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Randomized Linear Algebra in Scientific Computing

By Arvind K. Saibaba

People often think of randomness as a nuisance — something that we must contend with, rather than fully embrace. But what if randomization could be a useful tool instead of a hinderance?

Randomized numerical linear algebra (RandNLA) is an interdisciplinary area that spans mathematics, computer science, and statistics. This exciting field uses randomization, or *sketching*, to reduce the computational cost of core numerical linear algebra tasks such as matrix multiplication, the solution of linear systems and least squares problems, and low-rank compression. Since matrices are ubiquitous in data science and scientific computing, advances in RandNLA can reverberate across science and engineering. During the 2025 SIAM Conference on Computational Science and Engineering[1] (CSE25), which took place in Fort Worth, Texas, this past March, Daniel Kressner of École Polytechnique Fédérale de Lausanne delivered an invited presentation[2] about his recent work to advance RandNLA.

[1] https://www.siam.org/conferences-events/past-event-archive/cse25

[2] https://meetings.siam.org/sess/dsp_programsess.cfm?SESSIONCODE=82498

Origins and Current State of the Field

Kressner opened his CSE25 talk by tracing the origins of randomization in numerical linear algebra. It has long been common practice to use a vector with random numbers to initialize the power method and find an eigenpair. In this sense, the numerical linear algebra community has *always* utilized randomization, even if we did not explicitly analyze the impact of randomness. Over the last few decades, RandNLA has found new life in theoretical computer science and data science; it is now slowly starting to make its way into "mainstream" numerical analysis and scientific computing.

Kressner's lecture highlighted randomization's ability to accelerate computations in computational science and engineering settings. The newfound involvement of the numerical analysis community has shifted the focus away from reduced computational complexity and towards practical algorithms, numerical stability, and implementations on high-performance computing platforms. Present-day researchers are also applying RandNLA to different types of problems. For instance, data science applications require solvers for least squares and low-rank approximations, while scientific computing additionally necessitates solvers for large linear systems and the construction of surrogate models.

An impactful review article [2] introduced me to RandNLA as a Ph.D. student in 2012, and I found myself drawn to the field in subsequent years. From an algorithmic perspective, randomization is typically simple, elegant, and easy to implement; this simplicity allows users to reorganize other calculations to achieve parallelism or reutilize intermediate computations for overall computational speedup. From an analysis perspective, randomization is exciting because it involves tools from high-dimensional probability and non-asymptotic random matrix theory.

Sketching

Kressner provided a brief exposition on sketching in the context of randomization. Wikipedia defines[3] a sketch as a "rapidly

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[3] https://en.wikipedia.org/wiki/Sketch_(drawing)

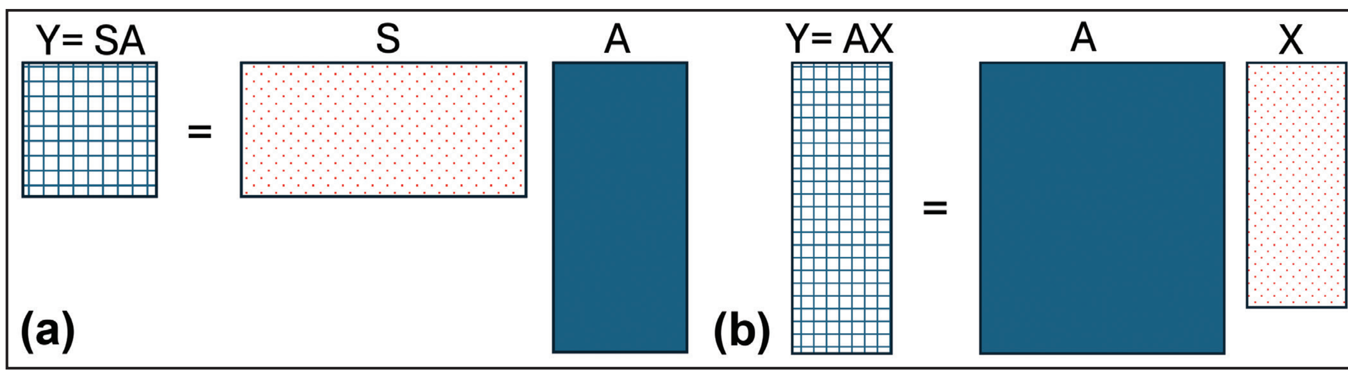

Figure 1. *Illustration of the two flavors of sketching a matrix A.* **1a.** *Sketching from the left.* **1b.** *Sketching from the right. Figure courtesy of the author.*

