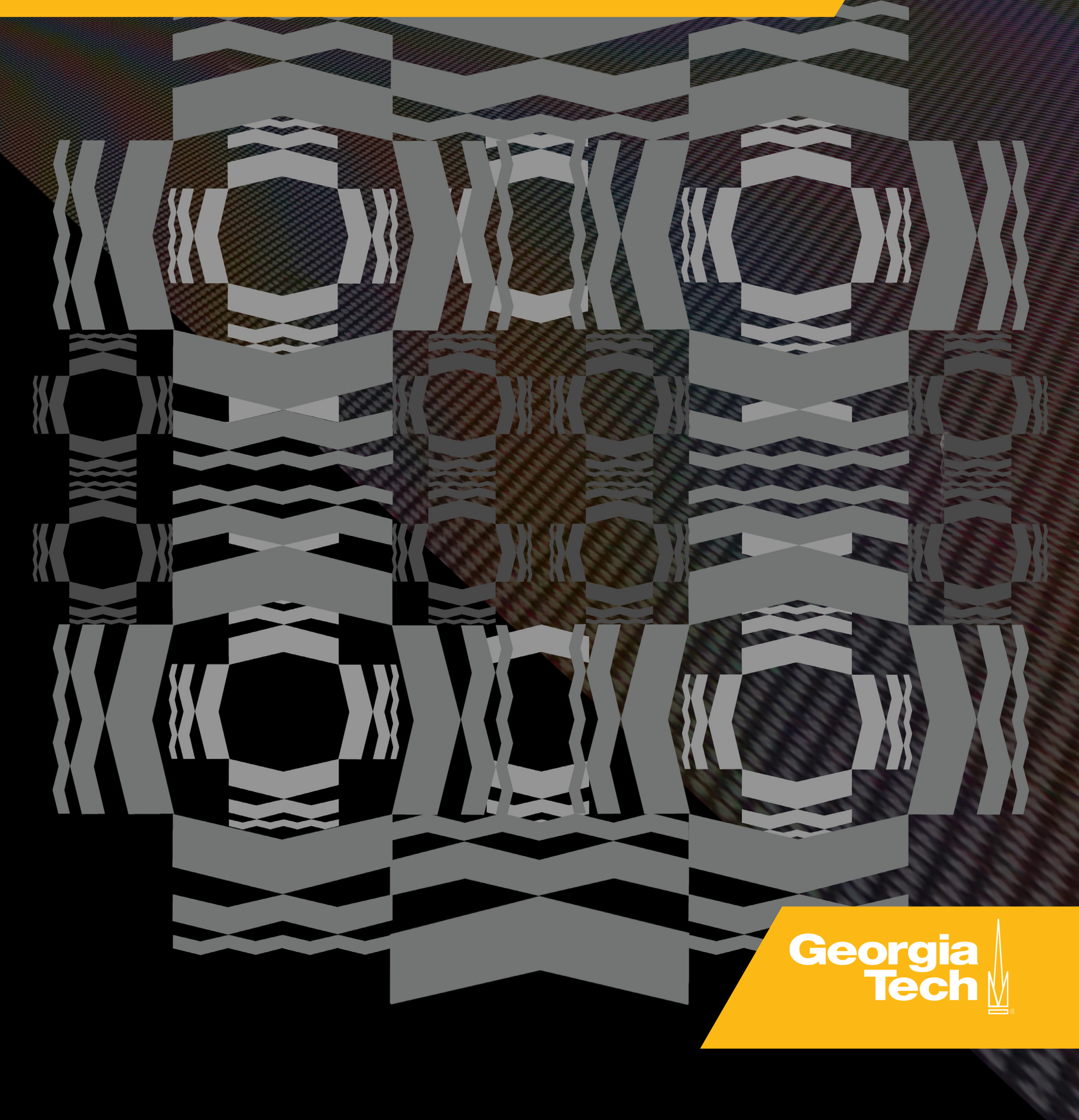
SCHOOL OF MATHEMATICS

PROOFREADER

FOR ALUMNI AND FRIENDS



Georgia Tech

CONGRATULATIONS TO COLLEGE OF SCIENCES FALL 2019 GRADUATES

MEET SIX GRADUATING STUDENTS FROM THE COLLEGE OF SCIENCES FALL 2019 GRADUATES

DECEMBER 10, 2019 | ATLANTA, GA

They chose to study at Georgia Tech. Once here, they discovered that the academic rigor and leading-edge science research they've heard so much about is true – and demands their best. Some found Tech overwhelming at times, but all succeeded.

Wherever their journey started, our graduates discovered something else in the heart of Atlanta: the Tech experience, which involves forming new and lasting friendships, stretching out of their comfort zones, becoming part of the Georgia Tech family, and more.

Check out our website to meet these six graduating students from the College of Sciences, including **Nicholas Pinto, B.S. in Mathematics**. Headed in various directions, each feels well-prepared for the next step in their professional life because of their Georgia Tech education. Georgia Tech helped them achieve their goals and join a larger community, one that values friendship and collaboration, as well as scholarship.

Congratulations, Fall 2019 graduates! We can't wait to see what comes next for you!

Maria Furukawa, B.S. in Chemistry, Polymers Concentration

Nicholas Pinto, B.S. in Mathematics and B.S. in Economics

Daughtry St. John, B.S. in Neuroscience

Shannon Valley, Ph.D. in Earth and Atmospheric Sciences

Andrea Welsh, Ph.D. in Physics

Caroline Zabinski, B.S. Biology with a certificate in Earth and Atmospheric Sciences

SoM REU POSTER SESSION

SCHOOL OF MATHEMATICS' SUMMER REU PROGRAM HOSTS ITS LARGEST SESSION YET

JULY 15, 2019 | ATLANTA, GA

Rachel Walker wants her future research to live at the intersection of mathematics and computer science. In Walker's view, that made Georgia Tech's Summer 2019 REU (Research Experiences for Undergraduates) program in the School of Mathematics the perfect choice for the rising senior from Central Washington University.

When she saw that she was accepted, "I was really excited because Georgia Tech is a really good school and they have a really strong math and computer science department," Walker says. "I knew it would be a great opportunity to meet faculty, to see how they approach research from a bigger school. And I get to work with people from around the country as well. I think that's been really cool."

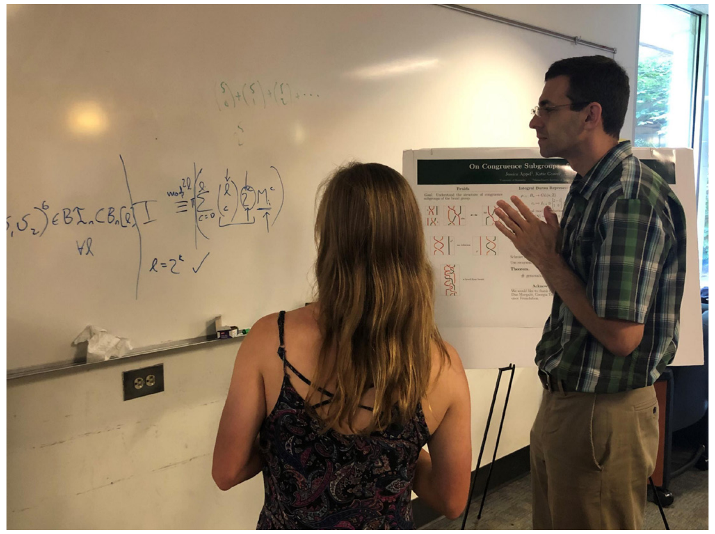
Walker was one of 27 students showing their work during the July 10 Skiles Classroom Building poster session that signaled the end of the Summer REU program. She's part of the largest group to take part in the 18 years that the School of Mathematics has been offering the National Science Foundation-funded program. (The College of Sciences also contributes funding.)

Igor Belegradek and Dan Margalit, professors in the School of Mathematics, co-managed this summer's REU program along with Michael Lacey, who served as principal investigator for the NSF grant. Belegradek says the program has grown substantially since the first six students took part in 2001. This year, students across Georgia and the U.S. sent in more than 300 applications for the program.

Belegradek says the growing interest from undergraduates is due to the high quality of research that's expected from them. "We're always aiming for research that's actually publishable. It doesn't always work like that, but that's the goal. A lot of other REU programs are focused on training students in how to do research. We're more focused on producing actual research.

"I think the best way to learn how to do research is to actually

Rachel Walker explains her Summer REU 2019 math research. (Photo by Yasmine Bassil)



School of Math Professor Dan Margalit listens to a Summer REU 2019 presentation. (Photo by Yasmine Bassil)

SOM REU POSTER SESSION

Undergraduates present their research during the School of Math's Summer REU 2019 poster session. (Photo by Yasmine Bassil)

do it. How else can you learn?" Belegradek says.

From Algebra and Geometry to Braids

Belegradek and Margalit wandered throughout the poster session to hear the students talk about their research and to make suggestions on their presentations. Although one of this summer's research themes involved braids – visual tools that help scientists get a handle on large, unwieldy blocks of data – the students tackled other branches of mathematics such as algebra, geometry, and topology (the study of objects that can be bent, twisted, or deformed, but not broken or torn.)

"What I'm really proud of with this poster session is that all the projects are really fitting into the research of the mentors and with the greater world of math," Margalit says. "So you're not only getting a chance to do math, but you're doing real math, math that matters in the world."

Summer REU students still get help with how to make a poster, nail a presentation, deal with ethical issues, and apply to graduate schools. But Margalit stressed that some of the areas of math students worked on this summer, namely machine learning and big data, are getting the attention of more experienced researchers. And the students are proving to be up to the challenge.

"I'm still surprised and impressed with how much they are able to understand and learn and take their own control of the problems. I get reminded every year of how talented the students are, and what they can do if you give them the chance."

A Chance to do Timely Research

Emily Zhang, a rising junior at Massachusetts Institute of Technology, teamed with Walker on their summer research. Zhang is a double major in mathematics and computer science; she was attracted by one of the program's research topics, optimization algorithms, which help scientists wrangle large groups of data.

"It was like math but also with applications in theoretical computer science, so I thought it was the perfect intersection of math and computer science to work on," Zhang says.

After she applied to several REUs across the country, Zhang says, "I got into the Georgia Tech one first. They were really fast with their response rate. They got back to me in less than a week. The other programs I applied to probably weren't going to get back to me soon enough."

"There's not much that stops you from getting into really meaningful and really deep research, as long as you have the right mentors around you, and they are plentiful," says Sidhanth Raman, a Georgia Tech rising senior. This is the mathematics major's first time to take part in the REU program.

"If you really want to, you can get the information you need and can hit the ground running. We have a very strong geometry and topology program here," he says. "I can't really speak to other schools, but I know there are phenomenal professors here and they're doing the best work they can possibly do, and they're letting students into it. You're allowing people to come into this community and partake."

Read the full story at
https://math.gatech.edu/news/som-reu-poster-session-0

NEW FACULTY MEMBER ALEX BLUMENTHAL IN THE NEWS FOR RECENT WORK

JANUARY 9, 2020 | ATLANTA, GA

New SoM Faculty member **Alex Blumenthal** and his coauthors, Jacob Bedrossian and Samuel Punshon-Smith, are in the news for developing the first rigorous proof explaining a fundamental law of turbulence.

Professor Blumenthal is a recent addition to SoM, who works in the areas of dynamical systems and smooth ergodic theory.

