THE UNIVERSITY OF ARIZONA
COLLEGE OF SCIENCE
Mathematics

MATHEMATICS

IN THIS ISSUE

page 2
View from the Chair

page 3
Buell Everything is Math Lectures

page 4
Fighting Fraud Online

page 5
What's in An Industry Career?

page 4-5, 9-11
Biographies

page 6
Hyperbolic Origami and the Geometry of Nature

page 9
Arizona Winter School: Nearly 25 Years of World-Class Research

page 10
A One-of-a-Kind Mathematics Outreach Center

page 12
Mathematics Master and Ph.D. Recipients, 2019

Fall 2019
Volume XIX, Single Issue

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View from the Chair

By Doug Ulmer

The department had a great year. While there is not enough space to list all our achievements, here are a few highlights.

In academics, changes to placement in our most basic courses led to **record-high retention and success rates.** We also saw strong growth in the number of students working toward our new **Statistics and Data Science undergraduate degree.**

Research continues apace, with new NSF **grants awarded** to eight faculty members. A team including Professor David Glickenstein was awarded a major Focused Research Group grant, and the Arizona Winter School (AWS) received renewed funding, making for an amazing 25 years of NSF support! In what is surely a first for our department, Professor Marek Rychlik was awarded funding from the National Endowment for the Humanities to support a project on optical character recognition for non-Latin scripts.

We welcomed **several new members to our team,** including five instructional faculty, eight post-doctoral fellows, and two assistant professors. An international search brought Misha Chertkov from the Los Alamos National Laboratory to lead the Program in Applied Mathematics. Misha is moving quickly to modernize the program and bring in new resources.

We were delighted to receive a **significant gift** from a graduate alumnus to support faculty research. We allocated the funds with a proposal-driven process, and awards ranged from new lab equipment and faculty travel to support for undergraduate research.

We were also happy to see several team members receive **well-deserved external recognition:** Our fabulous event organizer Aubrey Mouradian won the College of Science "Best of the Best" Staff Excellence Award, the Center for Recruitment and Retention won the Team Award for Excellence from the University of Arizona Employee Recognition Committee, Tina Deemer was awarded the Galileo Circle Copernicus Award (one of the highest honors in the College), and Joceline Lega won the inaugural University Excellence in Postdoctoral Mentoring Award.

We have several new leaders at the University and many changes are in progress. I am confident that we will have more good things to report next year. Meanwhile, please enjoy **articles on research, industry, and outreach in our 2019 newsletter.** ▲

Doug Ulmer *is a mathematician whose research emphasizes fundamental, curiosity-driven problems in number theory and algebraic geometry. He also enjoys building academic programs and research institutions with lasting impact.*

Contact him at **ulmer@math.arizona.edu**

The annual ***Duncan Buell Everything is Mathematics Lecture Series*** *gives the Tucson community a window into the mathematical research our UArizona faculty members do here in Tucson.*

The lecture series is made possible in part by a generous endowment by UArizona mathematics alumnus ***Duncan Buell****, now* ***Professor of Computer Science and Engineering at the University of South Carolina.***

Buell, a public intellectual himself, believes in the value of raising public awareness about the relevance, beauty, and applicability of mathematics in its many forms. ▲

Professor Duncan Buell

To give or find out more about this project and other giving opportunities please visit: math.arizona.edu/outreach/give/

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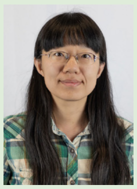
BIOGRAPHIES

Tenured Faculty

Misha Cherktkov joined UA as the Chair for the Graduate Interdisciplinary Program in Applied Mathematics. His areas of interest include statistical and mathematical physics applied to energy and communication networks, machine learning, control theory, information theory, computer science, fluid mechanics and optics. Dr. Chertkov received his Ph.D. in physics from the Weizmann Institute of Science in 1996, and his M.Sc. in physics from Novosibirsk State University in 1990. After his Ph.D., Dr. Chertkov spent three years at Princeton University as a R.H. Dicke Fellow in the Department of Physics. He joined Los Alamos National Lab in 1999, initially as a J.R. Oppenheimer Fellow in the Theoretical Division and then became a technical staff member in the same division. Dr. Chertkov has published more than 180 papers in these research areas. He is an editor of the Journal of Statistical Mechanics (JSTAT), associate editor of IEEE Transactions on Control of Network Systems, member of the Editorial Board of Scientific Reports (Nature Group), a fellow of the American Physical Society (APS) and a senior member of IEEE. Most recently, in January of 2019, he relocated to Tucson, AZ to become the Chair of the Program in Applied Mathematics at the University of Arizona.

