THE RIGHT ANGLE

McMicken College of Arts & Sciences

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Dear Alumni and Friends,

Time flies; one year has quickly passed. The last school year was another special period of challenges and achievements for the Math Department. With multiple retirements in recent years, the department was given one position to fill last year. Dr. Alex Konomi joined the statistics group this fall.

Our faculty and staff made remarkable achievements in multiple sectors. In terms of the Academic Analytics Index, a widely cited measure that UC uses to assess the research stature of its departments, the Math Department showed a surprising leap from 113th to 65th among 170 or so doctorate granting math departments nationwide. In our three strength areas, Probability and Statistics, Analysis and PDE, and Applied Mathematics, faculty were extremely active in publication, seeking external funding, giving external presentations, organizing conferences, serving as journal editors, and conducting research collaboratively with worldwide experts. The total amount of external funding of the department in 2013 was about $1 million, 5 times our past average. Eighteen faculty had external funding for their research, also a sharp increase from the past.

We graduated eight PhDs in 2013-14, well above the average of 5.5 for peer math departments in the American Mathematical Society. Our master's degree program is still in high demand by international students and contributed over $750,000 in tuition revenue this past year. The total number of graduating undergraduate math majors and minors has also grown sharply to over 100, more than triple the past level.

In another important change, the Math Learning Center was re-organized this summer as a part of the multi-purpose Learning Assistance Center. New Director Dr. Noel DeJarnette will teach part-time in the Math Department.

In short, the Math Department has made significant progress from multiple angles by the collective efforts of faculty and staff. It would be my great pleasure to host your visit to the Math Department in French Hall at any time.

Best wishes,

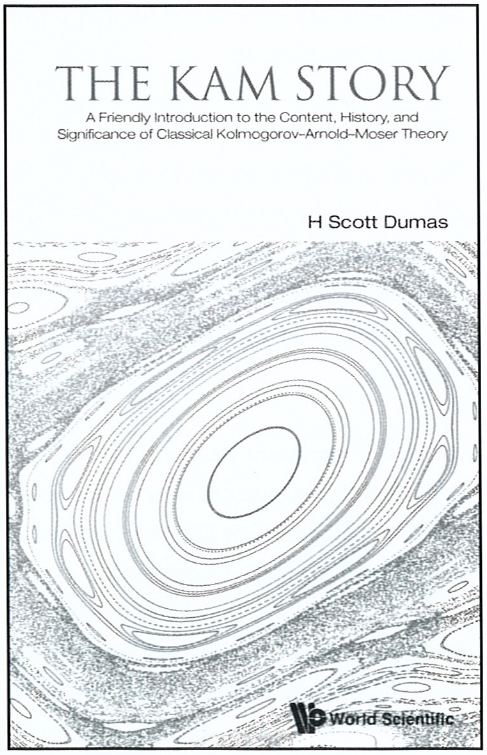
Shuang Zhang
Head & Professor

UNIVERSITY OF Cincinnati

KAM Theory

Faculty member Scott Dumas is the author of a new book on KAM (Kolmogorov-Arnold-Moser) Theory, a central part of the modern study of chaos theory. We asked Professor Dumas to provide some background on the topic of this recent publication.

The laws of classical mechanics were set forth in Isaac Newton's Principia and formed the basis for mathematical physics until they were superseded by quantum mechanics and relativity in the early twentieth century. Yet this overlooks a less well-known fact: the mathematical theory of classical mechanics itself went through a crisis that was not resolved until the second half of the twentieth century, well after the basic laws of modern physics were established.



To get an idea of the crisis, one must understand that Newton ran into problems right from the start when he tried to describe the motion of more than two bodies interacting by way of his universal law of gravitation. A two-body system, like the earth-moon, is stable. For more than two bodies this could not be shown, raising the specter that something as complicated as our solar system might disintegrate over time. More than a century later, these problems were revealed in more detail as mathematical astronomers used Joseph Fourier's new series to try to construct complete descriptions of planetary motions. Unfortunately, inside these Fourier series lurked "small divisors," denominators with factors that vanished on a dense set of values. Toward the end of the nineteenth century, Henri Poincaré proved that the small divisors prevented most of these "Hamiltonian systems" from being solved or "integrated" in the classical sense. Poincaré also showed that many trajectories of systems described by such series should behave "chaotically," and he further conjectured that these series could not be made to converge except in certain simple special cases. These results were tilting the balance toward an uncertain future for the solar system.

