this article, I would like to offer some advice I think may help in guiding those of you still early in your academic and/or professional careers:

Constantly work on improving your communication skills. Written and verbal communication is immensely important in almost every field you will pursue. I have found that creating a personal website - jwdinius.github.io -has helped to keep my written communication skills sharp. There are lots of free options for creating and hosting static websites and I encourage you to look into them.

Get involved in projects you are passionate about. The rise of GitHub and GitLab has democratized the development of some pretty amazing technological and scientific projects. Contributing to such projects is a great resume builder, as well as a fantastic place to engage (ahem, communicate) with like-minded people.

Make time to be creative. Sometimes science and engineering can be heavy on process and light on innovation. It takes work to keep your creative muscles from atrophying. Play music, learn to paint, or check out a maker website like the Arduino forums.

Make time for learning. Read technical books or take online courses. If you choose to pursue a career in AI or related fields, this may be necessary to keep up with the seemingly daily progress being reported.

Finally, perhaps most importantly, HAVE FUN! Never forget that the goal of study and professional advancement is to achieve a greater sense of fulfillment in each present moment. If you can remember to stop and appreciate this from time to time, you will find that stressful times are easier to weather.

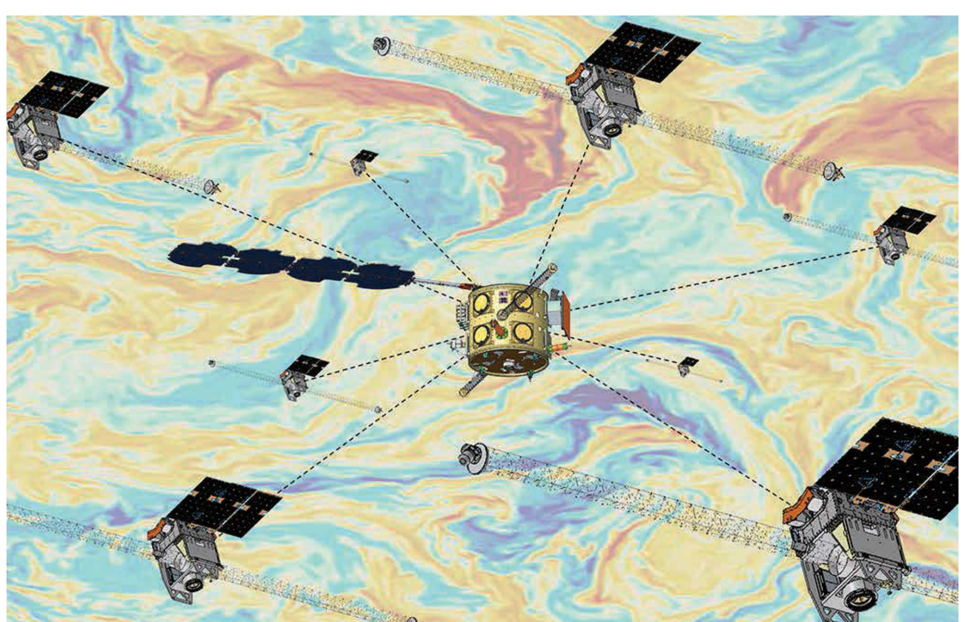

View of the Biological Sciences East Building, Highland Avenue Dorms and Arizona Stadium. Santa Rita Mountains in the background.

Current Student Profiles

Teddy Broeren (5th Year Student)

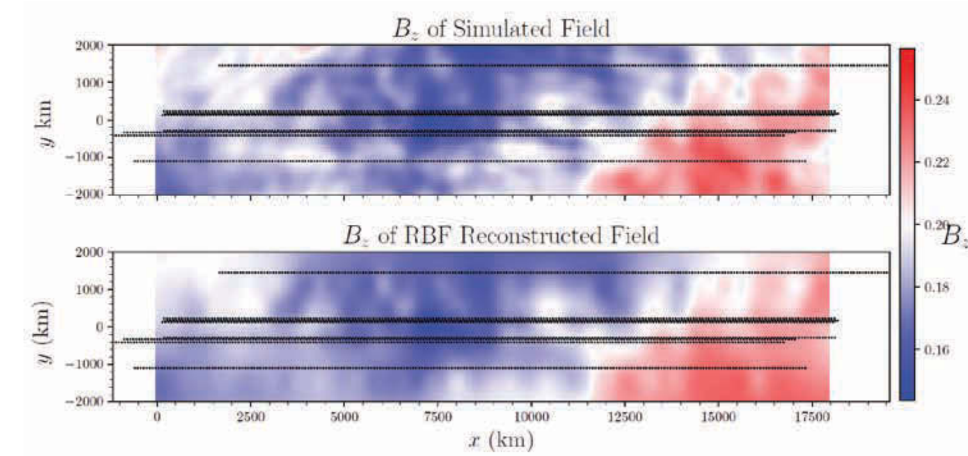
Theodore Broeren

The first thing I learned about applied mathematicians was that they are scarce. In the process of applying to undergraduate programs I looked through hundreds of universities in the Midwest, and only found a handful that offered an applied math BS in a dedicated department. It was important to me that the program had a strong focus on applications as that was where my interests lay. I ultimately chose to study at Northwestern University, where I gained hands-on experience working on collaborative, practical projects in two areas: racecars and space sciences. On my university's formula racecar team, I helped design, build, and race four different cars. My interest in the space-sciences manifested its first practical application when I helped to design and manufacture the scientific payload of a NASA CubeSat. At that same time, I was also performing dynamical systems research related to the formation of Saturn's rings. From these experiences, I knew that I wanted to continue to graduate school in an applied math program that let me delve into a space-related research area. Therefore Arizona, with its very interdisciplinary math program and well-known space research departments, was an ideal fit.