Tenure-track Faculty

Christopher Henderson grew up in Rochester, New York. After undergraduate and graduate studies at the University of Chicago and Stanford University, he spent a year at ENS de Lyon and three years at the University of Chicago as a postdoc. Mathematically, he is interested in partial differential equations and focuses on applications to the sciences. He has a one year old daughter to whom he happily gives up all of his free time. He is excited to be living near mountains once again so he and his family can hike and spend more time outdoors. Also, he enjoys growing cacti and succulents and walking his dog.



Xueying Tang grew up in a small town in China and obtained her Bachelor's degree in Mathematics and Applied Mathematics from Peking University in 2011. She then came to the US for graduate school and received her Ph.D.

continued on page 5

BIOGRAPHIES

Fighting Fraud Online through Big Data Analytics and Machine Learning

By Kyle Pounder

What happens in the seconds immediately after you click "complete purchase" in your Amazon mobile app or on BestBuy.com?

In such card-not-present (CNP) transactions, the merchant has **seconds to assess the fraud risk of your transaction. Do they approve or decline your order?** Do they send it to "manual review" for a fraud investigator to take a closer look? The decision is delicate. Incorrectly declined orders hurt the merchant's revenue and degrade the customer experience. Yet, approving fraudulent transactions results in revenue loss and possibly even financial penalties from the card issuers.

In my role at Emailage, a global fraud-prevention company based in Chandler, Arizona, I work with online merchants to build fraud models to make accurate split-second risk assessments. The **fraud systems we build typically combine "business rules" with machine learning (ML) models.** The business rules are if-then rules based on fraud management expertise (e.g., if the email provided is for a frequent customer and the cardholder name matches the name given on the transaction, then the transaction can be approved). The ML models pin down the merchant's intricate and evolving fraud patterns by examining hundreds of variables related to hundreds of thousands (or even millions) of historical transactions.

So, what **makes a good fraud model?** If it correctly classifies at least 99% of the transactions as fraud/not fraud, is it a good model? Not necessarily. Because most transactions are not fraudulent (in general, only around 0.5% of all transactions are fraudulent) a model predicting no fraudulent transactions would have an almost perfect classification accuracy (99.5%). The challenge we are facing is that of an unbalanced data set — the ratio of fraudulent transactions to non-fraudulent transactions is far from 1:1. Hence, **we need different metrics for evaluating performance.** Precision and recall are two metrics I often use in my work. Precision assesses the percentage of predicted fraud transactions that were actually fraud. Recall assesses the percentage of all fraud cases that the model was able to identify. A good fraud model aims for both high precision and high recall.

Both the frequency of data breaches and the constant evolution of the fraudsters' techniques mean this kind of modeling work is never really done—new ideas and improved methods for fraud detection are always needed. And mathematics has a big role to play. **At its core, fraud prevention is an exciting area for the application of math and statistics** through big data analytics and machine learning. ▲

Kyle Pounder is a Senior Fraud Decision Scientist at Emailage in Chandler, Arizona. He works with online merchants in their fight against fraud. Kyle earned a Ph.D. in mathematics in 2018 working with Ken McLaughlin on nearly singular Jacobi matrices and their applications to the finite Toda lattice.

Contact him at **kyle.pounder@emailage.com**

ALUMNISNAPSHOT

Industry Careers: Key Math Skills and the Value of Internships

By Carolyn Lanser

My work at Rincon Research entails collaborating in small teams to conceive, design, develop, analyze, and field high-performance digital signal processing applications and technologies for U.S. Defense and Intelligence customers. I began working at Rincon after graduating from UArizona with a double major in mathematics and computer science. As an undergraduate, my internship experiences felt valuable and rewarding. Today, after a 20-year long career in industry, it is clear to me that **a robust background in the mathematical sciences and participation in internships are key components for a successful career in industry.**