RESEARCHERS DEVELOP FIRST MATHEMATICAL PROOF FOR KEY LAW OF TURBULENCE IN FLUID MECHANICS

DECEMBER 11, 2019 | UNIVERSITY OF MARYLAND

What if engineers could design a better jet with mathematical equations that drastically reduce the need for experimental testing? Or what if weather prediction models could predict details in the movement of heat from the ocean into a hurricane? These things are impossible now, but could be possible in the future with a more complete mathematical understanding of the laws of turbulence.

University of Maryland mathematicians Jacob Bedrossian, Samuel Punshon-Smith and **Alex Blumenthal** have developed the first rigorous mathematical proof explaining a fundamental law of turbulence. The proof of Batchelor's law was planned to be presented at a meeting of the Society for Industrial and Applied Mathematics in December, 2019.

> Now that we have a much clearer understanding of how to use mathematics to study these questions, we are working to build the mathematical tools required to study more of these laws.

Although all laws of physics can be described using mathematical equations, many are not supported by detailed mathematical proofs that explain their underlying principles. One area of physics that has been considered too challenging to explain with rigorous mathematics is turbulence. Seen in ocean surf, billowing clouds and the wake behind a speeding

Mathematicians from UMD have developed the first rigorous proof for a fundamental law of turbulence. Batchelor's law, which helps explain how chemical concentrations and temperature variations distribute themselves in a fluid, can be seen at work in the variously sized swirls of mixing warm and cold ocean water. Credit: NOAA/Geophysical Fluid Dynamics Laboratory

vehicle, turbulence is the chaotic movement of fluids (including air and water) that includes seemingly random changes in pressure and velocity.

Turbulence is the reason the Navier-Stokes equations, which describe how fluids flow, are so hard to solve that there is a million-dollar reward for anyone who can prove them mathematically. To understand fluid flow, scientists must first understand turbulence.

"It should be possible to look at a physical system and understand mathematically if a given physical law is true," said Jacob Bedrossian, a professor of mathematics at UMD and a co-author of the proof. "We believe our proof provides the foundation for understanding why Batchelor's law, a key law of turbulence, is true in a way that no theoretical physics work has done so far. This work could help clarify some of the variations seen in turbulence experiments and predict the settings where Batchelor's law applies as well as where it doesn't."

Since its introduction in 1959, physicists have debated the validity and scope of Batchelor's law, which helps explain how chemical concentrations and temperature variations distribute themselves in a fluid. For example, stirring cream into coffee creates a large swirl with small swirls branching off of it and even smaller ones branching off of those. As the cream mixes, the swirls grow smaller and the level of detail changes at each scale. Batchelor's law predicts the detail of those swirls at different scales.

Seen in ocean surf, billowing clouds and the wake behind a speeding vehicle, turbulence is the chaotic movement of fluids that includes seemingly random changes in pressure and velocity.

The law plays a role in such things as chemicals mixing in a solution, river water blending with saltwater as it flows into the ocean and warm Gulfstream water combining with cooler water as it flows north. Over the years, many important contributions have been made to help understand this law, including work at UMD by Distinguished University Professors Thomas Antonsen and Edward Ott. However, a complete mathematical proof of Batchelor's law has remained elusive.

"Before the work of Professor Bedrossian and his co-authors, Batchelor's law was a conjecture," said Vladimir Sverak, a professor of mathematics at the University of Minnesota who was not involved in the work. "The conjecture was supported by some data from experiments, and one could speculate as to why such a law should hold. A mathematical proof of the law can be considered as an ideal consistency check. It also gives us a better understanding of what is really going on in the fluid, and this may lead to further progress."

"We weren't sure if this could be done," said Bedrossian, who also has a joint appointment in UMD's Center for Scientific Computation and Mathematical Modeling. "The universal laws of turbulence were thought to be too complex to address mathematically. But we were able to crack the problem by combining expertise from multiple fields."

An expert in partial differential equations, Bedrossian brought in two UMD postdoctoral researchers who are experts in three other areas to help him solve the problem. Samuel Punshon-Smith, now the Prager Assistant Professor at Brown University, who is an expert in probability, and **Alex Blumenthal** who is an expert in dynamical systems as well as ergodic theory, a branch of mathematics that includes what is commonly known as chaos theory. The team represented four distinct areas of mathematical expertise that rarely interact to this degree. All were essential to solving the problem.

"The way the problem has been approached is indeed creative and innovative," Sverak said. "Sometimes the method of proof can be even more important than the proof itself. It is likely that ideas from the papers by Professor Bedrossian and his co-authors will be very useful in future research."

The new level of collaboration that the team brought to this issue sets the stage for developing mathematical proofs to explain other unproven laws of turbulence.

"If this proof is all we achieve, I think we've accomplished something," Bedrossian said. "But I'm hopeful that this is a warmup and that this opens a door to saying 'Yes, we can prove universality laws of turbulence and they are not beyond the realm of mathematics.' Now that we are equipped with a much clearer understanding of how to use mathematics to study these questions, we are working to build the mathematical tools required to study more of these laws."

Understanding the underlying physical principles behind more laws of turbulence could eventually help engineers and physicists in designing better vehicles, wind turbines and similar technologies or in making better weather and climate predictions.

PROFESSOR AND POSTDOC WIN BEST ARTICLE AWARD

JULY 9, 2019 | ATLANTA, GA

Prof Michael Lacey and Dr. Robert Kesler have been awarded the Best Paper Award by Collectanea Mathematica for 2018.

The award, created in 2017, is granted to an article published in Collectanea Mathematica which demonstrates outstanding achievement in any branch of mathematics. The award comes with a cash prize of 2,000€ as well as a diploma and an invitation to give a lecture addressed to a wide audience at the award ceremony at the *Facultat de Matemàtiques i Informàtica* of Universitat de Barcelona that took place in October, 2019, at the Universitat de Barcelona.

Michael Lacey is a prolific mathematician and a gifted teacher and mentor. His work has touched on the areas of probability, ergodic theory, and he is a leading expert in harmonic analysis - or as Prof. Lacey puts it, the fine behaviour of Fourier series. Prof. Lacey has recieved support for his reserach from the National Science Foundation as well as from the award of the Salem Prize, the Guggenheim Foundation, the Fulbright Foundation, and the Simons Foundation.

Robert Kesler was a Postdoc in the School of Mathematics at Georgia Tech from 2016-2018, holding positions of an IMPACT Fellow in Analysis plus Electrical & Computer Engineering and a Visiting Assitant Professor in the School of Math. Dr. Kesler received his Ph.D. in Mathematics from Cornell University in 2016. He is currently working in Industry in the Los Angeles area.

EXTERNAL NEWS

LEONID BUNIMOVICH'S RESEARCH INTO BILLIARDS AND CHAOS APPEARS IN SCILIGHT

OCTOBER 7, 2019 | ATLANTA, GA

In the transition from mathematical billiards to physical billiards, where a ball goes from being a point particle to having a positive radius, it may seem intuitive to assume that no categorical difference exists between the two. A new proof-of-concept paper by Leonid Bunimovich says otherwise.

Bunimovich discovered as the radius of a physical billiard ball increases, the change in the behavior of the entire system is equivalent to modeling mathematical billiards with a smaller table. With increasing radius, the geometry of the system evolves.

For instance, some parts of the table may become inaccessible to the ball. This results in a progression in the dynamics of the system between mathematical and physical cases, and it may become more or less chaotic with changing radius.

"Anything is possible," said Bunimovich. "There are various types of transitions from order to chaos, and chaos to order."

An excerpt from the Scilight article https://aip.scitation.org/doi/10.1063/1.5128222

Article: "Physical versus mathematical billiards: From regular dynamics to chaos and back," by L. A. Bunimovich, Chaos (2019). The article can be accessed at https://doi.org/10.1063/1.5122195.

Leonid Bunimovich

SCHOOL OF MATHEMATICS ASSOCIATE PROFESSOR IS NOW A KAVLI FELLOW

MICHAEL DAMRON JOINS A LONG LINE OF GEORGIA TECH SCIENTIST HONOREES

NOVEMBER 22, 2019 | ATLANTA, GA

An associate professor in the School of Mathematics is the latest College of Sciences faculty member to be invited to a National Academy of Sciences (NAS) Kavli Frontiers of Science Symposium.

Michael Damron, who researches probability theory and mathematical physics, attended the fourth annual Israeli-American Kavli Frontiers symposium, on Sept. 18-19, in Jerusalem, Israel. The event was co-sponsored by the Israel Academy of Sciences and Humanities (IASH). Several countries host Kavli symposia each year.

As described on the NAS website, the Kavli Frontiers of Science Symposium "is the Academy's premiere activity for young distinguished scientists. Attendance at a symposium is by invitation only, and attendees are selected from among award winners for early career scientists in the U.S. and abroad."

"The conference was very interesting," Damron says. "All of the talks were meant to introduce the audience to the research area, and they were mostly very engaging, sort of like TED talks. I particularly liked the session on CRISPR, a gene editing tool, and also the session on cancer immunotherapy. It was a great opportunity because I have never attended a conference with such a wide array of topics, and spent so much time with top scientists in so many disciplines. The whole experience was extremely inspiring, not only for ideas in my own research, but also to cultivate a general creative mode of thinking. You never know where new ideas will come from."

I have never attended a conference with such a wide array of topics, and spent so much time with top scientists in so many disciplines.

"This symposium series is the Academy's premiere activity for distinguished young scientists," NAS president Marcia McNutt wrote in her invitation letter to Damron. "Unlike meetings that cover a single, narrow slice of science, these symposia are designed to provide an overview of advances and opportunities in a wide-ranging set of disciplines and to provide an opportunity for the future leaders of science to build a network with their colleagues."

Associate Professor Michael Damron, School of Mathematics

The attendees are designated Kavli Fellows. They include Sloan Fellows, Packard Fellows, MacArthur Fellows, Pew Fellows, Searle Scholars, and Presidential Early Career Awardees for Scientists and Engineers (PECASE).

More than 250 Kavli alumni have been elected to the National Academy of Sciences. Twelve have been awarded Nobel Prizes.

Since the inception of the program in 1989, over 5,000 distinguished young scientists have attended a Kavli symposium. Forty-five Georgia Tech researchers in a various disciplines have been invited.

The following lists College of Sciences professors who have attended Kavli Frontiers of Sciences Symposia since 2009:

Vinayak Agarwal, School of Chemistry and Biochemistry, 2019
Kenneth Brown, School of Chemistry and Biochemistry, 2013
Kim Cobb, School of Earth and Atmospheric Sciences, 2009
Michael Damron, School of Mathematics, 2019
Josef Dufek, School of Earth and Atmospheric Sciences, 2014
Kostas Konstantinidis, School of Biological Sciences, 2014
Martin Mourigal, School of Physics, 2019
Zhigang Peng, School of Earth and Atmospheric Sciences, 2013

NEW SCHOLARS FOR A NEW DECADE

FIVE OF 14 PETIT UNDERGRADUATE RESEARCH SCHOLARS FOR 2020 ARE FROM CoS

NOVEMBER 21, 2019 | ATLANTA, GA

The 21st class of Petit Undergraduate Research Scholars has been selected. These 14 scholars will immerse themselves into the multidisciplinary pool of research at the Petit Institute for Bioengineering and Bioscience at the Georgia Institute of Technology beginning in January 2020. Among them is SoM's Keevin Yin, one of five from Georgia Tech who are majoring in the sciences or mathematics.

"This is a diverse cohort of students whose expertise spans a wide range of majors, and not only at Georgia Tech, but other Atlanta universities also," notes Raquel Lieberman, Petit Scholar faculty advisor, a professor in the School of Chemistry and Biochemistry, and a Petit Institute researcher.