In the early- to mid-twentieth century, followers of Poincaré believed that most mechanical systems were not only nonintegrable and chaotic, but also "ergodic." An ergodic system evolves in such a way that its time-averages and space-averages are equal, which means almost every solution wanders repeatedly through every possible corner of phase space. If the n-body problem describing the solar system were truly ergodic, with probability one we'd be doomed. Yet scientists who worked with or accurately modeled such systems did not see the strongly chaotic/ergodic behavior predicted by theorists. This was the crisis in classical mechanics now several centuries in the making.

Meanwhile, in 1942, having escaped the Nazis and safely ensconced in the new Institute for Advanced Study in Princeton, Carl Ludwig Siegel took a first step in the anti-chaos direction by showing that certain series with small divisors could converge, provided that certain "Diophantine conditions" were satisfied.

The full resolution came at the 1954 International Congress of Mathematicians in Amsterdam, when the Russian mathematician Andrey Kolmogorov announced that he was able to combine Diophantine conditions with a rapid convergence procedure to show that the Fourier series of most Hamiltonian systems do in fact converge on a strange Cantor-like set of factors of the "small divisors." In the decade following, Kolmogorov's student Vladimir Arnold and Siegel's protégé Jürgen Moser fleshed out the theory by providing detailed proofs of Kolmogorov's claims; their names were soon combined to give Kolmogorov-Arnold-Moser theory (often abbreviated to KAM theory).

Thus the true picture of classical mechanics that eluded Newton, Poincaré and others was finally revealed: typical Hamiltonian systems are neither classically integrable nor totally chaotic. Instead they are a strange, fractal mixture of the two. For much more detail about this story and the mathematics behind it, see my new book: The KAM Story (A friendly introduction to the content, history, and significance of classical Kolmogorov-Arnold-Moser theory) by H. Scott Dumas. The book is available at UC libraries and is for sale on Amazon and elsewhere. Additional information can also be found on the publisher's website http://www.worldscientific.com/worldscibooks/10.1142/8955

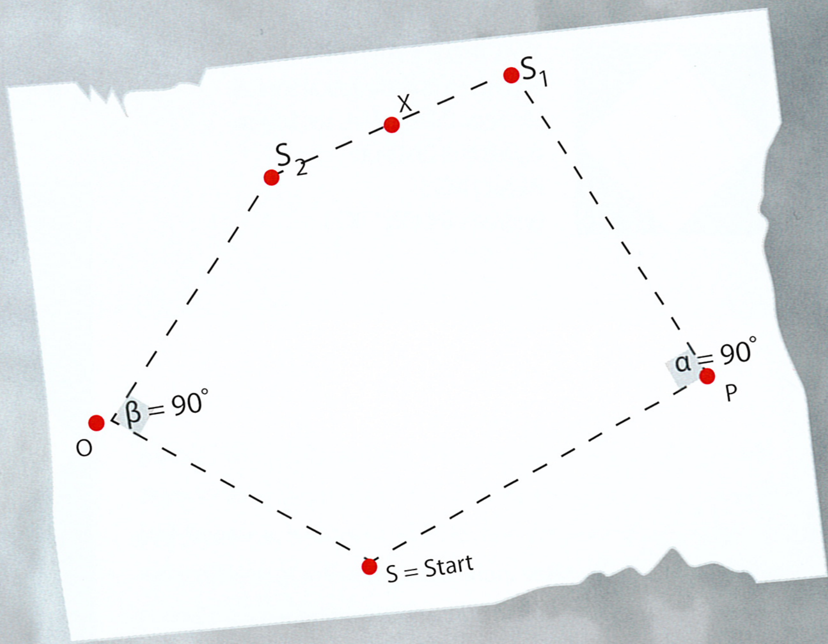
The Pirate Map

This is a map to secret treasure buried in a region dominated by two big trees — a pine tree P and an oak tree O. Here's how to use this map to find where the treasure is buried: start somewhere ----------- — a point S — and walk directly toward P. Turn left (toward O) 90 degrees and walk an equal distance again. Put a stake in the ground at this location S_1. Return to S and walk to O. Turn right (toward P) 90 degrees and walk the same distance again. Put a stake in the ground at this location S_2. The treasure is located at the midpoint of the segment from S_1 to S_2.