Helioswarm observatory

Following my first year in Arizona I met **Dr. Kris Klein**, my PhD advisor. I immediately started working with him on research for a proposed NASA mission to study space plasma turbulence found in the solar wind. The mission consists of a constellation of nine individual spacecraft that work together to collect measurements simultaneously at different spatial locations. As this is a greater number of spacecraft than has previously been flown as a single configuration, my role is to help develop mathematical techniques to analyze the data from a mission of this type. Eighteen months after I started working with Dr. Klein, NASA announced that our mission, HelioSwarm, was selected for funding!



Bz Simulated and Reconstructed Field

This funding means that I am now an official member of the NASA HelioSwarm Science Team, which is scheduled to launch around 2028. My graduate dissertation research has subsequently been funded by the mission and my work has revolved around different analysis techniques for multi-spacecraft missions: their development, uncertainty quantification, comparisons of them, etc. In the last three years I have researched and published papers about interpolating magnetic vector field measurements across a multipoint observatory. I have also quantified the uncertainty of a method of wave identification using multiple spacecraft. Because my work was a component of the original mission proposal, I am also a coauthor of the review article which outlines the NASA HelioSwarm mission: its scientific background, mission objectives, spacecraft trajectories, and onboard instrumentation.

Becoming a team member of this mission has given me many unique opportunities. I have met with and presented to interdisciplinary experts at our biannual science team gatherings, which take place at different locations around the country. In addition to these team meetings, I have had the opportunity to travel to seven different

ISSI Team Photo

conferences to present my research. The mission has also exposed my work to international colleagues.

Through my research, I have the honor of being a member of an International Space Sciences Institute collaborative team dedicated to the study of Cross-Scale Energy Transfer in Space Plasmas. I was invited to share my work with the other members of this small team in Bern, Switzerland during a pair of weeklong meetings. These meetings focused on the review of open questions involving multi-scale energy transport, dissipation, and particle energization in turbulent plasmas, with an emphasis on the synergy between state-of-art kinetic simulations and in-situ multi-spacecraft observations. Connections that I have formed with members on this international team provided me the opportunity to be a member of the scientific organizing committee of the Turbulent Energy Transfer in Space Plasmas workshop in Écully, France, as well as an early career convener of a nonlinear geophysics' session at the 2023 American Geophysical Union meeting in San Francisco.

Working in the space plasma physics community has spurred opportunities for me beyond even space applications. During 2022, I received a 12-week summer fellowship to work with plasma physicists and data scientists at Sandia National Laboratory. During this time, I used fluid/plasma simulations to develop data-driven equations of motion for the surface perturbation associated with the Rayleigh-Taylor instability. I think that working on a project outside of my academic research area gave me a fresh perspective as to what life could be like after I graduate and helped me develop new skills for conducting research.

I am grateful for all the opportunities that I have been given and am looking forward to what the future holds. I am in my fifth and final year in Arizona and I am currently applying for postdoctoral jobs. I hope to move back to the Midwest and get either a postdoctoral position at a university that allows me to continue working on the NASA HelioSwarm mission or get a computational mathematician position at a national laboratory. No matter where I end up, I am confident the skills, experiences, and connections cultivated here at the University of Arizona will serve as a solid foundation for my future work.

Addie Harrison (4th Year Student)

Addie Harrison

In high school, I had an experience that had a large impact on my initial career choice. This occurred when a female college student visited our high school calculus class, and she told the class that she was majoring in mathematics. The response of the classroom, including myself, was a vocal response of surprise that she would put herself through what is perceived as such an unachievable major. I believe this response arose from a number of patterns in the classroom culture throughout my childhood: lack of females in the field, disparity in the number of female students in the classroom, and difference in confidence in their abilities. Through this lens, it came as a shock that the young woman would intentionally choose a path in which she was predicted to fail.

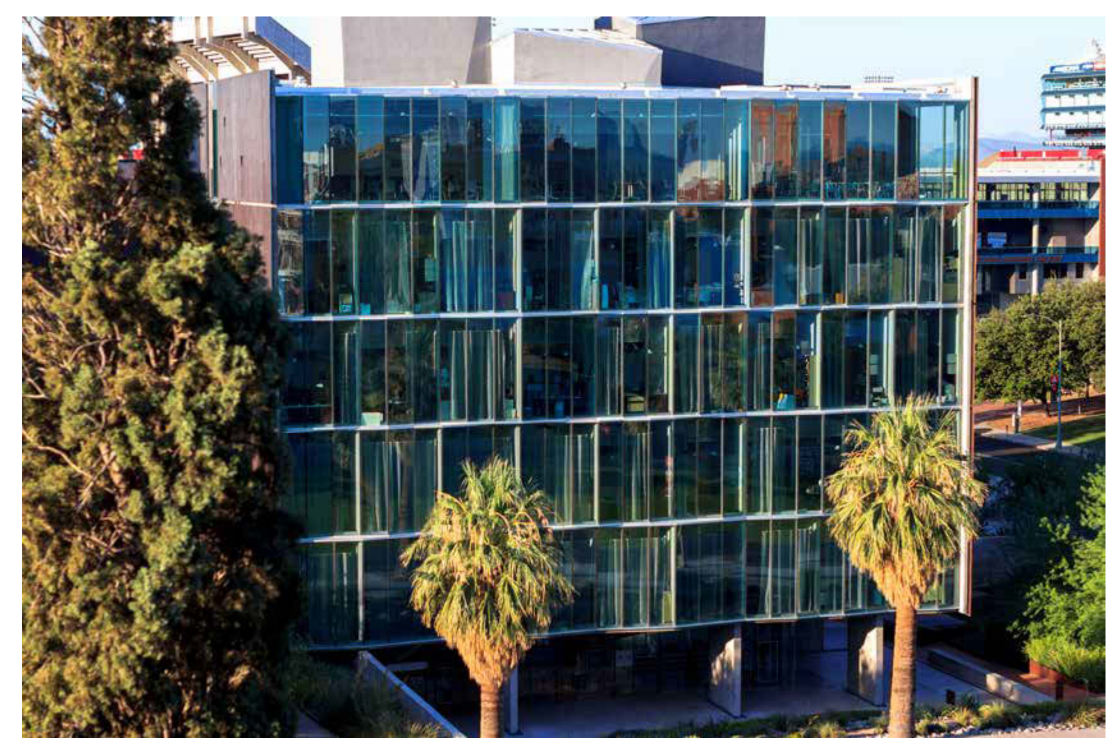
During my first two years of undergraduate at Wake Forest University (WFU), my confidence and love for mathematics was reborn. The confidence was sparked and maintained through the constant support and encouragement from **Dr. John Gemmer**, an alumnus of the University of Arizona (UofA) Program in Applied Mathematics. He fostered a classroom and research group in which questions and answers were discussed and celebrated rather than turned away. He also suggested and facilitated future summer research experiences and conferences that opened my eyes to the possibilities in careers if I continued to pursue mathematics in higher education. His support and the culture at WFU, which largely emphasizes support to all individuals, led to a change in perspective about the field of mathematics. At WFU, there was always an avenue to receive advice or encouragement, whether it be from tutors, clubs, or individual contact with professors. This perspective was reinforced in my final years as I was able to provide validation to younger students who I mentored while tutoring and being a teaching assistant. Based on these experiences, creating an inclusive learning environment is something I will continue throughout my academic and professional career.