Why are students of the mathematical sciences valuable in industry? A background in mathematics translates well into key skills needed in the industry field I work in. It is important, for example, to understand the bounds of a problem and the conditions under which a solution is valid. Ideas must be tested in a systematic and rigorous manner. Real world phenomena require consideration beyond a pure theoretical solution; questioning assumptions and thinking creatively to account for these factors is essential. Furthermore, good implementation requires logical and meticulous decomposition of an approach into realizable and verifiable pieces. **Students who have learned to think critically through training in the mathematical sciences possess these fundamental skills, as well as mathematics knowledge that is relevant in industry.**

Why are internships essential for students interested in industry careers? Exposure to a variety of environments (big/small company, varied fields) and experiences in industry during an undergraduate career can go a long way in selecting an enjoyable job that matches a particular personality and interests. As an intern, one learns first-hand that industry work is tied to something one can sell, and the importance of being able to explain how your solution meets the goals. Interns also develop skills that are attractive to employers, including effective written and oral communication with people with varied technical backgrounds, teamwork and collaboration, evaluation of ideas and technologies, and demonstration of the ability to transfer abstract knowledge to a concrete problem.

Internships play a crucial role in preparing for a career in industry so it is worth the time investment to seek out options and apply. Planning ahead is beneficial because the application process for many summer internships and research opportunities occurs in the fall. **It is valuable to participate in UArizona workshops to create quality resumes, talk with professors to learn about intriguing opportunities, and attend UArizona career fairs to interact with companies in a variety of fields.** In conjunction with hard work and dedication in mathematical studies, internships help students prepare for enjoyable industry careers. ▲

Carolyn Lanser is a Senior Scientist/Engineer at Rincon Research Corporation in Tucson, Arizona. Her work focuses on the development of high-performance digital signal processing applications and technologies. Carolyn is also a UArizona Math and Computer Science alumna, and a member of the UArizona School of Mathematical Sciences External Advocacy Board.

Contact her at **cll@rincon.com**

Photo Credit: NASA

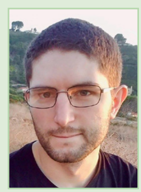
BIOGRAPHIES

continued from page 4

in Statistics from the University of Florida in 2017. Before joining the University of Arizona, she was a postdoc at Columbia University. Her research focuses on developing methods for analyzing complex, large, and high dimensional data. Outside of statistics, she enjoys hiking and reading.

Instructional Faculty

Samantha Kao worked in environmental education and outreach at UC Irvine and UCLA, before working at a rural community college in Washington state. During this time, she became involved in college mathematics education and developmental math. She obtained her master's in Mathematics from Western Washington University in June 2019 and is happy to join the University of Arizona's math department. She enjoys backpacking, surfing, and cooking.



Tynan Lazarus grew up on a small island off Seattle before attending the University of Hawaii at Hilo on the Big Island. Despite living in Hawaii, he did not achieve proficiency in surfing, but did walk on an active volcano. Tynan came back to the mainland to pursue a Ph.D. at UC Davis in fractal geometry, which he received in 2019. Having grown up in a family that worked in theatre, Tynan incorporates a bit of stagecraft in his lectures to help students engage in material. In his spare time, Tynan likes to bake, stargaze, go to all types of theatre, and is beginning to learn caseiculture (cheesemaking).

Megan Stone grew up in Columbus, Ohio and completed her Ph.D. at the University of Arizona in 2017. She works on problems in random matrix theory and enjoys teaching a variety of courses. She loves climbing and hiking with her husband and daughter.

Brandon Wilson grew up in Seattle, before earning his Bachelor's and Master's degrees in Mathematics from Brigham Young University. After teaching at Western

continued on page 9

BIOGRAPHIES

Hyperbolic Origami and the Geometry of Nature

By Shankar Venkataramani

"We have built a world of largely straight lines—the houses we live in, the skyscrapers we work in and the streets we drive on our daily commutes. Yet outside our boxes, nature teams with frilly, crenellated forms, from the fluted surfaces of lettuces and fungi to the frilled skirts of sea slugs and the gorgeous undulations of corals."