The puzzle is to explain why these rules always locate the treasure, no matter where the seeker starts (that is, independent of the starting point S).

You can play with this puzzle map using a GeoGebra (dynamic geometry) file at http://www.geogebratube.org/student/m150351. Just drag the starting point to confirm that no matter where you start, the secret instructions always lead you to the spot marked X.

Why does this work?



X marks the spot!

Math Teachers' Circle: #letsdomathtogether

The Cincinnati Math Teachers' Circle, a vibrant community of mathematics educators and mathematicians, uses this hashtag to communicate. The Circle began about four years ago when math teachers Linda Bollman and Steve Phelps, both graduates of UC Math's MAT program, and MAT program director Steve Pelikan were discussing the need for better professional development opportunities for the Tri-State's middle- and secondary-school math teachers. Bollman recommended the Teachers' Circle model and ran some pilot Circle sessions as part of her MAT project. The following autumn, Bollman, Phelps, and Pelikan began offering regular Math Circles for teachers.

Linda Bollman explains the need for the Circle this way: We get so busy as teachers we never have time to do and enjoy math the way we used to."

Teachers' Circles are designed to address this need. The Cincinnati Circle gets together one Saturday morning a month during the school year. Session organizers plan an inquiry activity that lets participants learn, apply, or think in a different way about mathematics related to what they teach. Participants work in teams to formulate and answer problems related to the topic. Once or twice during the Circle the whole group reassembles to share the discoveries they've made.

Educators and mathematicians agree that communicating the "mathematical practices" described in the new core content standards will be a challenge. The Math Circle helps teachers by letting them engage in mathematical practices and then reflect on how these practices can be incorporated in their classrooms.

The Cincinnati Math Teachers' Circle has served more than 50 participants, funded by two small grants from the American Institute of Mathematics and Math for America. You can learn more about Cincy Math Teacher's Circle from the wiki http://cincymathcircle.wikispaces.com . See above for a recent Math Circle puzzle that you might enjoy. Math Circle participants found many different solutions. Can you?

Transformation: MASS = The New Math & Science Support Center

The Math Learning Center (MLC) was established in 2005 when funding from the State of Ohio enabled the department to remodel space on the 6th floor of Old Chemistry. The Center offered walk-in assistance for freshman and sophomore-level math and statistics courses.

This summer the Math Learning Center underwent a significant transformation. Now part of the University's Learning Assistance Center, the Center has been renamed the Math and Science Support Center (MASS). Its scope and mission are being expanded under the guidance of Dr. Noel DeJarnette. The MASS Center now offers drop-in support for science and quantitative research courses that require strong math skills, like physics and chemistry, in addition to introductory math and statistics courses.

The Center provides study tables for the supported classes, allowing students from the same classes to have a place to work collaboratively under the guidance of well-trained tutors. This model seeks to help students build relationships with their peers and develop a level of comfort talking about mathematics. In addition to the study tables, the MASS Center will also provide access to software that students use in their classrooms or that supplements instruction.

DeJarnette comes to UC from the University of Illinois in Urbana-Champaign. He completed his PhD in mathematics there in 2013, working in geometric function theory. Most recently he served as Associate Director of Public Engagement for the Illinois Geometry Lab (IGL). A highly rated instructor, DeJarnette took an interest in undergraduate research and education through his role in the Illinois Geometry Lab. As the Associate Director of Public Engagement he worked with IGL members and local teachers to create and deliver hands-on activities that allowed community members of all ages to explore mathematics. Noel will be teaching one class per term for the department. We welcome him and look forward to benefiting from his insights into teaching and learning.

Transitions

On May 31, the department bid farewell to **Patti Jeffries**, our graduate program coordinator for the past eight years. Patti took great care of our graduate students, and we will miss her. We wish her the best in her future endeavors.