Fast forward to my first year at the U of AZ where I had the opportunity as a teaching assistant to directly interact with undergraduate students during office hours. One conversation with a freshman female student stands out in particular, in which she asked the simple question, "How did you even end up in this field?". This question impacted me strongly as it made me realize that diversity and representation is still very much an issue to overcome in the field. The young woman reacted with the same shock I had five years ago. In addition to my mathematical biology research, promoting diversity of women in STEM is a driving force in my goal to obtain a PhD in applied mathematics.

My journey with confidence in the field of applied mathematics has been a continual experience and mentorship has had a huge impact. Fortunately, the applied mathematics department encourages students to work with different advisors and through this I found my advisor and mentor, Dr. Laura Miller. She continues to bolster and support my endeavors as a researcher. This support, alongside my past undergraduate research and REU experience at Brown University in biological application and computational mathematics, has led me to the research I am doing today. These experiences prepared me for the work, but Dr. Miller has been instrumental in my ability to start on a research project in the large field of fluid dynamics, which was a very new endeavor for me. It is also with her guidance that I was able to get a traineeship for my second and third year with the University of Arizona's Computational and Mathematical Modeling of Biomedical Systems Training Grant. Following that, I was able to receive a traineeship with the Research Training Group (RTG) in Data Driven Discovery.

In my PhD, I want to develop predictive mathematical models that will improve the development of medical devices and the treatment of disease. In terms of mathematical tools, I am particularly interested in partial differential equations. My research interest was born through my intrigue with biological systems and their ability to be quantified using mathematics. I have always had an affinity for science and originally wanted to go in the direction of medicine, however, at WFU I quickly realized my curiosity tended towards the mathematics behind natural phenomena. After past and current research projects on pattern formation, image tracking of the human retina, and nematocyst firing, I have found my ultimate research passion which uses mathematics, alongside biology and physics, to improve lives by advancing our understanding and treatment of disease.

More specifically, my current research interest is in nematocysts, the stinging cells of cnidarians, as a natural system that can inform the design of microinjectors for targeted drug delivery. I use three different numerical models of nematocyst firing that are numerically solved using the immersed boundary method, created by **Dr. Charles Peskin**. For each model, we use two-dimensional code created by **Dr. Nick Battista**, **Dr. Laura Miller**, **Dr. Wanda Strychalski**, and **Dr. Christina Hamlet**. In each case, the elastic equations describing the nematocyst, barb, and prey are coupled to the full Navier-Stokes equations to study firing and ejection dynamics over a range of Reynolds numbers. The first model simulates the barb being accelerated from rest to a maximum velocity, and is then driven at that constant velocity for the rest of the simulation towards a flexible circle (prey) in two dimensions. The second is similar to our first, but instead fires two barbs that are accelerated to a maximum velocity, and then released. The third model simulates the ejection of the barb from the flexible capsule where the capsule contracts using a preferred motion. Both the internal fluid and the barb are then ejected from the capsule. For the second direction of my current project, I use computational fluid dynamic (CFD) software to study the flow of different barb shapes of nematocysts. My overall project goals are to understand the (1) fluid dynamics of firing and ejection, and (2) fluid flow past the barb. The combination of examining the flow past barb shapes with a model that simulates the interaction between the structures involved in nematocysts firing will lead to informing the design of microinjectors. All of which to say, if it were not for the influential mathematicians and mentors in my life, I would not have found my passion in using mathematics to explore the mathematics behind biological science, in addition to my personal confidence in mathematics and the career I am pursuing today.



The north façade of the Meniel Optical Sciences Expansion

News from Members and Affiliates

Bredas, Jean Luc (Chemistry & Biochemistry)

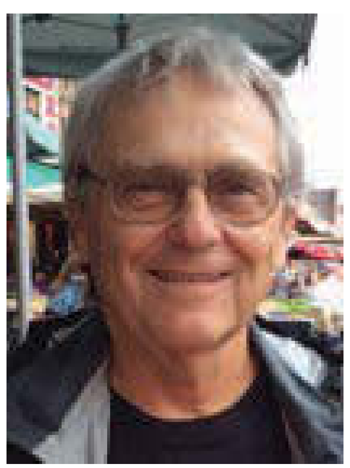
Highly cited researcher recognition as described here: Each year, Clarivate™ identifies the small fraction of the global research scientists and social scientists who have demonstrated significant and broad influence in their field(s) of research. This select group contribute disproportionately to extending the frontiers of knowledge and gaining for society innovations that make the world healthier, more sustainable and more secure.

Each researcher selected has authored multiple Highly Cited Papers™ which rank in the top 1% by citations for their field(s) and publication year in the Web of Science over the past decade. However, citation activity is not the sole selection indicator. A preliminary list based on citation activity is then refined using qualitative analysis and expert judgement.