A Particle-continuum Framework for Sea Ice Floe Dynamics

By Quanling Deng, Samuel N. Stechmann, and Nan Chen

Sea ice plays a key role in the Arctic and global climate systems by modulating critical momentum, heat, and material transfer processes between the ocean and atmosphere. Yet despite its importance, sea ice modeling poses a formidable challenge. The phenomenon itself spans vast scales; massive ice sheets that stretch for hundreds of kilometers coexist with smaller, fragmented ice floes that drift, collide, and fracture in the marginal ice zone (MIZ), where ice meets open water. Figure 1 depicts sea ice in the Beaufort Sea off the coast of Alaska and Canada, including ice floes in the MIZ.

Traditional models treat sea ice as a continuum material or plastic, e.g., a giant deformable sheet [5]. These models work well for large-scale simulations but struggle to capture the granular, chaotic motion of individual floes. In contrast, discrete element methods (DEMs) simulate each floe as an independent particle and track collisions and rotations in detail. However, the computational cost of DEMs scales prohibitively with the number of floes — rendering large-domain or long-term simulations impractical.

To address these challenges, we recently introduced a novel multiscale modeling framework that integrates the high-resolution accuracy of DEMs for small-scale floe interactions with the computational efficiency of continuum-scale models [4]. By uniquely bridging these scales, our approach—which published in *Multiscale Modeling and Simulation*,[1] an interdisciplinary SIAM journal—effectively simulates sea ice dynamics. Its broad applications range from accelerating multiscale data assimilation to improving climate predictions.

The Particle-continuum Multiscale Model

Our innovative framework adapts superparameterization—a powerful multiscale technique that was originally developed for atmospheric modeling—to sea ice dynamics for the first time. In atmospheric applications, superparameterization embeds high-resolution cloud-resolving models within each grid cell of a global climate model. Here, we extend this idea by instead nesting DEM simulations of individual ice floes within a continuum-scale sea ice model.

This particle-continuum implementation creates a unique two-way dialogue across scales (see Figure 2, on page 3). The large-scale continuum fields provide background information and constrain the motion of each DEM component, while the fine-scale interactions between floes collectively inform the evolution of bulk ice properties. By connecting these traditionally separate modeling paradigms, we can achieve high fidelity and efficiency in the representation of sea ice's inherently multiscale behavior. We also pursue systematic studies on the convergence behavior of this type of superparameterization technique, which provides a mathematical foundation for the modeling and computational framework.

[1] https://www.siam.org/publications/siam-journals/multiscale-modeling-and-simulation-a-siam-interdisciplinary-journal

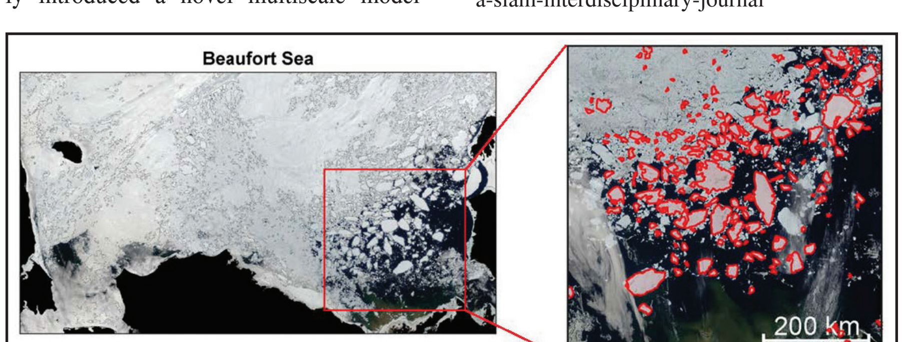

Figure 1. *A true-color image of sea ice in the Beaufort Sea from the Moderate Resolution Imaging Spectroradiometer. The image is oriented 90 degrees from standard polar stereographic coordinates so that the top is roughly north. The red box outlines the observed marginal ice zone (MIZ), and the inset on the right provides a close-up view of the MIZ on June 26, 2008; individual sea ice floes are outlined in red. Figure adapted from [1].*