The Petit Undergraduate Research Scholarship program began in 2000 with the goal of developing a new generation of leading bio-researchers by providing them with an opportunity to conduct independent research in Petit Institute labs, and other bio-related labs at Georgia Tech, for a full year. Since 2000, the program has funded more than 300 students, with about 80 percent of them moving on to pursue graduate degrees.

KEVIN YIN

Meet the 2020 Petit Scholars

(listed here with their university, major, and the principal investigator's lab they'll be a part of):

Cindy Aguilera-Navarro Agnes Scott College, Neuroscience, Tim Cope
Berna Aliya Georgia Tech, Neuroscience, Young Jang
Kasey Cervantes Emory, Biology, Arijit Raychowdhury
Ana Cristian Georgia Tech, Biomed Engineering, James Dahlman
Carolann Espy Georgia Tech, Chem/Biochem, Ingeborg Schmidt-Krey
Rachel Fitzgerald Georgia Tech, Chem/Biochem, M.G. Finn
Marina Holguin-Lopez Georgia State, Neuroscience, Todd Sulchek
Brandon Kassouf Georgia Tech, Biomed Engineering, Mike Davis
Amy Liu Georgia Tech, Biomed Engineering, Shuichi Takayama
Ananthu Pucha Emory, Neuroscience, Nick Willett
Milan Riddick Georgia Tech, Biomed Engineering, Andrés García
Kevin Tao Georgia Tech, Biomedical Engineering, Gabe Kwong
Paxton Threatt Georgia Tech, Chemistry and Biochemistry, Neha Garg
Kevin Yin Georgia Tech, Mathematics, Shuyi Nie

The *ProofReader* (Volume 12, 2020)

Stories by
Sal Barone
Renay San Miguel
and
The CoS Communications Team

Cover Art
Joshua Spiceland

Design Elements
Estella Dieci
Jana Pomerantz

Featured Article "How to Get Far with Small Effort"
by Rafael de la Llave
and edited by Sal Barone

THE "EARTHRISE" PHOTO FROM APOLLO 8 (PHOTO BY NASA)

APOLLO 11: ONE GIANT LEAP FOR SCIENTIFIC DISCOVERY

GEORGIA TECH RESEARCHERS, ALUMNUS REFLECT ON MOON LANDING'S IMPACT ON SCIENCE

JULY 19, 2019 | ATLANTA, GA

For those who were around at the time, it was history forever burned into their memories, with the roar from a rocket as tall as a skyscraper and 11 scratchy-sounding words uttered from the surface of the Moon.

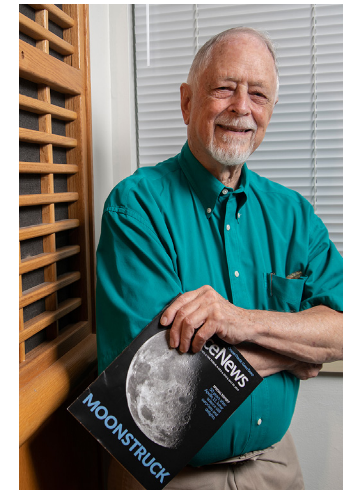
For those people, as well as those born after July 20, 1969, the 50th anniversary of the Apollo 11 Moon landing is a chance to loudly celebrate the advances in science and technology created by the space program.

"The money was well spent, and we should do it again," says Bob McDonald, a Georgia Tech alumnus who, as a young engineer for a NASA contractor, worked on the engines in that Saturn V rocket that lifted astronauts Neil Armstrong, Buzz Aldrin, and Michael Collins into space on July 16,1969.

Armstrong and Aldrin piloted their lunar lander to the Moon's surface on July 20, 1969. Later that day, Armstrong became the first man on the Moon. As he stepped off the lander, he told an estimated TV audience of a half-billion, "That's one small step for man, one giant leap for mankind."

Those memories flooded back on Saturday, July 20, 50 years to the day since that moment in history. We asked some

Georgia Tech College of Sciences researchers, including **SoM Professor Rafael de la Llave** – as well as an alumnus with a special connection to that day – their thoughts on how Apollo 11 and the space program impacted the cause of science and technology in the U.S.



He's 83 years old and enrolled in the Online Master of Science in Analytics program, making him Georgia Tech's oldest graduate student, according to Georgia Tech Professional Education. This will be his fourth degree from Tech. He already has a B.S. in Chemical Engineering ('57) and a Masters ('61) and Ph.D. ('66) in Nuclear Engineering. McDonald had a unique front-row seat for the Apollo program.

(Photo by Christopher Moore/ Georgia Tech)

Bob McDonald

"I was a brand new engineer working for Rocketdyne, who had a contract to manufacture the J2 engines for the Saturn rocket. There were five J2s on the Saturn second stage to get into Earth orbit. A single J2 powered the third stage to the Moon and back.

"The J2 was a new, liquid hydrogen- and liquid oxygen-fueled engine. To prevent the rocket exhaust from melting the engine, liquid hydrogen was pumped through small tubes down to the end of the engine bell, then back up to the combustion chamber for burning. My job was to do the heat transfer and flow calculations for the hydrogen in those tubes to make sure temperatures would be within design limits. This was prior to engine testing when the temperatures could be measured directly. When the engine was tested and performed correctly, my job was finished.

"One interesting thing about the [Apollo] project was that we already knew all the science and math needed for success. We knew where the Moon was, how far we had to travel, how long it would take, and how much energy was required. What we did not have was any of the hardware, the machinery, or equipment necessary to make the trip. Developing, testing, and learning to use the necessary equipment was a job for the engineers. Engineering and science are like one pair of gloves, and both benefitted. At the end of the project the United States was stronger, more prosperous, and wiser than when it began. The money was well spent, and we should do it again."

A professor in the School of Mathematics, de la Llave researches dynamical systems, including the study of orbits. In 2015, de la Llave and two other scientists received a $100,000 NASA grant to research how math could help make space travel less costly and more efficient.

Rafael de la Llave

"When the Moon landing happened, I was a kid in Spain. Like everybody else in the world, I was deeply moved and full of admiration.

"The Moon landing changed the vision we had of our planet and of our species. It was technology impacting on religion and philosophy, not just on everyday life, from GPS, and mobile cameras to wireless technology.

The Moon landing also changed politics; it showed that big democratic and united organizations, where ideas percolate up and down, are more efficient than rigid ones. It was an accomplishment that made the whole world reflect."

APOLLO 11'S SATURN V ROCKET LAUNCHES JULY 16, 1969 (PHOTO BY NASA)

AMS 2019 ELECTIONS INCLUDE TWO TECH PROFESSORS FOR CANDIDATES

SEPTEMBER 23, 2019 | ATLANTA, GA

The September issue of the Notices of the AMS featured SoM Professors Dan Margalit and Prasad Tetali who are running to serve on two AMS committees.

Prasad Tetali has been selected as a candidate for the Nomination Committee, and Dan Margalit is a candidate for a Member at Large of the Council.


Prasad Tetali

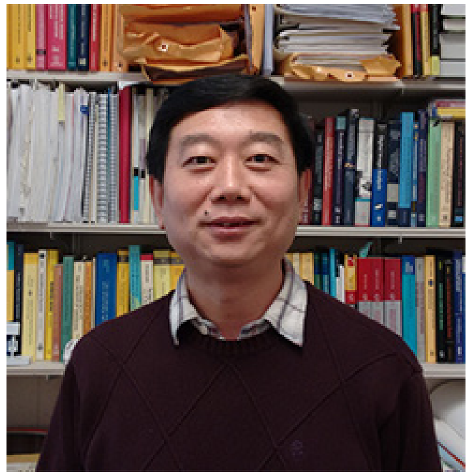

Dan Margalit

Check out the September issue of Notices of the AMS at https://www.ams.org/journals/notices/201908/201908FullIssue.pdf

HAOMIN ZHOU AWARDED FOR COMPUTATIONAL MATH ACHIEVEMENTS

GEORGIA TECH MATHEMATICIAN RECEIVES THE 2019 FENG KANG PRIZE

AUGUST 20, 2019 | ATLANTA, GA


Haomin Zhou

School of Mathematics Professor Haomin Zhou has been named one of two recipients of the 2019 Feng Kang Prize. The prize is awarded every two years to Chinese mathematicians working in computational mathematics.

The award recognizes Zhou's contributions in two areas: the development of computational method based on wavelets and partial differential equations for signal/image procesing and the theory of optimal transport on graphs and its applications to engineering.

Winners are selected by the Institute of Computational Mathematics and Scientific/Engineering Computing of the Chinese Academy of Sciences, in Beijing. The prize is named after Feng Kang, the famous mathematician and physicist who pioneered Chinese computational mathematics.

Zhou shares the 2019 prize with Jun Hu, a mathematics professor in Peking University, in Beijing.

CHRISTINE HEITSCH RECEIVES 2019 CoS FACULTY MENTOR AWARD

SEPTEMBER 23, 2019 | ATLANTA, GA

Congratulations go to Christine Heitsch, who has been awarded a 2019 College of Sciences Faculty Mentor Award. The College and its ADVANCE Professor jointly established this award to recognize the efforts and achievements of our colleagues in helping guide junior faculty through informal consultation, shared experiences, or advice and encouragement. This award recognizes the important contributions made in the School of Mathematics which help the next generations of faculty succeed.

Christine continues our strong tradition of mentorship in the School of Mathematics, as observed in the list of past recipients (including herself).

Past recipients include:

- Shui-Nee Chow (Mathematics)
- Jennifer Curtis (Physics)
- Luca Dieci (Mathematics)
- John Etnyre (Mathematics)
- Facundo Fernandez (Chemistry & Biochemistry)
- Christine Heitsch (Mathematics)
- Rigoberto Hernandez (Chemistry & Biochemistry)
- Wendy Kelly (Chemistry & Biochemistry)
- Joel Kosta (Biological Sciences)
- Raquel Lieberman (Chemistry & Biochemistry)
- Ronghua Pan (Mathematics)
- Rodney Weber (Earth & Atmospheric Sciences)
- Brett Wick (Mathematics)
- Haomin Zhou (Mathematics)

GREG BLEKHERMAN RECEIVES CoS CULLEN-PECK AWARD

SEPTEMBER 23, 2019 | ATLANTA, GA

Congratulations go to Greg Blekherman, who was selected to receive a 2019 College of Sciences Cullen-Peck Scholar Award in recognition of his innovative research. Greg is in good company with past School recipients of this award, including Jen Hom, Anton Leykin and Sung Ha Kang.

Cullen-Peck Scholar Awards: These awards recognize innovative research led by College of Sciences faculty who are at the associate professor or advanced assistant professor level. They are made possible through the generosity of alumni couple Frank Cullen *(BS '73 Math, MS '76 ISyE, PhD '84 ISyE)* and Libby Peck *(BS '75 Math, MS '76 ISyE)*, who wish to recognize and support faculty development within the College of Sciences.

YAO YAO SELECTED AS SLOAN FELLOW FOR 2020

FEBRUARY 17, 2020 | ATLANTA, GA

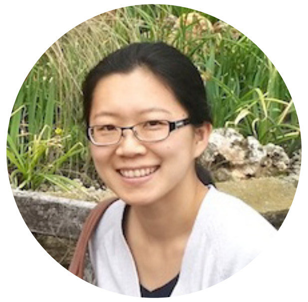
The fellowships, awarded yearly since 1955, honor early-career scholars whose achievements mark them as among the very best scientific minds working today. A full list of the 2020 Fellows is available at the Sloan Foundation website at https://sloan.org/fellowships/2020-Fellows.