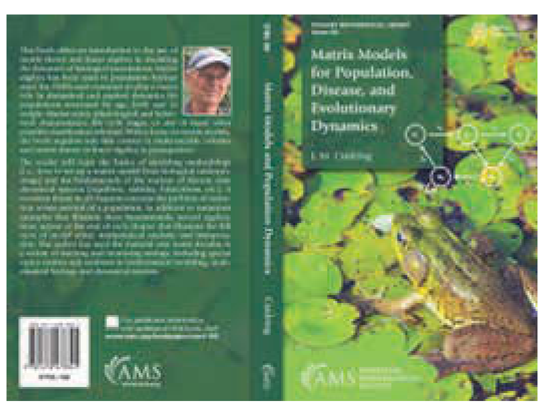
Butcher, Eric (Aerospace & Mechanical Engineering)

This year I received a 4-year grant ($800k) from ARO for a project titled: “Nonlinear Oscillator Synchronization and Multi-Agent Consensus on Compact Manifolds with Novel Feedback Coupling and Complex Network Optimization”

Cushing, Jim (Mathematics)



Jim Cushing



Matrix Models for Population, Disease, and Evolutionary Dynamics, Jim Cushing

This year I finished two books: Matrix Models for Population, Disease, and Evolutionary Dynamics, Student Mathematical Library, American Mathematical Society, and Modeling Behavior and Population Dynamics: Seabirds, Seals, and Marine Iguanas, Interdisciplinary Applied Mathematics, Springer Nature. The latter book was co-authored with **Shandelle Henson**, a former postdoc in the Mathematics Department (1994-1997), and her field ecologist husband **James Hayward**. I gave two invited talks at the 2023 Joint Meetings held in Boston on topics from the book. I also published a paper on the evolutionary adaptation of pathogen resistance by Darwinian principles resulting from an ongoing collaboration with co-author Nakul Chitnis, a former student of the Applied Mathematics Program (2000-2005). I gave a plenary address on this topic (honoring the late Aziz-Abdul Yakufu, a dear friend and collaborator) at the 6th Computational and Mathematical Population Dynamics Conference, held last May at the University of Manitoba in Winnipeg, CA.

Deymier, Pierre (Materials Science & Engineering)

New Frontiers of Sound: The University of Arizona has been awarded $30 million over five years to establish a new National Science Foundation Science and Technology Center. The New Frontiers of Sound, which comes with an additional $30 million funding option over the following five years, will bring together researchers working in topological acoustics, from partner institutions the California Institute of Technology; the City University of New York; Georgia Institute of Technology; Spelman College; University of Alaska Fairbanks; University of California, Los Angeles; the University of Colorado Boulder; and Wayne State University.

Topological acoustics allows researchers to see and exploit properties of sound that were not previously visible, like looking at the field with a new pair of eyeglasses – or better yet, listening to it with a new pair of hearing aids. Having such a precise level of control over soundwaves could revolutionize areas including computing, telecommunications, and sensing. Quantum-like computing speeds, improved battery life for electronics, and sensing changes in aging infrastructure or the natural environment due to climate change are just a few applications for this growing field. https://news.arizona.edu/new-frontiers-sound

Guo, Bo (Hydrology &Atmospheric Sciences)

Received the Humboldt Research Fellowship for Experienced Researchers. This fellowship will, in part, support his planned sabbatical visit to the University of Stuttgart in Germany.

Imbert-Gerard, Lise Marie (Mathematics)

Received a Department of Energy Early Career Research Program award from the Advanced Scientific Computing Research program.

Jun, Kwang-Sung (Computer Science)

Received an NSF grant this year to study: CIF: Small: Theory and Algorithms for Efficient and Large-Scale Monte Carlo Tree Search.

The project consists of three main directions: the foundations of MCTS, large-scale MCTS, and the design of experiments for MCTS. Each direction contains several main objectives: (i) for the foundations of MCTS, the focus is to improve maximum mean estimator and leverage tools from a related problem called pure exploration to develop algorithms with strong guarantees and study information-theoretic limits of MCTS; (ii) for the large-scale MCTS, the focus is to analyze and improve existing heuristics for large-scale MCTS problems such as progressive widening, incremental depth expansion, and function approximations; (iii) for the design of experiments for MCTS, the focus is to develop experimental design methods to efficiently train function approximations for MCTS with a small number of samples. In addition to theoretical and algorithmic developments, the project also aims at implementing all algorithms developed as open-source software, evaluating them using benchmark datasets, and applying them to material science tasks via the interdisciplinary teams of undergraduates as part of the educational aim.

Kunyansky, Leonid (Mathematics)

Spent May and June participating in the program "Rich and Nonlinear Tomography - a multidisciplinary approach", held at the Isaac Newton Institute for Mathematical Sciences, in Cambridge UK. Within the program, I took part in two workshops: " Rich and non-linear tomography in medical imaging, materials, and nondestructive testing" and "New tomographic methods using particles". Also took part in the one-week workshop "Tomographic Inverse Problems: Mathematical Challenges and Novel Applications" at The Mathematisches Forschungsinstitut Oberwolfach (Research Institute for Mathematics, situated in the German Black Forest).

Lemoine, Derek (Economics)

Received an NSF grant is to study the economic value of weather forecasts. We test whether more accurate forecasts reduce mortality and whether the credibility of forecasts affects how people use them, and we show how to use these estimates to determine the public's willingness to pay for more accurate forecasts.

Awarded best paper prize: https://www.aere.org/outstanding-publications. Ashley Langer and Derek Lemoine for "Designing Dynamic Subsidies to Spur Adoption of New Technologies,"

Paper accepted: https://www.aeaweb.org/articles?id=10.1257/mac.20200369&&from=f AMERICAN ECONOMIC JOURNAL: MACROECONOMICS: VOL. 16, NO. 1, JANUARY 2024 (pp. 29-65) Title: Innovation-Led Transitions in Energy Supply

Rafelski, Johann (Physics)

Is an elected UA Faculty Senator, and directly faculty-elected member of the UA Strategic Planning and Budget Advisory (SPBAC), representing interests of the UA faculty. He has been actively addressing the ongoing budgetary crisis where he is the voice working to protect the academic programs from being held responsible for miscalculations and budget overruns of non-academic UA programs.