—Margaret Wertheim[1]

In a world built with straight lines, nature is filled with beautiful, undulating shapes. A natural question is—Why? **Why are frilly, crenellated forms ubiquitous in nature and what potential evolutionary benefits arise from these shapes?** To investigate this question, we first have to step back and look at some ideas from the geometry and mechanics of thin objects.

Playing with a sheet of paper or with a plastic bag will show that **thin objects are very easy to bend, but much harder to stretch.** While it is easy to bend the sheet in one direction — say by rolling it up— once it is rolled up it is no longer possible to bend it more in a different direction.

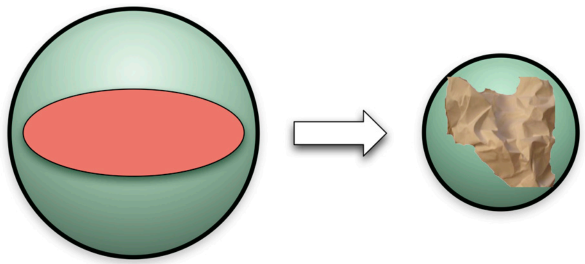


Fig. 2. Paper crumples when squeezed

This is of course very familiar to pizza-lovers everywhere. To pick up a slice of pizza without having it flop down, we bend it into a U-shape between our thumb, index and middle fingers. This idea is the key to understanding the mechanics of thin sheets – Thin objects can bend easily without stretching, but among all the possible ways to deform them, only a few are pure bending with no stretching.

What does happen if we try to bend a flat sheet of paper in two directions? It crumples! Crumpling takes a lot more energy than rolling up a sheet of paper and crumpled sheets are "strong" enough that they can be used as a packing material.

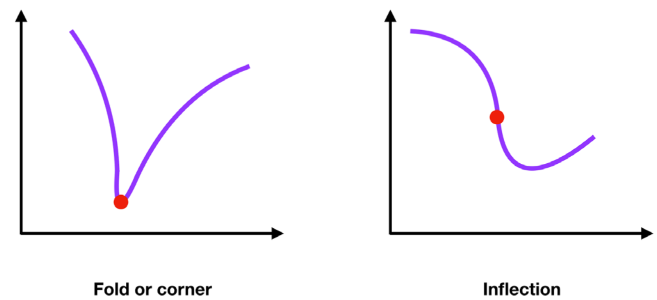


Fig. 3. Folds vs. Inflections

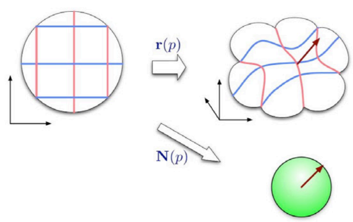
The basic "unit" of a crumpled sheet is a fold. A crumpled sheet can be viewed as a flat sheet + lots of sharp folds = Origami! Origami, the art of paper folding, originated in Japan in the 1600's. Origami starts with a square sheet of paper, and using only folds with no cutting or gluing, transforms this square sheet into an incredible variety of shapes. Origami thus reveals the remarkable potential for possible shape transformations that are all within a single flat sheet of paper.

Naturally occurring thin objects exploit this potential with a twist. Understanding how this is possible involved ideas from disparate areas of mathematics, including **partial differential equations, discrete geometry and calculus of variations.** This circle of ideas was incubated and fully developed here at the University of Arizona in collaborations with my students **John Gemmer, Toby Shearman and Ken Yamamoto**[2]**.**

Figure 1: Natural surfaces. Images courtesy Toby Shearman, Laszlo Ilyes and Joe Watkins
LASZLO ILYES from Cleveland, Ohio, USA - Lettuce Sea Slug, CC BY 2.0,https://commons.wikimedia.org/w/index.php?curid=3808482

$$N = N(u, v), \quad N \cdot N = 1$$

$$\partial_u N \perp N, \quad \partial_v N \perp N$$



$$\partial_u \mathbf{r} = \partial_u N \times N, \qquad \partial_v \mathbf{r} = -\,\partial_v N \times N$$

Fig. 4. The mathematical equations describing unstretched and inflected hyperbolic surfaces.