The Alfred P. Sloan Foundation awards this coveted fellowship to 126 early-career scholars which represent the most promising scientific researchers working today. Their achievements and potential place them among the next generation of scientific leaders in the U.S. and Canada. Winners receive $75,000, which may be spent over a two-year term on any expense supportive of their research.

Yao Yao is an Assistant Professor in SoM whose research interests include the mathematical analysis of nonlinear PDEs arising from fluid mechanics and mathematical biology.

To receive a Sloan Research Fellowship is to be told by your fellow scientists that you stand out among your peers. A Sloan Research Fellow is someone whose drive, creativity, and insight makes them a researcher to watch.

- Adam F. Falk, president of the Alfred P. Sloan Foundation



Yao Yao

NSF CAREER GRANT AWARDED TO LUTZ WARNKE

FEBRUARY 17, 2020 | ATLANTA, GA

The Faculty Early Career Development (CAREER) Program is a Foundation-wide activity that offers the National Science Foundation's most prestigious awards in support of early-career faculty who have the potential to serve as academic role models in research and education and to lead advances in the mission of their department or organization.

Lutz Warnke is an Assistant Professor of Mathematics at Georgia Institute of Technology, whose research focuses on probabilistic combinatorics and random discrete structures. Prof. Warnke research interests include random graphs and processes, phase transitions, and combinatorial probability as well as applications thereof to extremal combinatorics, Ramsey theory, and related areas.

Professor Warnke's other accolades include 2014 the Richard-Rado-Prize (German Mathematical Society), and in 2016 the Dénes König Prize (SIAM), and his research is supported by an NSF grant, a 2018 Sloan Research Fellowship, and now this 2020 NSF CAREER award.

Lutz Warnke

GEORGIA TECH MATHEMATICIANS WIN BEST ARTICLE AWARD

MATTHEW BAKER, JOSEPH RABINOFF COAUTHORED INFLUENTIAL PAPER

JUNE 6, 2019 | ATLANTA, GA

The journal Research in the Mathematical Sciences has selected a paper coauthored by Georgia Tech mathematicians Matthew Baker and Joseph Rabinoff as one of the inaugural recipients of its Best Article Award.

The journal recognized the paper – titled "Lifting harmonic morphisms I. metrized complexes and Berkovich skeleta" – as outstanding and highly influential. Other authors are Omid Amini, of CNRS, Paris, and Erwan Brugallé, of Université Pierre et Marie Curie, Paris.

The article is about finding algebraic functions between algebraic curves. Algebraic curves are one-dimensional shapes defined by polynomial equations. For example, $x^2 + y^2 = 1$ is the equation which defines a circle.

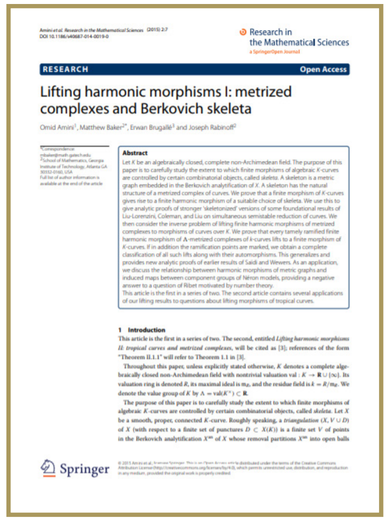
"In some sense, algebraic curves are well understood," Baker says. He is a professor in the School of Mathematics and associate dean for faculty development in the College of Sciences. "But the theory is very rich, and there's still a lot we don't know about them."

MATT BAKER

JOE RABINOFF

The essential idea of the paper is to chop algebraic curves into simpler pieces and then keep track of two things: which pieces are connected to what others and which pieces of one curve are sent by the function to what pieces of another curve.

"It turns out that this method is enough to recover a lot of information about the original pairs of curves and the function between them," says Rabinoff, a former associate professor in the School of Mathematics. "One subtlety is that the whole construction is carried out in an exotic context called "Berkovich spaces" and their skeleta, which arise naturally in number theory."



the Mathematical Sciences
a SpringerOpen Journal

RESEARCH Open Access

Lifting harmonic morphisms I: metrized complexes and Berkovich skeleta

Omid Amini[1], Matthew Baker[2*], Erwan Brugallé[3] and Joseph Rabinoff[2]

*Correspondence: mbaker@math.gatech.edu
[2]School of Mathematics, Georgia Institute of Technology, Atlanta GA 30332-0160, USA
Full list of author information is available at the end of the article

Abstract
Let K be an algebraically closed, complete non-Archimedean field. The purpose of this paper is to carefully study the extent to which finite morphisms of algebraic K-curves are controlled by certain combinatorial objects, called *skeleta*. A skeleton is a metric graph embedded in the Berkovich analytification of X. A skeleton has the natural structure of a metrized complex of curves. We prove that a finite morphism of K-curves gives rise to a finite harmonic morphism of a suitable choice of skeleta. We use this to give analytic proofs of stronger 'skeletonized' versions of some foundational results of Liu-Lorenzini, Coleman, and Liu on simultaneous semistable reduction of curves. We then consider the inverse problem of lifting finite harmonic morphisms of metrized complexes to morphisms of curves over K. We prove that every tamely ramified finite harmonic morphism of Λ-metrized complexes of k-curves lifts to a finite morphism of K-curves. If in addition the ramification points are marked, we obtain a complete classification of all such lifts along with their automorphisms. This generalizes and provides new analytic proofs of earlier results of Saïdi and Wewers. As an application, we discuss the relationship between harmonic morphisms of metric graphs and induced maps between component groups of Néron models, providing a negative answer to a question of Ribet motivated by number theory.
This article is the first in a series of two. The second article contains several applications of our lifting results to questions about lifting morphisms of tropical curves.

1 Introduction
This article is the first in a series of two. The second, entitled *Lifting harmonic morphisms II: tropical curves and metrized complexes*, will be cited as [3]; references of the form "Theorem II.1.1" will refer to Theorem 1.1 in [3].
Throughout this paper, unless explicitly stated otherwise, K denotes a complete algebraically closed non-Archimedean field with nontrivial valuation val : $K \to \mathbf{R} \cup \{\infty\}$. Its valuation ring is denoted R, its maximal ideal is $\mathfrak{m}_R$, and the residue field is $k = R/\mathfrak{m}_R$. We denote the value group of K by $\Lambda = \mathrm{val}(K^\times) \subset \mathbf{R}$.
The purpose of this paper is to carefully study the extent to which finite morphisms of algebraic K-curves are controlled by certain combinatorial objects, called *skeleta*. Let X be a smooth, proper, connected K-curve. Roughly speaking, a *triangulation* $(X, V \cup D)$ of X (with respect to a finite set of punctures $D \subset X(K)$) is a finite set V of points in the Berkovich analytification X^{an} of X whose removal partitions X^{an} into open balls

Springer

The award-winning mathematics paper

"The paper provides a piece of foundational work that is useful in many areas of mathematics," Baker says. "For example, it has become an important tool in a relatively new area called tropical geometry. It is also the starting point for studying wildly ramified functions between algebraic curves. This topic is of interest to several groups of mathematicians around the world."

The paper provides a piece of foundational work that is useful in many areas of mathematics.

Research in the Mathematical Sciences, launched in 2013, is an international, peer-reviewed hybrid journal covering the full scope of theoretical mathematics, applied mathematics, and theoretical computer science. The journal launched the Best Article Awards to celebrate its fifth anniversary.

RECENT PROMOTIONS IN SoM

MARCH 30, 2020 | ATLANTA, GA

Greg Blekherman, Promoted to Full Professor

Dr. Grigoriy Blekherman works in the interdisciplinary area of applied algebraic geometry and seeks to combine techniques from real and complex algebraic geometry and convex geometry to address fundamental questions in several areas of mathematics, with relevance to engineering, physics and theoretical computer science.

Prof. Blekherman's research has been recognized by both a Sloan Research Fellowship as well as a NSF CAREER Award.

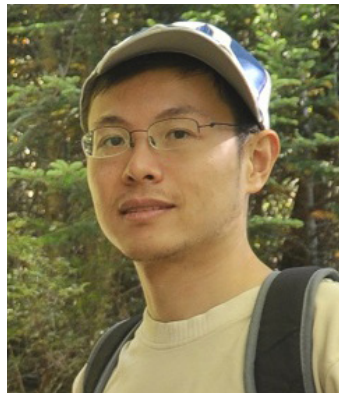
In addition to superior research, Prof. Blekherman's excellence in teaching has been recognized by the CETL-BP Junior Faculty Teaching award, and by selection as Provost Teaching and Learning Fellow. Prof. Blekherman sits as an associate editor of SIAM Journal on Applied Algebra and Geometry, and among other prestigious speaker invitations has been an invited lecturer at several international graduate schools.

Before joining Georgia Tech in 2011, Dr. Blekherman held postdoctoral positions at Microsoft Research, Virginia Bioinformatics Institute, Institute for Pure and Applied Math at UCLA, and UC San Diego. He received his Ph.D. from the University of Michigan in 2005.

Prof. Blekherman's research Interests include Applied Algebraic Geometry, Convex Geometry and Optimization, and Mathematical Biology.

My work focuses on the interplay between convex and algebraic geometry (both real and complex), especially in the area of sums of squares approximations to nonnegative polynomials, and tensor ranks and their generalizations.

Molei Tao, Promoted to Associate Professor with Tenure



Dr. Molei Tao joined Georgia Tech as an assistant professor in 2014. The main theme of Prof. Tao's research is to analyze, simulate and control systems characterized by multiple scales, geometric structure, and randomness.

As an applied & computational mathematician who develops theoretical tools to solve practical problems, Dr. Tao has published in leading journals in both math and applied disciplines, as well as high profile conference papers. He has received funding from multiple sources, including an NSF CAREER Award in 2019. Prof. Tao has been actively mentoring Ph.D. students and postdocs, as well as student researchers at other levels.

Prior to joining Georgia Tech, Dr. Tao was a Courant Instructor at NYU and a postdoctoral researcher at Caltech. He received his Ph.D. in Control & Dynamical Systems with a minor in Physics in 2011 from Caltech.

Prof. Tao designs algorithms for faster and more accurate computations and develops mathematical tools to answer scientific questions to analyze/design engineering systems. Examples include:

- Extrasolar and Solar planetary dynamics
- Rare events modeling and quantification
- The resonant control of mechanical systems, including the engineering problems of energy transfer and harvest
- The interplay between dynamics and machine learning

My main objective is to analyze, simulate, and control systems characterized by multiple scales, geometric structures (e.g., symplecticity), and randomness.

ENID STEINBART PROMOTED TO PRINCIPAL ACADEMIC PROFESSIONAL

MARCH 30, 2020 | ATLANTA, GA

The rank of Principal AP is the highest in the GT academic professional career ladder, awarded to those demonstrating superior performance and recognized by peers, with successful and measurable related experience, including but not limited to supervision of others' work, significant responsibility and authority within program area, and demonstrated impact.

Dr. Steinbart joined Georgia Tech in 1999, and has been SoM's Director of Undergraduate Advising and Assessment since 2000. Before joining Georgia Tech, she received her Ph.D. in Mathematics from the University of Illinois at Urbana-Champaign, after which she progressed to Full Professor at the University of New Orleans. Twice recognized with GT's Outstanding Undergraduate Academic Advising Award, Dr. Steinbart has also received the Outstanding Academic Advisor -Certificate of Merit from the National Academic Advising Association (NACADA), and the Class of 1940 Course Survey Teaching Effectiveness Award. She has taken leadership roles in many activities that advance undergrad success at GT, including leadership of Club Math, implementation of SoM's new Math Major, developing the Math Undergraduate Seminar in 2008, and twice chairing GT Advising Network's Academic Advisor Best Practices Conference.