Tang, Xueying (Mathematics)

Received an NSF grant on statistical methods for response process data analysis and had a publication: X. Tang (2023) A latent hidden Markov model for process data. Psychometrika.

Grand Canyon hike, current student Saheed Ganiyu, Fall 2023

News from Alumni

Arciero, Julia (PhD 2008) was awarded the 2023 Kathryn J. Wilson Award for Outstanding Leadership and Mentorship of Undergraduate Research at Indiana University-Purdue University Indianapolis (IUPUI). She was nominated for the award by eight of her previous REU students, and she has served as the PI on three NSF REU grants at IUPUI since 2015 and has mentored over 40 undergraduates on applied math research. She looks forward to working with the next cohort of students in Summer 2024.

Julia Arciero with REU Students, Summer 2023

Berman, Ben (PhD 2015) is entering his fifth year working at the MITRE Corporation where he leads the Image Science & Optics group in the Emerging Technology Innovation Center. Ben's family is happy and healthy; their second child, Victor, was born in August 2023.

Burton, Jackson (PhD 2016) is currently a Scientific Director in Pharmacometrics at Biogen primarily doing semi-mechanistic and statistical modeling of clinical trial data for therapies in Alzheimer's and Parkinson's disease. On the side, he is in the early stages of starting a business focusing on data analytics for small to medium sized businesses focusing on Ecommerce businesses primarily. In personal life, Amy and I will be married 11 years the day after tomorrow, and our son Isaac is 4.5 now. We are still in Tucson, and planning on staying long term as remote work has become much more accepted.

Gershuny, Victoria (PhD 2019) My family welcomed a new baby girl, Serafina, in September 2023.

Kopriva, David (PhD 1982) had a great visit to the UA campus in November to give a colloquium in the AME department to summarize his recent work, entitled "Ingredients for Robust DG Spectral Element Viscous Compressible Flow Solvers". It was his first time on campus to give a talk since his thesis defense. He was amazed at how much the campus has grown and filled in but found that the math building is still easy to locate. In addition to meeting the AME faculty, who are in a "new" building with incredible views, David got a tour of the Applied Math facilities and was updated on the new program. Tucson was only a seven-hour drive from home near San Diego so that gave me lots of opportunities to remember how beautiful the Sonoran desert and Catalina mountains are, at least in November... This year, another open-source spectral element solver with David's contributions (HORSES3D = "High ORder Spectral Element Solver 3D") was released by collaborators at the Polytechnic University of Madrid. Other open-source codes containing algorithms from his book "Implementing Spectral Methods" include FLEXI (U. of Stuttgart), FLUXO (U. of Cologne), Trixi (U. of Cologne), and the well-known PETSc. At the urging of the Cologne group, David open-sourced his quadrilateral/hexahedral mesh generator HOHQMesh, which can generate meshes for the spectral element solvers. Otherwise, David's days generally consist of a ten-mile bike ride, an hour of guitar practice, and a bit of math and some coding for projects with his collaborators in Germany and in Sweden.

David Kopriva at lunch with his advisor and mentor Yousuff Hussaini

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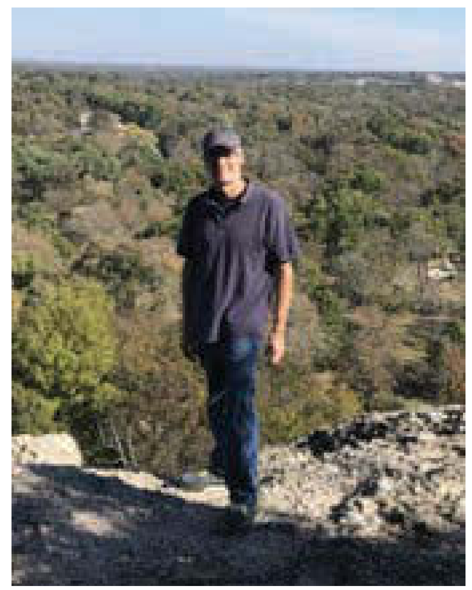
Lane, Emily (PhD 2004) is still based at NIWA the National Institute of Water and Atmospheric Research. In February this year, the east coast of New Zealand was hit by extra tropical Cyclone Gabrielle. This caused severe flooding in several regions. In response to that I was asked to lead an extreme weather response fund project to model flooding in the two hardest hit regions. This project involves researchers from NIWA, Auckland and Canterbury universities and consultancy WSP. The project builds on research from a 5-year project I am leading which is creating a system to understand flood hazard and risk over all in New Zealand which is now in its fourth year.

Pineda, Angel (PhD 2002) is doing mathematics at Manhattan College. This year, his NIH R15 grant on task-based evaluation of neural network reconstructions in MRI was renewed and he was awarded the 2024 AMS Award for Distinguished Public Service for supporting mathematics in developing countries. It was a year with a lot of external validation! I am attaching a picture with Orna Amir (PhD 1999) when she visited NYC. The UA applied math friendships last forever!

Pond, Sergei (PhD 2003) since 2016, he has been a professor of Biology at the Institute of Genomics and Evolutionary Medicine at Temple University in Philadelphia (lab.hyphy.org). He directs the Center for Viral evolution, and their lab develops statistical tools and methods for genomic sequence analysis (www.hyphy.org, www.datamonkey.org). These projects both started while he was at the UofA and are still going strong 20+ years later. We also did a lot work on COVID/SARS-CoV-2 in the last couple of year:(https://www.nytimes.com/2022/01/24/science/omicron-mutations-evolution.html) This year he made into the Clarivate Top 1% most cited researchers in the "Cross-field" category. He has two kids (Gavin, 7th grade; Vera, 4th grade).