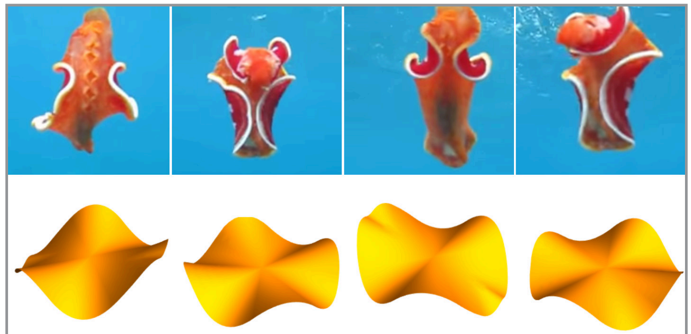


Fig. 5. (Top) A free swimming sea-slug (Images used with permission from Wavelength reef cruises) .

(Bottom) A mathematical model of a bio-inspired robot from solving the equations in Fig. 4.

Rather than starting with a flat sheet, **natural objects start out as curved, hyperbolic sheets, like a saddle or a flower.** For hyperbolic sheets, the basic unit of deformation is not a fold; rather it is a softer **bending mode,** called an **inflection.** And surfaces with lots of inflections have the characteristic frilly shapes we see in nature.

Fig. 4 displays the equations that describe the possible inflections of a hyperbolic sheet. These equations are an example of a **completely integrable system[3].** By understanding the nature of the solutions to these equations and how to control them, we can design frilly surfaces that move in particular, smooth ways, for example mimicking a sea-slug as in Fig. 5.

Natural objects therefore have all the flexibility of origami but with a much lower energy cost. They can exploit inflections to achieve large shape transformations without stretching! **We hypothesize this ability to manipulate their shapes "easily" confers an evolutionary advantage** and is one of the reasons why nature repeatedly uses the motif of a frilly, crenellated surface. In ongoing work, we are trying to understand the forces and deformations of thin hyperbolic objects. This is central to explaining how flowers bloom, sea-slugs swim without any joints, and for applications to building soft robots that are resistant to wear and tear. ▲

Shankar Venkataramani is a Professor in the Math department and in the Program in Applied Mathematics. His research interests are at the intersection of Mathematics and its applications, especially to problems in physics, geoscience and astronomy.

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NONABELIAN CHABAUTY

Jennifer Balakrishnan
Computational tools for quadratic Chabauty

Bas Edixhoven
Geometric quadratic Chabauty

Minhyong Kim
Foundations of nonabelian Chabauty

David Zureick-Brown
Classical Chabauty

with **Bjorn Poonen**, Clay Lecturer

TUCSON, MARCH 7-11, 2020

Funded by the National Science Foundation
Supported by the National Security Agency
Organized in partnership
with the Clay Mathematics Institute

Nearly 25 Years of World-Class Research Here, in the Tucson Desert

By Bryden Cais

The **Arizona Winter School (AWS)** was founded in 1997 with the ambitious goal of creating an intense and immersive workshop in which mathematics graduate students from around the world would work under the guidance of leading experts to solve problems at the forefront of two research fields: **number theory and arithmetic geometry.** In the twenty-two years that have followed, the AWS has been held on a different "hot topic" each year, and has become the premier training and research workshop for graduate students working in these fields. It has hosted over 2000 distinct participants from more than 315 different institutions spread across 35 countries, and currently attracts approximately 250 graduate students each March to Tucson for the 5-day workshop.

The AWS advances the fields of number theory and arithmetic geometry by **generating new research and a wealth of pedagogical materials,** including detailed lecture notes, research project descriptions, problem session outlines, and high-quality video recordings of all the lectures. These resources are made both widely available and easily accessible in perpetuity through the AWS website. Furthermore, the AWS provides **a unique and rich environment for mathematics research and collaboration.** This space forges connections among peers and fosters mentoring relationships between students, postdoctoral scholars, and senior researchers. Such connections and collaborations are very frequently the beginning of enduring and fruitful working relationships, which ensure continued advancement of research in these fields far into the future.