MICHAEL LACEY AND MOHAMMAD GHOMI NAMED SIMONS FELLOWS 2020

FEBRUARY 28, 2020 | ATLANTA, GA

Congratulations go to SoM Professors Michael Lacey and Mohammad Ghomi for their recent award of the prestigious Simons Fellowship for 2020. This fellowship aims to make sabbatical research leaves more productive by extending them from a single term to a full academic year.

Awards are be based on the applicant's scientific accomplishments in the five-year period preceding the application and on the potential scientific impact of the work to be done during the leave period.

A Simons Fellowship in Mathematics provides salary replacement for up to half of the Fellow's current academic-year salary, and up to $10,000 for expenses related to the leave. The Fellow's home institution will receive an additional 20 percent overhead on allowable expenses.

Michael Lacey

Mohammad Ghomi

GEORGIA TECH LAUNCHES FRANCES O. HITE SCHOLARSHIPS

ENDOWMENT AIMS TO SUPPORT WOMEN IN MATHEMATICS

NOVEMBER 18, 2019 | ATLANTA, GA

From left: Hite children Kevin and Pamela; Bruce Hite; Esther Gallmeier; Charlie Crawford, Bruce's longtime friend; and Erin Green, College of Sciences development associate (Courtesy of Bruce Hite)

Georgia Tech has named Esther Gallmeier as the first recipient of the Frances O. Hite Scholarship Endowment. Gallmeier is a second-year student in the School of Mathematics.

Georgia Tech alumnus Bruce L. Hite formed the endowment in loving memory of his wife, Frances "Fran" Orr Hite. Bruce graduated from Georgia Tech in 1972 with a B.S. in building construction.

Born in Shelbyville, Tennessee, Fran earned a B.A. degree in mathematics from Vanderbilt University in 1972. After her death in May 2019, friends and family established the scholarship endowment in her honor. The goals are to perpetuate Fran's memory and to encourage women in mathematics by providing scholarships to deserving students.

Frances "Fran" Orr Hite, 1972 (Courtesy of Bruce Hite)

"This scholarship came as a surprise to me, and I'm very grateful," Gallmeier says. She adds that she appreciates the Hite family's support for women in mathematics.

Gallmeier completed high school in Oak Ridge High School, in Oak Ridge, Tennessee. She was attracted to Tech by the experience of a former student in her high school who went to Tech to major in mathematics. "He loved it here," she says. "As a result, I was attracted to studying mathematics at Tech. Also, Georgia Tech is incredible at providing opportunities for undergraduates in research and internships. We are definitely well-connected with companies from all over."

One Frances O. Hite scholarship will be awarded annually to a qualified student, preferably a female student, pursuing a degree in the School of Mathematics.

For information about creating an endowment, supporting our students, or dontating to the School of Mathematics please email comm@math.gatech.edu

STUDENT RECOGNITION OF EXCELLENCE: CLASS OF 1934 AWARD

TWO SoM FACULTY AWARDED FOR TEACHING

MAY 19, 2020 | ATLANTA, GA

Each year GT rewards faculty members with exceptional response rates and scores on the Course-Instructor Opinion Survey (CIOS). The reward includes a cash prize and recognition at GT Celebrating Teaching Day

The criteria for selection for the award included a student response rate of 85% and above. CIOS scores were based on the sum of three scale items: (Q. 16) Instructor's respect and concern for students; (Q. 17) Instructor's level of enthusiasm about teaching the course; (Q. 18) Instructor's ability to stimulate my interest in the subject matter. Ties were broken by response rate.

John Etnyre is a Professor in the School of Mathematics, whose research intrestes include the topology of low dimensional manifolds and its relation with geometry and dynamics. Prof. Etnyre was also awarded the College of Sciences Faculty Mentor Award in 2017 as well as numerous research awards including a NSF CAREER award and Simons Fellowship, and is a Principal Investigator (PI) for the RTG: Research Training in Geometry and Topology $2.1 million grant from the NSF which solidifies the Georgia Tech Geometry and Topology (GTGT) group as one of the premier destinations for this area of research.

Neha Gupta is a recent addition to the School of Mathematics. Prof. Gupta is an Academic Professional in the School, and is the course coordinator for the freshmen Calculus I class, MATH 1551, as well as the Director of Scheduling for the School of Mathematics.

John Etnyre

Neha Gupta

FULMER PRIZE CO-AWARDEES MICHAEL LACEY AND GREG MAYER

2020 SCHOOL OF MATHEMATICS FULMER PRIZE

MAY 19, 2020 | ATLANTA, GA

We thank the late Howard Woodham (Georgia Tech alumnus, Engineering '48) for the establishment of the Herman K. Fulmer Faculty Teaching Fund Endowment for the School of Mathematics (SoM), in memory of Professor Herman Fulmer, his former mathematics professor. Each year this award recognizes one of our faculty who exhibit genuine regard for undergraduate students during the first few years of their Engineering studies at Georgia Tech.

The prize recognizes the work over several years to support student success; in particular, the distance learning students in Math 1554. Not only has the course content and delivery improved and aligned with our other offerings, but the program has grown and advanced, with a new asynchronous version now being launched. This course has wide impact throughout the Institute, from recruitment to providing students with a head start at Georgia Tech as they join different programs that rely on a solid background in Linear Algebra.

Michael Lacey

Greg Mayer

TOP GRADUATE STUDENTS WIN EARLY CAREER AWARDS

YUCHEN HE AWARDED LARRY O'HARA FELLOWSHIP

Research opportunities that opened up to Georgia Tech students during their undergraduate years expand significantly when students continue their work as graduate or doctoral students.

Georgia Tech College of Sciences encourages that work with the annual presentation of Larry S. O'Hara Graduate Scholarships, given to outstanding doctoral students who are scheduled to graduate in the calendar year following their nominations.

Yuchen He is a Ph.D. candidate in the School of Mathematics under Professor Sung Ha Kang, and his primary research focus is Lattice Indentification and Separation.

Yuchen shares this award with Suttipong Suttapitugsakul (School of Chemistry and BioChemistry), Deborah Ferguson (School of Physics), and Hyeonsoo Jeong (School of Biological Sciences).

Yuchen He

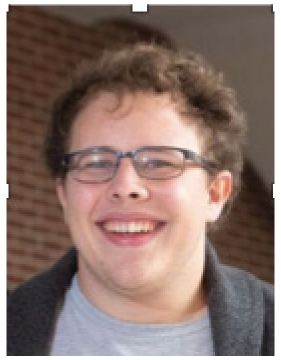
UNDERGRADUATE RESEARCH AT TECH

GEORGIA TECH CoS UNDERGRAD RESEARCH AWARD

Georgia Tech undergraduates have a unique opportunity when they start studies on campus: They have a chance to engage in the kind of research that other schools might not offer until they are in graduate studies. In Georgia Tech's College of Sciences, undergraduates can ask questions, use their skills, and test their knowledge to solve problems and explore issues no one has ever addressed before.

Every year, a select group of undergraduates distinguishes itself with meaningful research, guided by faculty members and other mentors who get to watch the development of some of the country's best young scientific minds. Steven Creech, a mathematics major, researches under the guidance of Professor Matthew Baker. He studies algebraic number theory and algebraic geometry. Creech is also an undergraduate teaching assistant and the president of Club Math.

Steven is one of three recipients of this years CoS Undergrad Research Award. He shares the honor with Amitej Venapally (Biochemistry and Computer Science) and Sara Brokmeier (Psychology).



Steven Creech

THE 2020 USG ACADEMIC RECOGNITION DAY AWARD

TRIPLE-MAJOR RECIEVES USG TOP HONOR

Gurevich, who is set to graduate in May 2020, will pursue a Ph.D. in applied mathematics in the fall. "My goal is to teach and perform research as a professor, looking for new ways to use mathematical tools to advance our understanding of fields like physics and biology. My education at Georgia Tech has given me the opportunity to acquire a very broad skill set that is extremely valuable for an academic career. I have always appreciated how math helps us find connections between seemingly distant scientific areas."

"Getting this award was wonderful and unexpected news," Gurevich says. "It really means a lot to me to have been selected out of so many outstanding students at Georgia Tech, and I am very honored to have the results of my hard work recognized. I'm grateful for all of the support I have received from the Georgia Tech community, particularly my professors and advisors."

Georgia Tech President Angel Cabrera and Daniel Gurevich at the USG Academic Recognition Day Awards Feb. 11. (Photo by Angel Cabrera)

TA AWARDS

MAY 19, 2020 | ATLANTA, GA

School of Mathematics Awards

Numbering 78 graduate TAs and 26 undergraduate TAs, the School of Mathematics has a robust and highly trained teaching assistant cohort. TAs are expected to not only teach the material well, but also engage the students in discussions, facilitate group learning, and hold office hours or Math Lab hours.

Led by the excellent Klara Grodzinsky, who is the TA coordinator as well as the course coordinator for the Calculus II course MATH 1552, and who is herself a highly awarded and sought after instructor, these undergraduate and graduate students strive every semester for excellence.

CTL "TA of the Year Award" School Finalists:

- Graduate Student Instructor: Yoan Delchev
- Graduate Teaching Assistant: Cvetelina Hill
- Undergraduate Teching Assistant: Max Poff

Outstanding Math Lab Tutor:

- Kofi Amanfu
- Trevor Gunn

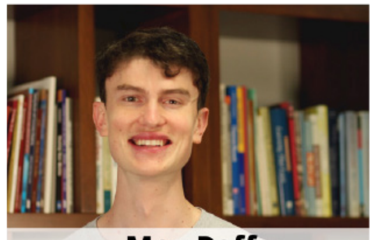
Outstanding Student Evaluations in Spring 2019:

- Thibaud Alemany
- Sally Collins
- Mollene Denton
- Yuchen He
- Cvetelina Hill
- Ian Katz
- Jesse Jiang

Cvetelina Hill

Outstanding Student Evaluations in Fall 2019:

- John Chiles
- Bryan Clark
- Joseph Cochran
- Steven Creech
- Abhishek Dhawan
- Athreya Gundamraj
- Wade Kovalik
- Justin Lanier
- Jack Olinde
- Max Poff



Max Poff

Honorable Mentions:

- Santana Afton
- Yana Charoenboonvivat
- Catherine Chen Kieffer
- Christina Giannitsi
- Kyle Jiang
- Shaojun Ma
- Athulya Ram Sreedharan Nair
- Anshul Tusnial
- Tao Yu

Outstanding Undergrad TA

- Ariana Calvache
- Zachary Stiles

Yoan Delchev

Institution-wide Awards

In addition to the above School of Mathematics awards, the following TAs were given institute-wide recognition for excellence in teaching. This year, the School of Mathematics TAs were represented in every possible category, congrats!

2020 Georgia Tech Graduate Student Instructor of the Year

- Aditya Anupam (Literature, Media, and Communication)
- **Yoan Delchev (Mathematics)**
- Anthony Harding (Economics)

2020 Georgia Tech Graduate Teaching Assistant of the Year

- **Cvetelina Hill (Mathematics)**
- Elaine Rhoades (Physics)
- Yushuo Yang (Economics)

2020 Georgia Tech Undergrad Teaching Assistant of the Year

- Brandon Kang (Industrial and Systems Engineering)
- Caroline Kish (Computer Science)
- **Max Poff (Mathematics)**

Congratulations to all the winners, and thanks to all the TAs for all their hard work!

FEATURED ARTICLE

HOW TO GET FAR WITH SMALL EFFORT

written by Rafael de la Llave
edited by Sal Barone

From the beginning of time, humankind has had two aspirations:

- Get far with little effort,
- Predict the future.