Stapleton, David (PhD 1990) I love getting this newsletter every year because I feel like I am keeping in touch with my family members. Yes, I still carry so many great memories of many of you after all these years! Many of you will also remember my wife Debby from her work in the algebra self-study program at the U of A. We are in Oklahoma, where I teach full-time at the University of Central Oklahoma and part-time at Oklahoma State University. We have three adult kids: Cindy, Matt, and Jared, who have all taken college interest/degrees in mathematics, education, and/or computer science. Personally, I am very excited this year because my first textbook, Advanced Calculus for Mathematical Modeling in Engineering and Physics, has been completed and will be coming out soon under the Academic Press label of Elsevier. I have also been working on a few updates for the new edition of Numerical Linear Algebra with Applications (currently in its first edition) by William Ford, whose second edition I imagine will appear in 2025. On the nostalgia front, I still have my volleyball set that we sometimes practiced with on the mall and when I was fortunate enough to get some volleyball in here at UCO with the College of Mathematics and Science volleyball team, I could still remember our old games. That is all from me. Blessings, and continued success to all of you!


David Stapleton, University Central Oklahoma

Xiao, Zhuo-Cheng (PhD 2020) is happy to share his next step: he will join New York University, Shanghai as an assistant professor in mathematics and neuroscience in the next Spring semester.

Recent PhD Graduates

Acevedo, Alberto (PhD, Fall 2023)

Bell, Brian (PhD, Fall 2023) has accepted a position with the A-4 group at Los Alamos National Laboratory

Fries, William (PhD, Summer 2023) is a Modeling Engineer at Raytheon in Tucson, AZ

Johnson, Gregory (PhD, Summer 2023) is currently an instructor in the Mathematics Dept at the University of Arizona

Luna, Kevin (PhD, Spring 2023) is a Research Mathematician at the Air Force Research Laboratory

McBride, Jared (PhD, Summer 2023) is an Assistant Professor of Mathematics at Southern Virginia University

Woodward, Michael (PhD, Fall 2023) is a Postdoctoral Researcher at Los Alamos National Laboratory


Current Students, Applied Math 2nd Years getting together for pizza!

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.

2023 Don Wilson Fund Recipients:

Brian Toner (5th year student) was awarded $500 to present a talk titled "Deep learning reconstruction of radial T2 weighted data sets with data consistent unrolled neural networks" at the International Society for Magnetic Resonance in Medicine (ISMRM) Annual Meeting in Toronto, Canada in June, 2023.

Sarah Pungitore (5th year student) was awarded $500 to present a talk titled "Computable Phenotypes for Post-acute sequelae of SARS-CoV-2: A National COVID Cohort Collaborative Analysis" at the AMIA 2023 Annual Symposium in New Orleans in November, 2023.

Donations

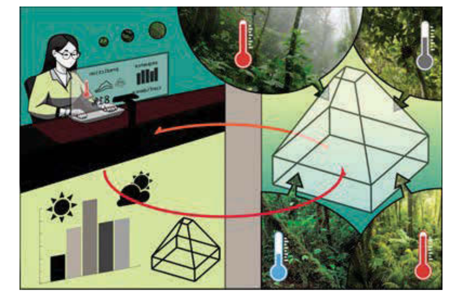
Thank You! to Arthur Lo (PhD 2004) for his annual contribution to the Applied Mathematics General Fund.

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 much appreciated!

Current Student Achievements

Arnold, Andrew (2nd Year Student) Recently **Ilya Kuk**, **Ildar Gabitov**, and I received a Innovative Projects in Energy grant from the the university's Institute for Energy Solutions for our project proposing innovation in building climate modeling and control. This is a fairly selective grant, a first for the



applied math department as far as I am aware, and it connects us to a network of researchers across campus. It is a continuation of our collaboration with the researchers and facility managers at Biosphere 2. We are also looking for collaborators with expertise in control theory and its implementation.

Bell, Brian (6th Year Student) attended a conference "Topological, Algebraic and Geometric Learning Workshops 2023" and published An exact kernel equivalence for finite classification models . Abstract: We explore the equivalence between neural networks and kernel methods by deriving the first exact representation of any finite-size parametric classification model trained with gradient descent as a kernel machine. We compare our exact representation to the well-known Neural Tangent Kernel (NTK) and discuss approximation error relative to the NTK and other non-exact path kernel formulations. We experimentally demonstrate that the kernel can be computed for realistic networks up to machine precision. We use this exact kernel to show that our theoretical contribution can provide useful insights into the predictions made by neural networks, particularly the way in which they generalize.

Brian Bell and friends at ICML

Received travel support from LANL 100% Support for ICML 2023 Honolulu, HI and LANL 100% Support for DefCon 2023 Las Vegas, NV and IEEE Vis 2023 Melbourne Australia. Summer internship at LANL and defended this year and accepted a job at LANL in A-4.

Bormanis, Ari (3rd Year Student) had a summer internship at Los Alamos National Lab (LANL) focused on applying machine learning to Magnetohydrodynamics (MHD). More specifically, we used neural networks to predict features of MHD simulations like the fluid velocity field and magnetic field. This work resulted in the paper "Solving the Orszag-Tang vortex magnetohydrodynamics problem with physics-constrained convolutional neural networks" which we submitted to the Physics of Plasmas journal and is currently under review. My faculty mentor was **Alex Scheinker** and my postdoc mentor was **Chris Leon**.

Huynh, Edward (2nd Year Student) presented his recently published paper "Remarks on the Preservation and Breaking of Translational Symmetry for a Class of ODEs" at the 2023 Joint Mathematics Meeting (JMM) in Boston.

Nasreldine, Sam (3rd Year Student) presented a talk titled "Modeling a Subsurface Biosphere on Europa: Implications for Detection via Future Exploration '' at AbGradCon 2023 at the Scripps Institution of Oceanography held May 22-25. Here is the video: https://www.youtube.com/watch?v=DIZJLwKP3z0 I presented a poster of the same title at the Workshop on the Origins and Habitability of the Galilean Moons held by the Institute Origines of Aix-Marseille Université at the Palais du Pharo in Marseille, France held October 24-26, 2023. I also was granted the UArizona NASA Space Grant Fellowship and became a UA SkySchool instructor this year.