The topic of the 2020 Arizona Winter School is "Non-Abelian Chabauty," an emerging area of number theory that began with the pioneering ideas of French mathematician Claude Chabauty (1910—1990). Introduced in his seminal 1941 paper, what has come to be known as "Chabauty's method" is an i**ngenious technique for studying the solutions of certain systems of equations with rational coefficients.** The method, a hybridized version of calculus and modular arithmetic, is called p-adic analysis (where p is a prime number). Chabauty's method was refined into a powerful and effective computational tool in 1985 by American mathematician Robert Coleman (1954—2014). In 2007, South Korean mathematician Minhyong Kim (1963—) pioneered a **fundamentally new approach for exploring Chabauty's ideas, which promises to vastly expand the applicability of Chabauty's method.** The 2020 AWS will feature lectures by leading experts who will provide a comprehensive introduction to this circle of ideas, and engage students in open-ended research projects. ▲

Bryden Cais is an Associate Professor in UArizona Mathematics, and lead organizer of the AWS. Bryden studies connections between the geometry of algebraic varieties and the arithmetic of Galois representations, particularly as they apply to fundamental problems in number theory. He loves the outdoors and especially enjoys exploring the mountains of southern Arizona.

Contact him at **cais@math.arizona.edu**

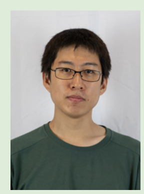
BIOGRAPHIES

continued from page 5

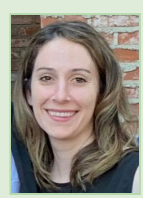
State Colorado University and Florida Gateway College, he returned to school for a Ph.D. in Engineering and Applied Science from Idaho State University, and has completed all requirements other than the dissertation. In addition, he completed an engineering internship at ON Semiconductor. He is passionate about helping students connect their studies with the actual applications and technological tools they can expect in their future careers. Outside of the classroom, he enjoys playing with his two kids, computer programming, and hand tool woodworking.

Postdoctoral Research Associates

Colin Clark was born in the US and spent his formative years living in Harare, Zimbabwe. After receiving his bachelor's degree from Walla Walla University, he returned to Zimbabwe for two years to teach math at a local high school. He obtained his Ph.D. in Applied Mathematics from the University of Arizona under the supervision of Larry Winter in May 2019. His research focuses on the applications of probability to address current problems in Hydrology and Geophysics. In his free time, he enjoys time outdoors in the desert with his wife and dog.



Sungyoon Cho received a Bachelor's degree in Math from Yonsei University, Seoul, South Korea. He completed is Ph.D. in the Department of Mathematics at Northwestern University in 2019. His research interest is number theory and arithmetic intersection theory.



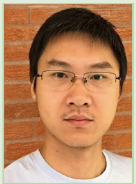
Christina Duron received her Ph.D. in Mathematics at Claremont Graduate University in April 2019. Under the supervision of Dr. Ami Radunskaya and Dr. Johanna Hardin from Pomona College, I investigated the distribution of the betweenness centrality in exponential random graph models. My current research interest lies in network theory with applications in mathematical biology.

continued on page 10

BIOGRAPHIES

BIOGRAPHIES

continued from page 9



Weihua Liu grew up in Changsha, China. He received his Bachelor and Master degree in science from Zhejiang University with a thesis about quantum measurements and quantum logics. He completed his Ph.D. in math at the University of California, Berkeley. Before coming to Tucson, he finished a three-years postdoctoral program at Indiana University Bloomington. His research primarily focuses on free probability which is a very young theory that can be applied for studying operator algebras, random matrices and many other areas.

Postdoctoral Research Associates

Yong-Suk Moon was born in Germany and grew up in South Korea. He completed his Bachelor's degree in Math and Physics and Master's degree in Statistics from Stanford University. He received his Ph.D in Math from Harvard University in May 2016. Before coming to Tucson, he was a postdoctoral scholar at Purdue University. His research interests lie in Number theory, especially in Langlands programs. He spends his spare time with my family, and also enjoy playing Brazilian jiu jitsu and wrestling.

Ethan O'Brien grew up in Oregon, but spent most of his adult life in the northeast. He studied at Rensselaer Polytechnic Institute as an undergraduate, then received his Ph.D. from the Courant Institute (a part of New York University). Before arriving to Tucson, he was a postdoctoral researcher at Carnegie Mellon University. He studies the calculus of variations, and in particular pattern formation in material science. In his spare time he enjoys hiking and playing the fiddle.