Mathematics has been helping to predict the future for a long time. Astronomers observed thousands of years ago that the positions of the planets predicted seasons and this was invaluable in planting, harvesting, etc. More recently, the prediction of hurricanes saves thousands of lives every year.

Mathematics also helped in moving things as any of our mechanical engineers can attest.

It is natural that the two goals go together: If one can predict the future, one can get far.

The surprising fact is that now, mathematics are showing that unpredictability of the future can help to go far without effort. One can compare this with Jiu-jitsu: turning the force of the attack into your advantage. It requires quite a number of clever ideas that have been growing for a long time.

In the following, I would like to explain some of the beautiful ideas and their applications, specifically relating to the design of space missions.

The study of motions of bodies in outer space is particularly rich because there is no friction and there are many interesting dances among the planets that occur over massive time-scales. Friction makes prediction very easy (everything eventually stops), but on the other hand the aspirations to get far are frustrated by friction.

Prediction in Mathematics - Differential Equations

A very important tool[1] that mathematicians have used for a very long time to predict the future is differential equations. A differential equation is a situation when the rate of change of a state[2] is prescribed as a function of the state. For example, the Newton's laws of mechanics tell you what is the acceleration of a body -- the rate of change of the velocity -- as a function of the position and the velocity.

Once this law of motion is fixed -- people get Nobel prizes for finding the right form of these relations -- and we determine the initial conditions precicesly, then the full future is determined. (If we know the initial conditions and we know how the system is changing, then we know what is the state a bit later, and hence, we can calculate what will be the state a bit later, and then the state a bit later after that, and so on...)

This power was precisely stated by Laplace[3] as follows:

> We may regard the present state of the universe as the effect of its past and the cause of its future. An intellect which at a certain moment would know all forces that set nature in motion, and all positions of all items of which nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in a single formula the movements of the greatest bodies of the universe and those of the tiniest atom; for such an intellect nothing would be uncertain and the future just like the past would be present before its eyes.

The Geometric Program

The first idea that appeared to deal with differential equations -- still used quite a lot in our sophomore courses -- is to manipulate the equations using the rules of calculus to obtain explicit formulas for the solution.

1 It should be said that there are other tools: notably mathematicians have been making statistical predictions, quantum mechanics has introduced intrinsically random elements, more recently, people have been using other tools such as combinatorics to model physical phenomena. Let us hope that the ProofReader can cover these new tools.

2 Typically, the state of a system is prescribed by a few numbers such as the positions and the velocities.

3 This often quoted statement is may be slightly out of context. It appears precisely in Laplace's book on probability, which deals with non-deterministic models. Of course, Laplace had written 6 wonderfull volumes in Celestial Mechanics where all the motions of planets -- alas not the Moon -- have been predicted and compared to observations. Book fanatics are encouraged to take advantage of public domain sites and compare the prologues of the two editions of Laplace's book on probability.

Starting in the XIX century -- a watershed moment was the Ph. D. thesis of Henri Poincaré -- mathematicians started to think of differential equations as tubing in a river. Consider the following thought experiment. Your velocity -- the rate of change of the position -- is determined by your present position (it should match the velocity of the river at your position). Think for example of a river that has quiet places, eddies, white waters, etc. Considering the chaotic eddies and flow of the river, the place where you end up depends a lot on where you start.

The surprising fact is that now, mathematics are showing that unpredictability of the future can help to go far without effort. One can compare this with Jiu-jitsu: turning the force of the attack into your advantage.

This point of view helps with the intuition that the behavior of the solutions of a system of differential equations may be qualitatively different depending on the initial conditions. It turned out, much of the study of differential equations became not the study of formulas, but the study of shapes[4], and the rules of manipulating those shapes without changing their fundamental properties.

Nowadays, those who engage in research in this area have to keep active simultaneously these two points of view: the development of formulas and the imagination of shapes. Neurologists tell us that these two capabilities reside on different sides of the brain, so working in dynamics, you get a whole brain workout[5]. One can think of this as the *Cross Fit* of the brain. In recent times, one also has to add the numerical calculations on the computer[6] so that in addition you get to work out parts of the brain you did not realize you had.

The Chaos Revolution

The pronouncement of Laplace about perfect determinism has implicit that one knows exactly the initial conditions. When one knows the initial conditions only approximately -- as it is unavoidable in practice -- clearly, one cannot predict the future exactly, only approximately.

The question is to make quantitative how much precision in the initial data one needs to know the final result with some accuracy.

In the cases that are treated by formulas (e.g. the orderly motions of the planets as in an *orrery*[7]) the accuracy in the final answer is roughly the same as the accuracy in the initial data. The fact that in some cases the distance between orbits with similar initial conditions could grow faster than expected was hinted in papers by Poincaré, Lyapunov, Hadamard, but they were ignored for a long time. What galvanized the scientific community was a 1963 paper by E. N. Lorenz (a meteorologist!). Lorenz discovered that even in simple models a very small uncertainty in the initial data, could grow *very fast* into uncertainty in the predictions. One example in Lorentz 1963 paper was that a small change in the initial data of the atmosphere of the size of the shaking of a wing of a butterfly could grow in 6 months into an uncertainty in the prediction of the size of a typhoon. This example gave rise to the name *butterfly effect* that has since entranced the popular press. The main point is the very rapid speed at which uncertainty could grow[8].

This was a great blow to the idea of reading all the future from initial conditions. Theoretically possible, but highly impractical.

Of course, one does not just throw ones arms up in despair and quit.

This is an exercise that I like to run in the differential equations classes. Students pick initial conditions in the Lorenz model that differ only in the 7 decimal digit and study them numerically. After running the simulation for a short time,

4 The need to think carefully about all this shapes etc. gave rise to new mathematical disciplines. Notably the discipline now known as *topology* had its beginnings in the *Analysis situs* of Poincaré.

5 Keep in mind that some of the shapes we need to imagine and manipulate only exist in six or more dimensions, so that is really fun.

6 The first electronic computers were developed precisely to solve differential equations and compute ballistic tables. Computers are another field that had its origins in differential equations.

7 These are wonderful machines full of gears with sprockets which when moved with a crank rotate like the planets. The Rittenhouse orrery has been a pride of Princeton University for 250 years.

8 An interesting question is why the pioneering mathematical papers did not have an inpact while Lorenz's paper caught fire. Undoubtedly unappealing writing and a high entry bar played a role. It seems to me also that the availability of computers which made all this easy to visualize played role as well.

the solutions do not look like each other at all. On the other hand, even if one picks rather different initial conditions, histograms of times of visit look exactly the same[9].

The fact that one can obtain statistical regularities when detailed predictions are impossible is very common[10]. Actuaries cannot tell whether any of my students will have children -- even they themselves cannot tell now -- on the other hand, actuaries can have a pretty accurate idea of how many children will be born in Atlanta in the following years.

One of the very important mathematical realizations in the 1970's and 80's -- growing up in parallel on both sides of the Iron curtain lead by Anosov, Sinai, Ruelle and Bowen -- was that precisely in the situations when one gets the very dramatic growth of uncertainty, one gets to make very sharp statistical predictions.

In astrodynamics, the size of the perturbation is the amount of fuel spent in creating them. Hence, in the places where there is chaos (in the right directions) one can trade accurate predictions for *fuel*.

Making the relations above precise (and incorporating the new tool of the computer) was a very exciting scientific period in which Mathematicians and Physicists came together like forlorn lovers. The tools needed ranged from measure theory, fractal geometry to statistical mechanics, thermodynamics, field theory. Many people refer to this period as *The chaos revolution*. This indeed has changed the way all work, from basic scientific questions to computer graphics, is performed. Indeed, the common language has changed. Georgia Tech was a very key player in the chaos revolution. Both in Physics and Mathematics. Let us hope that somebody will gather stories from that period in future issues of the ProofReader.

Now Back to Moving Far in an Easy Way

Coming back to the original problem. The key observation is that chaos, even if it makes it difficult to make precise predictions, it may make possible to get far. Small perturbations can grow.

If the growth happens in a desirable direction, this is great news. We can just make a small perturbation and let it grow. In practice, this presents difficulties since one needs to choose the direction of the original kick very precisely to get a big growth, and the growth only happens in a direction the system chooses. Nevertheless, it is interesting that one can think of doing something like this. Precisely in the places where prediction is difficult (but possible thanks to the mathematical developments), one can hope to make tiny perturbations (whith small effort) and let them grow to very large sizes that, if attempted directly, would have required lots of effort.

In astrodynamics, the size of the perturbation is the amount of fuel spent in creating them. Hence, in the places where there is chaos (in the right directions) one can trade accurate predictions for *fuel*.

Astronomy

The earliest models of astronomy were basically objects that rotated periodically. The sun rotates over the sky with period of about 24 hours. With a little bit more of accuracy, one observes that the circles of the sun oscillate with a period of about 365 days. Then, there are planets, also moving in periods corrected by periods. Basically, it could be modeled by clocks (and orrerys) in which wheels with sprockets move around. Nowadays, one can get the JPL ephemerids that give you similar models that describe very accurately the motion of the planets, moons and many asteroids very accurately over thousands of years.

The model of planets rotating each of them on its orbit, does not have any chaos. If we take an orrery and move one sprocket ahead, we will stay an sprocket ahead forever and the changes in initial conditions do not grow (or grow very slowly).

Resonances

It is known in mechanical systems that when forces have exactly the same frequency as the natural frequency of the motion, the effect accumulates; however, when the force occurs at a different frequency, one finds the effect

9 The reader who is unfortunate not to know how to solve a differential equation numerically can try to repeatdly apply the rule $x_{n+1} = 1-2x_n^2$ in a pocket calculator. Same results: Uncertainty in individual trajectories, but statistical predictability.

10 Indeed, it was the subject of the book of Laplace where the determinism quote appears.

to average out[11].

We have all seen it in playground swings. If one pushes the swing with the right frequency, it will get energy. If we push with a wrong cadence (sometimes when the swing is coming to us, sometimes when it is going away), the effects will neutralize.

The effect of resonance is the basis of communications. Our cell phone generates a few milliwats of radiation. Nevertheless, it is picked up by an antenna miles away because the frequency of the emission is precisely the natural frequency of the antenna.

Resonances in Astronomy

In spite of the enormous success of the orrery model of the solar system, it was already known by Newton that this exquisite and repetitive order could be unstable[12]. The reason is that the planets push and pull on the others though their mutual gravitational forces. It is known that in many circumstances, the push and pulls average out and nothing dramatic happens.

Nevertheless, there are circumstances when the forces accumulate over time so that, even small forces can lead, over time to appreciable effects.

If we consider the motion of a small body in the solar system, it will be very close to an orrery (with one body more) having its own frequency, except in the places where the push and pulls of the planets have the same frequency as the natural frequency of the body (which depends of the orbit which the body is following).

In the region where the forcing is happening, one gets that the solutions grow and therefore small perturbations grow. In other words, adding the small effect of the planets may open up some regions of chaos in the orrery system[13].

Kolmogorov-Arnold-Moser theory

It was realized in the 1950's and 60's (in the work of A. Kolmogorov, J. Moser and V. I. Arnold) that in the cases where the frequency does depend on the orbit, this allows to prove long term stability. If the orbits in some area of phase space are affected, they will gain energy and move out of this region and indeed stop being affected. Hence, one expects that a large fraction of the orbits survive.

Making this seat of the pants argument rigorous is a highly non-trivial task, and is called KAM theory -- in homage to the initials of the founders. It involves subtle mathematics, differentiability and quantitative smallness conditions, and even number theoretical properties of numbers[14].