Pawar, Rishi (2nd Year Student) worked for the Computer Science Research Institute at Sandia National Labs in Albuquerque New Mexico during the summer of 2023 and was later converted into a year-round intern. He also attended the 11th Complex Motion in Fluids Summer School hosted at the University of Cambridge, UK. Meeting students from all over the world was certainly an enlightening experience.

Sung, Eric (1st Year Student) submitted a paper that was accepted for publication in Physical Review D (PRD). It will appear on PRD very soon since my advisor and I sent our edits. Here are the details: Title of paper: Decoherence-free entropic gravity for Dirac fermion, Journal: Physical Review D. He also had a fellowship with the Army Educational Outreach Program (AEOP) this summer where he worked on this paper and research remotely from Tulane University.

Puente, Patricia (5th Year Student) had the pleasure of attending the Society of Chicanos/Hispanics & Native Americans in Science (SACNAS) Conference in Portland, Oregon in October 2023 as a UA-SACNAS chapter officer. Funding was provided by the Modern Math Workshop, a two-day workshop that took place in conjunction with the SACNAS conference.

Sharma, Akshita (3rd Year Student) completed an internship last summer at Wells Fargo (financial services industry) in Charlotte, North Carolina. Her position was in Quantitative Research and Analytics and she will be going back there for a second internship next summer.

Toner, Brian (5th Year Student) presented a digital poster titled "Deep learning reconstruction of radial T2 weighted data sets with data consistent unrolled neural networks" at the International Society for Magnetic Resonance in Medicine (ISMRM) 2023 annual meeting. The conference took place June 3-8, 2023, in Toronto, Ontario, Canada and he was fortunate to receive financial support through the Don Wilson travel award, Herbert E. Carter travel award, and University of Arizona Cancer Center CRTEC travel award.

Van Boxel, Danielle (4th Year Student) presented her research on "BARN: Bayesian Additive Regression Networks" at the Arizona Women's Symposium in Math, held in Flagstaff, AZ in November. And she reprised this for the iShowcase Poster Session in Tucson in December. The Data Diversity Lab run by **Dr. Román-Palacios** in the UA School of Information sponsored her travel and ongoing machine learning research. She also presented a practical talk on "Theory and Application of BART: A Bayesian Machine Learning Model" at the Women in Data Science in Tucson in April (the very day before her Comprehensive Exam, which she passed). Finally, Danielle's research was featured in "Queerd Science" in Tucson in November, a live theatrical production which interprets STEM research through dance and music.

Whitman, Sheila (3rd Year Student) NSF Grant, Due to societal challenges such as climate change and disruptions in supply chains, there is an urgent need for rapid design and discovery of new materials to enable sustainable production. CALPHAD (Calculation of Phase Diagram) is a computational approach used in Materials Science and engineering to predict and understand the behavior of materials at different temperatures, pressures, and compositions. CALPHAD allows researchers to predict and optimize materials with desired properties, such as more sustainable alloys (mixture of metals).

The current CALPHAD methodology requires significant expertise and a researcher's subjective intuition. My goal is to lower the barriers to CALPHAD for a wider community (including industry) by streamlining and automating the CALPHAD tasks by cutting-edge artificial intelligence tools. With the support of the NSF Fellowship, I will develop a CALPHAD framework that will include natural language processing for data extraction from literature, data-driven thermodynamic models, interactive multiverse representation of phase diagrams and other elements of human–computer interaction.

Yousuf, Marium (2nd Year Student) had a summer internship at Argonne National Laboratory, and attended the Neuroscience 2023, Society for Neuroscience, Washington D.C., USA and Arizona Women's Symposium in Mathematics, Flagstaff, AZ and received the Herbert E. Carter Travel Award, Graduate College, University of Arizona (October 2023).

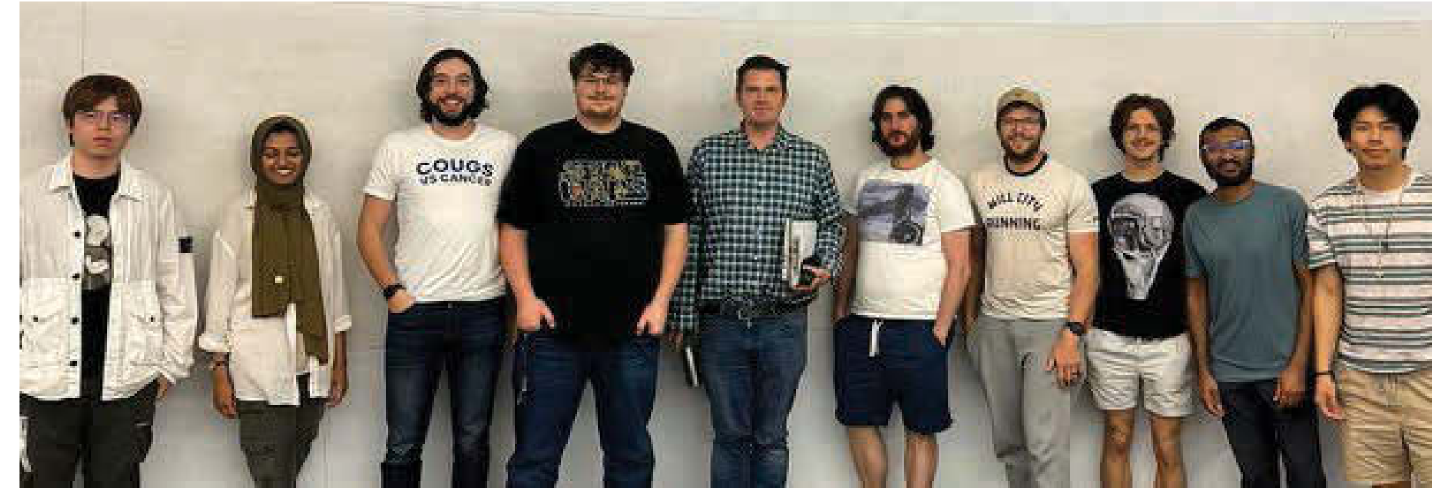
Miriam Yousuf at Society for Neuroscience Conference