Alexander Thomson grew up in Maryville, Missouri. He moved to Springfield, Missouri to study at Missouri State University where he completed a B.S. in Mathematics. He then began his graduate work at Kansas State University where he completed his doctorate in the summer of 2019 and joined the Mathematics Department in August 2019. As a graduate student he taught courses from College Algebra to Differential Equations. In his free time Alex enjoys bicycling, cooking, and board games.

continued on page 11

BIOGRAPHIES

The Secret is Out: There is No Place Like Arizona's CRR for Mathematics Teachers!

By Melissa Hosten & Rodrigo Gutierrez

Where are Southern Arizona teachers on Saturdays? Chances are you will find them at the University of Arizona (UArizona), participating in a mathematics education workshop hosted by the **Center for Recruitment and Retention of Mathematics Teachers (CRR), a one-of-a-kind outreach center** housed under the Department of Mathematics.

Founded in 2001 thanks to the creative vision of mathematics professor Fred Stevenson, the Center has thrived under leadership with extensive experience at K-12 local schools. When co-directors Melissa Hosten and Rodrigo Gutiérrez first came to the CRR, they had **one goal: ensuring that the Center was no longer a "best kept secret" in mathematics education.** After all, the CRR has grown tremendously since it first started serving Southern Arizona's schools nearly 20 years ago, beginning with two programs focused on high school mathematics, and then expanding to serve K-16 and special education mathematics teachers. Today, the Center offers seven programs, in addition to multiple outreach events such as Game Nights and Pi Day. The CRR also maintains a listserv that keeps more than 1,200 Southern Arizona teachers connected: the Center partners with 27 school districts, as well as charter and private schools in three counties. **It is fair to say that the secret has gotten out.**

The CRR's vision is simple: ensuring every Arizona child has access to an excellent mathematics teacher. How do we make that vision a reality? By attracting and preparing mathematically talented college students to become mathematics teachers, and by retaining and supporting mathematics teachers already in the classroom. Our teacher programs enable us to **improve teachers' competence, confidence, and instructional strategies, while simultaneously developing their leadership skills** at the grade, department, school, district, and regional levels. What is more, the Center offers these supports to teachers at no cost. In fact, some programs even compensate teachers for participating. By providing a variety of professional learning opportunities at no charge, we strive to improve mathematics quality and equity throughout Southern Arizona.

One of our unique-in-the-nation initiatives is the annual Mathematics Educator Appreciation Day (MEAD). **MEAD is Arizona's largest K-16 mathematics education conference. It features approximately 100 sessions attended by**

more than 600 teachers. MEAD also includes a banquet and nationally recognized keynote speakers. Regular attendees include the Mayor of Tucson, the State Superintendent for Public Instruction, Pima County's Schools Superintendent, College of Science leadership, and many other friends and advocates of our mission.

CRR also serves the Tucson community through the AmeriCorps program Student Thinking Enrichment through Mathematics Mentors. The initiative brings together **students from across the the University campus who volunteer in 6th-12th grade classrooms and support diverse learners,** including those who struggle and those who are ready to be further challenged. UArizona student volunteers earn one credit of mathematics in the AmeriCorps program, an educational award for service, and a living stipend. Last year, our students amassed more than 10,000 volunteer hours, mentored more than 90 students, and tutored more than 3,900 students.

The Center **also supports High School students in earning college credit** through the Advanced Placement Practice Exam Day. Students from all over Pima and Santa Cruz counties come to the University for a mock AP calculus or statistics exam. The multiple choice section is scored, and then students are taught how to score their free response questions. They learn how the scorers think, and ways to improve the students' explanations and justifications. This experience sets many students on a path to earning a degree.

Our many great programs are enhanced by our great team, which was recently honored with the University's Team Award for Excellence, recognizing our outstanding management of UArizona people and resources, and community service.

Please visit our website at https://crr.math.arizona.edu/ to find out more about how we serve Southern Arizona teachers and students.

Melissa Hosten co-directs CRR, is the recipient of the Copper Apple Award for Mathematics Leadership in Arizona, and the University of Arizona College of Science STAR Award. She is involved in assessment and instruction projects at local and national levels. She specializes in the areas of equity and access, especially as these pertain to gender.

Rodrigo Gutiérrez co-directs CRR, is a past fellow of the Center for the Mathematics Education of Latinas/os (CEMELA), and a Clinical Assistant Professor in the Center for Mathematics Education at the University of Maryland. He works at the intersection of teacher development, math education, and social justice, focused on Latinx and emergent bilinguals.