The department welcomes **Ryan Therkelsen**, who joins the department this fall as an educator assistant professor. A former project NeXt fellow and award winning instructor, Ryan taught at Bellarmine University before coming to UC. He started participating in the Cincinnati Math Circle while at Bellarmine. We're glad he decided to shorten his commute!

Visit our website at www.artsci.uc.edu/math

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The HYPOTENEWS

Dr. Jacqueline Hughes-Oliver (BA 1986), Professor of Statistics at North Carolina State University (NCSU), is the 2014 recipient of the Blackwell-Tapia Prize. This national prize, named after David H. Blackwell and Richard A. Tapia, is awarded biannually "to recognize a mathematical scientist who has contributed and continues to contribute to research in his or her field of expertise, and has served as a role model for mathematical scientists and students from under-represented minority groups or contributed in other significant ways to addressing the problem of the under-representation of minorities in mathematics."

After graduating Phi Beta Kappa from UC, Jackie earned her PhD in statistics at NCSU in 1991. During her graduate studies she worked for a year at the National Institute of Environmental Health Sciences, and she spent a post-doctoral year at the University of Wisconsin at Madison before returning as a faculty member to NC State. She has made numerous contributions in the field of statistics both in methodological research and in applications including drug discovery, transportation modeling, cheminformatics, and genomics. Jackie served for five years on the Committee on Minorities in Statistics of the American Statistical Association, and has been the keynote speaker at many conferences that address diversity.

Her prize was awarded in November at the Eighth Blackwell-Tapia Conference, hosted by the Institute for Pure and Applied Mathematics at UCLA. Congratulations, Jackie!

Professor Steve Pelikan has been chosen to receive the 2014 Ohio Council of Teachers of Mathematics Kenneth Cummins Award for Exemplary Mathematics Teaching. This award is named after a faculty member at Kent State University who was well known in the mathematics community for his outstanding teaching and for conducting numerous summer and academic year institutes for high school mathematics teachers. When Steve was chosen for this honor, he was cited for his long-time support, encouragement, and education of math teachers in the Southwest Ohio region through the MAT program, and through his work in creating, supporting and promoting the Cincinnati Math Teacher's Circle. (See separate article.)

Alex Konomi Joins the Department

The department welcomes statistician **Alex Konomi**, who comes to the department from a post-doc position at the Pacific Northwest National Laboratory, one of the U.S. Department of Energy's research labs, where he worked in the Computational Mathematics Division. Professor Konomi earned his PhD in statistics at Texas A&M University in December, 2011.

Professor Konomi's primary research has dealt with developing computational methods to implement Bayesian approaches to inference for "big data." His work involves nonparametric multivariate regression, model selection, statistical shape analysis in images, and optimization algorithms. Interdisciplinary application areas have included research in mechanical engineering, applied mathematics, climatology, ecology, and material science.

Although the word "big" in the term "big data" emphasizes the enormous quantity of data, in fact these large data sets usually have a highly complex structure. Researchers typically have to segment or partition the data in order to explore it, create models, and draw inferences. Similarly, when computer experiments are used to simulate the outputs of complex systems at different input values, it's prohibitively expensive to explore the whole input parameter space. "Calibration" is the process of finding a possible set of model parameter values that best reproduces the reality of experimental data. Another approach is to create a statistical "surrogate" model (or "emulator") using a smooth Gaussian process. The state of the art now uses extensions of so-called "Bayesian treed Gaussian processes" that combine Gaussian processes with a type of hierarchical partitioning strategy named for its tree-like structure.

Konomi is actively involved in developing and implementing solutions in this area. Using Bayesian methods, he has proposed and implemented modeling approaches to construct a new type of emulator to model computer experiments with distinct outputs that evolve in space and time, and he has extended Bayesian calibration into non-stationary models. His work in image analysis involves object segmentation and shape classification of gold nanoparticles. One of the merits of this development is the ability to analyze shapes in images with overlapping objects, having different morphological properties, with an unknown number of objects present. Much of his research has been computer-intensive and relies on Markov chain Monte Carlo (MCMC) algorithms for inference. In addition, he is working on full-scale approximation techniques to increase computational speed in computer code outputs.