I also published two papers:

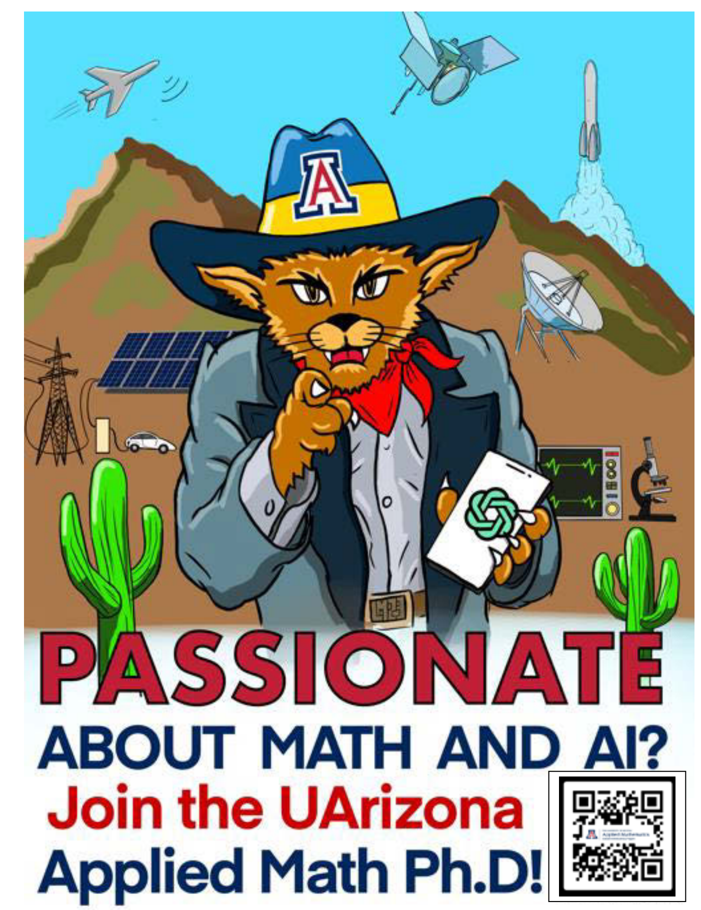
Marium Yousuf, Jean-Marc Fellous, Misha Chertkov (2023, November 11-15). Detecting replay in multi-unit spiking data: Bayesian networks [Poster Presentation]. Neuroscience 2023, Society for Neuroscience, Washington D.C., USA

Marium Yousuf, Jean-Marc Fellous, Misha Chertkov (2023, November 17-19). Detecting replay in multi-unit spiking data: Bayesian networks [Poster Presentation]. AWSiM 2023, Arizona Women's Symposium in Mathematics, Flagstaff, AZ, US.

New Students Fall 2023



Left to right: **Heng Wu**, New York University, **Aiza Kabeer**, Drexel University, **Jake Callahan**, Brigham Young University, **Ian Luff**, Northern Arizona University, **David Ryan**, University of California, San Diego, **Eric Chirtel**, University of Waterloo, Canada, **Blake Bates**, University of Minnesota, **Jay Schaffer**, Ohio State-Athens, **Novel Dey**, Georgia Southern University, **Eric Sung**, Tulane University.



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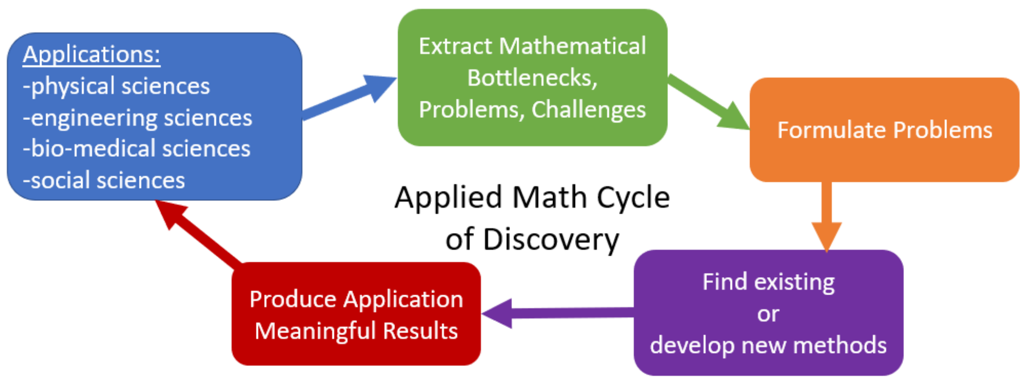


Core courses provide hands on teaching of the AM-cycle methodology

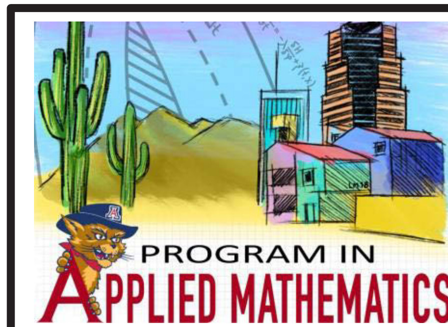
- Training in **methods** (Math/APPL **581**), **theory** (Math/APPL **584**), **algorithms** (Math/APPL **589**)
- Math (quantitative) and Application-specific (qualitative) intuition

"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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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

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Misha Chertkov
Chair, Applied Math

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

Colin Clark
Postdoc, Applied Math

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

This newsletter is published annually by the Program in Applied Mathematics

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To submit articles or news items, contact grad-appliedmath@arizona.edu