When one carries the proof in detail one is lead to the statement that there is a large measure set of initial conditions which are stable for all time.

Very similar arguments -- if a point happens to be in a resonance, the dynamics moves the point out of it -- leads to another famous result, the Nekhoroshev theorem, which states that all orbits are stable for a long time (provided that the system satisfies some mild assumptions).

Arnold diffusion

The KAM theory and Nekhoroshev theory show that stability is the norm (KAM says stability for all time happens in large measure and Nekhoroshev says stability happens at all points for a long time). On the other hand, paraphrasing Lincoln,

almost all conditions all the time and all conditions almost all the time is far from all conditions all the time.

Indeed, in 1964, V. I. Arnold published a remarkable four page paper in which he constructed an example in which arbitrarily small perturbations indeed accumulate. These are the four pages

11 Those who have taken the standard course in differential equations will remember the chapter of the method of undetermined coefficients, when in some cases, one has to add a factor t^s. Very often weird mathematical facts are the basis of amazing gadgets.

12 Indeed one of the most unexpected predictions -- confirmed by observation -- of Newtonian theory is that planets could affect each other's orbits as well as the trajectory of passing comets.

13 We omit some subtleties such as the fact that, because of the equations are non-linear, one can also get (much smaller) regions of chaos when combinations of integer multiples of the frequency of the planets matches an integer multiple of the frequency of the small body. This distinction s very important to recognize in order to understand the distribution of asteroids, as well as planets, the rings of Saturn etc.

14 In my opinion, the theorem is much harder to to *imagine* and comprehend than to prove. A very complete proof starting from undergraduate analysis can be done in 3 hours†. Realizing that one can bring together number theory, analysis, geometry to analyze dynamics, requires much ... more.
†: See https://smartech.gatech.edu/handle/1853/61347 and https://smartech.gatech.edu/handle/1853/61421

of mathematics that I have spent more time on than any others. (and I had the help of some people who had indeed spent even more time than me). The mathematician J. Moser (the "M" in KAM theory) in the journal *Mathematical Reviews* writes,

> *The details of the proof must be formidable, although the idea of the proof is clearly outlined.*

Be this a warning to the people who believe that the difficulty of reading a paper is proportional to the length[15].

How can the orbits in Arnold's example manage to avoid all the previous arguments? The reason is that Arnold's example is cleverly chosen in such a way that when when things are pushed out of one resonance, they land smack into another one. This follows very clearly from the formulas, but the remarkable paper had a very deep geometric insight. These very complicated jumps and maneuvers -- they are so complicated that can only happen in six or more dimensions -- are organized by some amazing objects inside the resonances themselves. V. I. Arnold called these objects *whiskered tori*. One can think of these whiskered tori as some interesting shaped eddies in the -- six dimensional -- river. By sticking around them one can hitch a ride to move long distances for free. Again, the difficulty lies in proving the actual existence of these whiskered tori and describing their intersections, which requires (very!) hard analysis.

In this research, one has to learn how to deal comfortably with six dimensional objects. One can, of course, use formulas and deal with them using the right side of the brain, but the game gets to be quite interesting when one can start having mental images in the left side of the brain of how shapes look like in 6 -- or more -- dimensions. Again, the use of computers -- there are good software to plot in high dimensions -- is invaluable to assist this effort.

Further Developments on Arnold Diffusion and Wiskered Tori

Starting around the turn of the millenium, there were very important developments in the theory of Arnold Diffusion. With the geometric program started by Arnold, the whiskered tori were joined by a plethora of other higher dimensional objects and tools, namely normally hyperbolic manifolds, normally hyperbolic laminations, correctly aligned windows etc. Besides these geometric methods, there are additional other methods, but we will not discuss them here since they have not yet lead to predictions in concrete models.

Applications

Concurrently with the geometric program for Arnold diffusion, there appeared another program to make much more constructive proofs of the existence of invariant objects in dynamics. These constructive proofs yield results in concrete systems and can be turned into computational algorithms. One can estimate the error of these computations and conclude rigorously that they are correct (computer assisted proofs). This new generation of algorithms are not only provably correct and very precise, but they are also three or more orders of magnitude faster than previous algorithms.

At the beginning, the proofs of KAM theory involved very strong smallness assumptions. By now, however, there are concrete systems -- a bit on the academic side -- in which the rigorous upper and lower bounds agree in three significant digits.

Now, the rigorous theory is on the verge of making contact with really practical problems. We have several good ideas of how some geometric objects generate motions and we have very good tools to compute them. The theory does not only lead to theorems, but also to very practical algorithms.

If one considers the approximation given by Newton's laws (ignoring radiation pressure) one can start making a map of interesting geometric objects in the vicinity of future missions. Putting together the numerical computation and rigorous mathematical analysis, one can get a catalogue of motions in space (some of them rather sophisticated) that can be done just by coasting along the resonances and the tides. For reasons we do not understand, many celestial objects are in very approximate resonance[16].

By taking advantage of resonaces and the landmarks that are generated around them, one can design maneuvers that do not require any fuel. At the moment, this does not include considerations of time spent, and ignores several effects such as friction, solar pressure, etc. Nevertheless, it is clear that by incorporating these fuel free motions into real missions, one can design real missions which use significantly less fuel.

This is very similar to the ideas of ancient sailors who had charts in which they listed currents, tide tables and dominant winds. Sailors designed their routes so that they took advantage of these naturally occuring pushes. Of course in motion of space craft is more complicated than the motion in a sea that can be characterized by two coordinates. For a spacecraft one needs three positions and three velocities (one may also need some more numbers to take into account the positions of planets). So that rather than the navigation maps that sailors spread on a table, we need to handle a six dimensional map that can only be spread inside a brain.

To bring all this to fruition one needs to develop new mathematics that incorporate effects such as the firing of the rockets, radiation, friction (which are not described by Newton's laws). Of course, all these new and deep mathematics need to be accompanied by constructive methods which lead to computations. It is a labor intensive job that requires both developing new mathematics and new algorithms.

A bonus of the work is that the same type of analysis can be useful in chemistry (the molecules are like a solar system of atoms). There are differences: the Newton laws are changed into more complicated forces and one does not have any exactly solved model as Kepler laws. Much more important is the fact that, all atoms of an element are identical[17]. Hence, there are many more resonances and much more complicated effects.

On the personal side, one of the perks of the job is that, after working on the things for a while (using computers and mathematical analysis) one can start seeing things in 6 dimensions.

15 I remember hearing V. I Arnold say several times that his only contribution to dynamics was one example.

16 Laplace and DeSitter observed very dramatic resonances in the moons of Jupiter. Janus and Epiphemetus are approximately in the same orbit -- they do a little dance when one overtakes the other.

17 Isotopes have small differences in the mass.

USING MATH TO TOUR THE SOLAR SYSTEM

RAFAEL DE LA LLAVE'S NUMBER CRUNCHING FOR NASA SCIENCEMATTERS SEASON 3 EPISODE 4

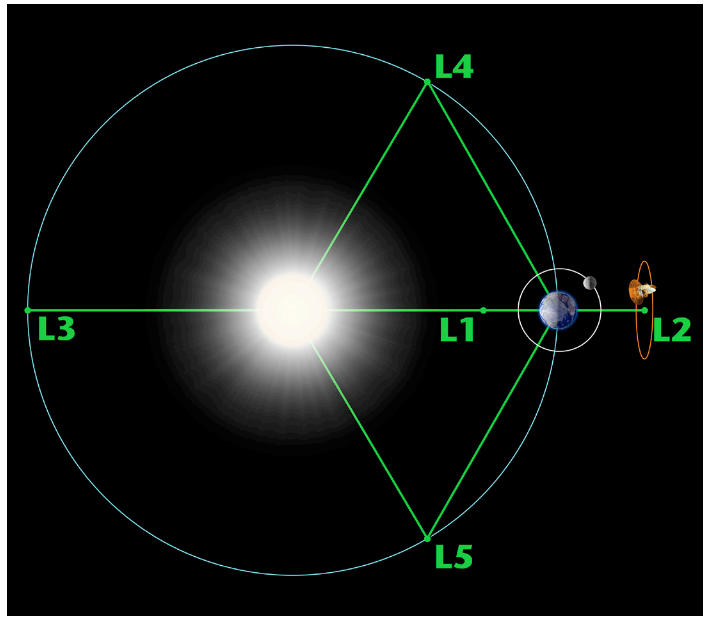
OCTOBER 8, 2019 | ATLANTA, GA

How can NASA stretch its fuel dollars for future missions to Jupiter and Saturn and their potentially habitable moons? By using mathematical concepts that have been around for centuries, School of Mathematics Professor Rafael de la Llave crunches the numbers for the space agency as it looks to save money during its next phase of exploration.

Rafael de la Llave in the classroom

De la Llave's efforts are the focus of ScienceMatters Season 3 Episode 4.

De la Llave is using a 2018 NASA grant to study how to use mathematics to save the space agency fuel costs for future tours of the solar system. His tools include mathematical concepts and theories like Hamiltonian systems, Lagrange mechanics, and Arnold diffusions. Fortunately for NASA, De la Llave is fluent in this kind of math talk.



Lagrange points in space (Courtesy NASA.gov)

ScienceMatters podcasts are available for subscription at Apple Podcasts and Soundcloud.

A RENOWNED MATHEMATICIAN

ROBIN THOMAS TRIBUTE

The recent passing of Regents' Professor Robin Thomas has left a hole in the School of Mathematics, and in our hearts. Robin was known not just for his extaordinary mathematical renown, but also for his kindness and mentorship. The lives he touched are many, and we wished to share the thoughts and prayers of some of them, in tribute to a great man.

Pace Academy Announcement

I am writing to let you know that Pace parent Dr. Robin Thomas passed away on March 26 following a long and courageous battle with ALS. Robin was 57 years old. He leaves behind his beloved wife, Sigrun Andradottir, and three children: Misha Andra-Thomas '17, senior Klara Andra-Thomas and eighth-grader Martin Andra-Thomas.

Born in Prague, Czechoslovakia, Robin earned his doctorate from Charles University in 1985. His passion for mathematics led him to the U.S., where Robin joined the Georgia Tech faculty in 1989. He was appointed a Regents' Professor in 2010, an honor given to outstanding tenured full professors.

Robin twice received the Fulkerson Prize in discrete mathematics; he won the Neuron Prize for Lifetime Achievement in Mathematics; and he was an American Mathematical Society and Society for Industrial and Applied Mathematics fellow. In 2016, he was named the Class of 1934 Distinguished Professor, the highest honor for a Georgia Tech professor.

"Follow your passion, value your education and work hard," Robin told graduates when he delivered Georgia Tech's Fall 2016 Ph.D. and Master's Commencement address, "Don't give up in the face of hardship, and have fun."

Robin followed his own advice and lived with passion for his family and his profession. He will be missed. Please join me in keeping the Andra-Thomas family in your thoughts and prayers as they mourn this great loss. Remind them that, despite our distance, they are surrounded by a school family that loves and cares for them.

May Robin rest in God's peace.

Memorial Fellowship Announced

In memory of Regents' Professor Robin Thomas, family and friends are raising funds to support a graduate fellowship in the Algorithms, Combinatorics, and Optimization (ACO) Ph.D. program at Georgia Tech.

We cannot think of a more fitting way to honor Robin's legacy than by supporting future generations of graduate students, scholars and leaders in the ACO program. Graduate fellowships help to recruit the most promising students to Georgia Tech and support and encourage them in their full-time course of study by allowing them to focus their attention on their studies and research.