Michael Perkins is a University of Arizona graduate in Teaching and Teacher Education. He coordinates the CRR induction program. Michael was previously a Mathematics Specialist in the Flowing Wells School District. His interests include enabling rich mathematical discourse in high school classrooms.

Contact them at **crr@math.arizona.edu**

BIOGRAPHIES

continued from page 10

Ahmed J Zerouali was born and raised in Guercif, Morocco, before moving to Montreal for his undergraduate and Master's studies. Prior to joining the University of Arizona as a Postdoctoral fellow, Ahmed completed his Ph.D. at the University of Toronto in August 2019. His research interests lie at the intersection of differential geometry, representation theory and mathematical physics. In his spare time, Ahmed enjoys movies, books, or simply going on long walks in quiet places.

Staff

Ellen Gauthier grew up in Tucson, and graduated from the University of Arizona (3rd generation Wildcat). Prior to joining the UArizona Department of Mathematics, she taught four years at an elementary school in the Amphi School District. Ellen currently enjoys coaching synchronized swimming, volunteering for local schools and classrooms, and reading.

Justin Oros was born in Las Vegas, Nevada and raised on a small ranch outside of Benson, Arizona. His love for computers started in the 2nd grade when he first set eyes on an Apple Macintosh. By the age of 11, he was building his own PCs running the Linux operating system. Justin previously worked in Information Technology for 15 years with an Engineering firm in Tucson maintaining Microsoft systems but recently joined the Mathematics department at The University of Arizona in 2019, where he maintains systems he is most passionate about, utilizing GNU Linux. When not at work, you might find him hiking, cycling, or enjoying craft beer at a local brewery.

Arnulfo Velásquez taught middle school mathematics for over twenty years at Tucson Unified School District, and retired in May 2019. Awarded with the Bilingual Teacher of the year by NABE. Worked as a Teacher in Residence with the UArizona College of Education from 2011 to 2013, and is teaching Math Methods to prospective K-8 teachers.

BIOGRAPHIES

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Mathematics

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UArizona Mathematics Master and Ph.D. Recipients, 2019

A complete list of graduates since 1992, including master's recipients and links to recent theses, may be found online at: http://math.arizona.edu/people/grads/recent

Doctoral Degrees

Yan Dai. Mirror Model and Critical Percolation
- Advisor: Tom Kennedy
- Employer: Jacksonville University, Jacksonville, FL
- Position: Assistant Professor

Lanbo Fang. Eigenvalue Asymptotics of Narrow Domains
- Advisor: Leonid Friedlander

Angelica Gonzalez. Spectral Properties of 3-Regular Graphs Related to One-Face Maps
- Advisor: Nicholas Ercolani
- Employer: Raytheon
- Position: Engineer

William Lippitt. Clumping, Stick-breaking, and an Inhomogeneous Markov Chain
- Advisor: Sunder Sethuraman
- Employer: University of Arizona, Tucson, AZ
- Position: Visiting Assistant Professor

Andrew MacLaughlin. Using Homogeneous Structures to Measure Homogeneity of Riemannian Manifolds
- Advisor: David Glickenstein
- Employer: Raytheon
- Position: Engineer

Mohamad Moussa. Beyond Raid 6 — Efficient Error Correcting Code for Dual-Disk Corruption
- Advisor: Marek Rychlik
- Employer: American Express
- Position: Senior Engineer

Dylan Murphy. Additions for Jacobi Operators and the Toda Hierarchy of Lattice Equations
- Advisor: Nicholas Ercolani
- Employer: University of Arizona, Tucson AZ
- Position: Lecturer, School of Information

Yuan Tao. The Potential Exterior to Close-to-touching Discs
- Advisor: Shankar Venkataramani
- Employer: Ventana Medical Systems
- Position: Biostatistician

Belin Tsinnajinnie. Indigenous and Latinx Students' Developing Mathematical Identities
- Advisor: Marta Civil
- Employer: Santa Fe Community College
- Position: Assistant Professor and Co-Chair in Mathematics

Master Degrees

Angela Kraft. Constructing Irreducible Representations of Finite Groups
- Advisor: Klaus Lux