To make an online gift, please visit:
http://development.gatech.edu

TRIBUTES

Noga Alon

Robin and I first met in 1989 in Bellcore, and right from the beginning I admired his mathematical talent and remarkable personality. We have written three joint papers, the first one appeared in 1990. Robin has been an outstanding researcher and a superb speaker and mentor. Amazingly he maintained his activity until recently; I had email communication with him during the last few months. He will be deeply missed by all of us.

R. Gary Parker

Robin Thomas was a "lifer" in the ACO Program. He was on the original Program Coordinating Committee, and he served as the dissertation advisor of the Program's first graduate, Dan Sanders (1993). When he stepped up and took over the leadership position after Richard Duke retired, he was no caretaker; rather, he shepherded the Program skillfully, preserving---even enhancing, I would submit---its position as one of Tech's elite interdisciplinary doctoral programs. In my mind, Robin Thomas was ACO.

George Nemhauser

Robin was a brilliant mathematician, a great leader of the ACO program and a wonderful colleague and mentor to students. His absence is a great loss.

Chun-Hung Liu

Robin is definitely one of the people who changed my life. I had received his enormous support since I entered Georgia Tech. It continuously benefits me even today. Robin offered me constant encouragement not only verbally but also through his action. I am very grateful that he attended my hooding ceremony even though he had become very difficult for moving. The conversation with Robin was always inspiring, and his suggestions were always comprehensive and considerate. He is a role model not only in academia but also in daily life. It is very amazing that he continuously expressed deep ideas, conducted research and provided professional service even when he was suffering serious illness. It was very shocking to hear the bad news. His persistence made me think that everything was under control and he could maintain the status for much longer. R.I.P.

Prasad Tetali

Robin was a remarkable human being, full of resolve and resilience. He was invaluable and inspiring as a colleague and this loss will be felt for a long time to come. He was greatly influential in shaping the ACO PhD program -- upholding its rigor through his research, teaching, mentoring and service -- making it internationally renowned and successful, and we are forever indebted to him for that.

Matt Baker, on his blog:

My previous post was about the mathematician John Conway, who died recently from COVID-19. This post is a tribute to my Georgia Tech School of Mathematics colleague Robin Thomas, who passed away on March 26th at the age of 57 following a long struggle with ALS. Robin was a good friend, an invaluable member of the Georgia Tech community, and a celebrated mathematician. After some brief personal remarks, I'll discuss two of Robin's most famous theorems (both joint with Robertson and Seymour) and describe the interplay between these results and two of the theorems I mentioned in my post about John Conway.

Lance Fortnow, on his blog:

Graph Theorist and Georgia Tech Math Professor Robin Thomas passed away Thursday after his long battle with ALS. He was one of the giants of the field and a rare double winner of the Fulkerson Prize, for the six-color case of the Hadwiger Conjecture and the proof of the strong perfect graph theorem.

If you start with a graph G and either delete some vertices or merge vertices connected by an edge, you get a minor of G. The Hadwiger conjecture asks whether every graph that is not (k+1)-colorable graph has a clique of size k as a minor. Neil Robertson, Paul Seymour and Thomas proved the k=6 case in 1993 and still the k>6 cases remain open.

A graph G is perfect if for G and all its induced subgraphs, the maximum clique size is equal to its chromatic number. In 2002 Maria Chudnovsky, Robertson, Seymour and Thomas showed that a graph G is not perfect if and only if either G or the complement of G has an induced odd cycle of length greater than 3.

Robin Thomas was already confined to a wheelchair when I arrived at Georgia Tech in 2012. He was incredibly inspiring as he continued to teach and lead the Algorithms, Combinatorics and Optimization PhD program until quite recently. Our department did the ALS challenge for him. In 2016 he received the Class of 1934 Distinguished Professor Award, the highest honor for a professor at Georgia Tech. He'll be terribly missed.

EXTERNAL NEWS

ARTICLE ON DIVERSITY AND INCLUSION PICKED UP BY AMS NOTICES

NOVEMBER 18, 2019 | ATLANTA, GA

An article, co-authored by SoM NSF Postdoc Marissa Loving, about increasing diversity and inclusion in math culture was picked up by AMS Notices. Read the full article, "Broadening the Horizons of Teaching and Diversity in Mathematics Departments", below.

Marissa Loving was also the subject of the award winning essay of Lu Paris, the The Grand Prize Winner of the 2020 AWM Student Essay Contest.

AMERICAN MATHEMATICAL SOCIETY

https://www.ams.org/journals/notices/201911/rnoti-p1831.pdf

CHRISTINE HEITSCH AWARDED UIUC DEPARTMENT OF MATHEMATICS ALUMNI AWARDS

APRIL 10, 2019 | ATLANTA, GA

Christine Heitsch (second from the left).

The UIUC Alumni Achievement Award is given to alumni who by outstanding achievement have demonstrated the value derived from a mathematics education. Nominees may qualify for outstanding professional achievement; cumulative performance through the years; or recent acknowledgement by community or professional peers.

Christine Heitsch BS Mathematics
- with Highest Distinction and Magna Cum Laude 1994

Christine Heitsch is a Professor in the School of Mathematics at Georgia Institute of Technology and is Director of the Southeast Center for Mathematics and Biology (SCMB), an NSF-Simons Research Center for Mathematics of Complex Biological Systems. She received her PhD from University of California Berkeley in 2000. During her trail-blazing career she has leveraged mathematics, especially combinatorics, to understand the role and function of RNA in biological systems.

Southeast Center for Mathematics and Biology

ALUMNI CONTRIBUTION

FELIX HAUSDORFF'S POEM "DEN UNGEFLÜGELTEN"

BEN ELKINS, BSAM'88 MSAM'92

There is really nothing better than when I get a letter from someone who enjoys the ProofReader, but it is hard to beat when the reader is so appreciative that they decide to contribute something to the next edition! My heartfelt thanks goes out to Ben Elkins *(BSAM '88, MSAM'92)* for his translation of Hausdorff's first poem.

Correspondence recieved January 9th, 2020:

If you are reading this entry, you are well aware of the role Felix Hausdorff holds within the hallowed halls of Mathematics. Known for so much and so much named after him, Hausdorff holds a singularly distinct role in the development of Point-Set Topology and Descriptive Set Theory to name a few areas that owe their discovery to him.

But Hausdorff was also a writer and poet, philosopher and welcomed participant in scholarly non-mathematical circles as well. Toward the end of the 19th and very beginning of the 20th century, Hausdorff in fact published several non-mathematical works under the pseudo-name, Paul Mongre.

While writing my thesis under Prof. George Cain ZT"L in 1992, he gifted to me a passionate curiosity for Hausdorff's "other" works and I've spent much of the last nearly 3 decades tracking down and reading this unique body of literature. Hausdorff's philosophy is heavily influenced by Kant and Nietzsche; however, his poetry is all together different. It is enchanting, fantastical and at times concupiscent.

Although I research, publish and present on Hausdorff's philosophy, (most recently at the AMS Regional meeting held at The University of Wisconsin, Madison, WI.) I seem to return to his more fanciful works as they provide me the human side of Hausdorff. A glimpse into this polymath, Renaissance man whose seminal contributions to mathematics, I believe, have fully yet to be realized.

Here I present to you the English translation of Hausdorff's 1st poem without commentary that appears in his Ekstasen (Volume of poetry. Verlag H. Seemann Nachf., Leipzig 1900)

Ben Elkins
benjaminjosephelkins@gmail.com

ProofReader

To The Wingless Ones

I am riding my happiness.
Therefore it cannot fly away from me!
All happiness wants to fly.
Wants to glide with butterfly wings flaming like gold above clouds of flower scent.
Those that sing and speak and dance their happiness.
I do not envy them.
Not their earth-bound happiness
That walks the Earth, forcibly tamed and bridled.
Harnessed with rattling chains.
With words that stomp around like horses.
You cannot fly.
That is why you tied up happiness
So that it shall not fly away from you.
I am riding my happiness
I myself am flight and storm of my happiness
Who lashes the clouds of trembling flower's scent
With wings flaming like gold.

Den Ungeflügelten

lch fliege mein Glück,
Drum entfliegt es mir nicht!
Alles Glück will stiegen,
Mit goldbrennenden Falterflügeln
Über Blumenduftgewölk gleiten.
Die ihr Glück singen und sagen und tanzen,
Ich neide sie nicht,
Nicht ihr eingebundenes Glück,
Das mit zähem Zwange gezähmt und gezäumt, In klirrende Maße und Ketten geschirrt
Die Erde beschreite,
Mit roßgleich stampfenden Worten.
Ihr könnt nicht fliegen,
Drum bandet ihr das Glück,
Daß eurer Haft es nicht entfliege.
Ich fliege mein Glück,
Bin selbst meines Glückes Flug und Sturm,
Der zitternder Blumen Duftgewölk
Mit goldbrennenden Flügeln peitscht!

DONATE TO SoM

Stay in Touch!

We look forward to future opportunities to stay in touch with you. We're very grateful for help in all forms, large and small, from our friends. Here are some ways you can stay involved with the School of Math, along with our Friends of the School of Math and our Alumni:

Give to the School of Math:

Your gift can have a large impact on the education and research efforts of the School of Mathematics. Below are some of the many ways this can happen.

Support the Bright Future of Mathematics

Undergraduate Scholarships: Everyone knows that college affordability is a serious issue for many families. Funds for undergraduate scholarships help support deserving students as they work toward a Math degree, a very valuable degree whose worth increases every day.

Graduate and Postdoctoral Fellowships

Our graduate students and postdoctoral researchers are the future of the discipline, integral to all of the efforts of the School—from teaching to research to outreach. Supporting them with fellowships, thesis/research prizes, travel-and professional-expense funds or other types of support has a large impact on their professional development, the School, and the discipline. The School's increased quality and quantity in postdoc and graduate recruitment illustrates how a named fellowship attracts and promotes top talent.

Connect with High Schools

The High School Mathematics Competition is an inspiring event where students gather with others interested in mathematics and compete for scholarships. It is run entirely by undergraduate and graduate student volunteers, with scholarships to bring these talented high school students to Georgia Tech. Contributions toward prize money or operating expenses ensures and expands the on-going inspiration and impact of this event (for registration and other details see http://hsmc.gatech.edu). The School also runs a large distance learning program for High School students, with potential for many areas of growth.

Recognize Teaching, Research, and Leadership in Mathematics

A central part of the mission of the School of Mathematics is teaching, with very talented and dedicated teaching faculty, as well as an extensive training program in teaching for our graduates and postdocs. Recognizing the best of them through awards for excellent teaching and mentoring underlines the importance of these efforts and encourages increased excellence. A named award would be a great way to remember an alumnus, former faculty member, or previous instructor who had a big impact on your life. Likewise, School members are leading research efforts, events, and training at Georgia Tech and around the world, so you may want to recognize their impact.

Create an Endowed Chair

Through an endowed professorship, a donor creates an enduring tribute that realizes their vision of mathematical excellence, provides exceptional opportunities for students and researchers at all levels, and promotes connections locally and globally.

Share your story

We ask all alumni, past visitors, and friends of the School to please update your contact information along with your news, with an email to comm@math.gatech.edu. More info on our webpage. We hope to hear from you soon!

Visit us!

Or even better, deliver your story in person by visiting the School. We especially welcome opportunities for visits from alumni to stop by and connect with our students and School members.

CREATING THE NEXT®

www.math.gatech.edu

School of Mathematics
Georgia Institute of Technology
686 Cherry Street
Atlanta, GA 30332-0160 USA

email: comm@math.gatech.edu