The Particle Approach: DEM Simulations

DEM models simulate each floe as an independent entity. As the numerous floes interact with each other, the motion of the lth floe is governed by Newton's laws:

$$\frac{\mathrm{d}\mathbf{x}^l}{\mathrm{d}t} = \mathbf{v}^l,$$

$$m^l \frac{\mathrm{d}\mathbf{v}^l}{\mathrm{d}t} = \sum_j (\mathbf{f}_n^{lj} + \mathbf{f}_t^{lj}) + \text{ocean drag}.$$

Here, $\mathbf{x}^l$ is the displacement, $\mathbf{v}^l$ is the velocity, and $\mathbf{f}_n^{lj}$ and $\mathbf{f}_t^{lj}$ are normal and tangential contact forces between floes. We can also write a similar set of equations for the angular position and velocity. While DEM does ultimately capture collisions and rotations, the simulation of millions of floes across an ocean basin is computationally prohibitive.

Moment Equations: From DEMs to Continuum Models

To transition from DEMs to continuum models, we employ a Boltzmann equation that governs the probability distribution of floe states. Integrating this equation over the velocity/size space yields moment equations for mass, momentum, and angular momentum that constitute the

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Texas State University SIAM Student Chapter Sparks Mathematical Joy at Julia Robinson Math Festival

By Eirian Whitson and Iván Ojeda-Ruiz

Participants of the Julia Robinson Math Festival, which took place at the San Marcos Public Library in April, work on the "Star Battle" puzzle. Photo courtesy of Ash Demian.

The Texas State University SIAM Student Chapter[1] orchestrated a successful and engaging Julia Robinson Math Festival[2] on Saturday, April 19, at the San Marcos Public Library.[3] The four-hour event brought the joy and practicality of mathematics to the people of San Marcos, Texas, and fostered a lively atmosphere of mathematical exploration for attendees of all ages.

This collaborative initiative was spearheaded by the Texas State University SIAM Student Chapter under the guidance of advisor Iván Ojeda-Ruiz. The chapter partnered with Texas State's Department of Mathematics and the San Marcos Public Library to cultivate a meaningful connection between the university and the local community. The festival—made possible by the Julia Robinson Mathematics Festival nonprofit,[4] which seeks to empower math appreciation outside of the classroom—effectively showcased mathematics' real-life applicability through a variety of interactive games, challenges, and puzzles.

The San Marcos Public Library buzzed with energy as participants explored a wide array of activities.[5] Favorites like "Skyscrapers" and "Cup Stacking" offered hands-on fun, while "Four Color Challenge" and "Sprigs" (hosted by the Texas State University Math Club[6]) encouraged creative problem solving. The SIAM student chapter had its own table that featured the "Magic Flowers" puzzle and a "Map Coloring" challenge. Bobcat Racing,[7] a Texas State student engineering team, added to the excitement with a racecar simulator.

Dedicated student and faculty volunteers from Texas State played a crucial role in the festival's success, providing guidance and ensuring a safe and stimulating environment for everyone. The leadership team comprised director Eirian Whitson—who oversaw the event and led the other volunteers—and assistant directors Kristan Beluso and Ashok Paudel, who managed attendee check-in. Beluso, Paudel, and Nishant Shrestha also handled registration, while Adriana Martinez and Ari Rider supervised the refreshments. The various games were facilitated by Ishmum Tihami ("Skyscrapers"), Shreejal Bhattarai and Burcu Cinarci ("Cup Stacking"), Cameron Poole and Angel Verde-Salas ("Gerrymandering"), Haley King ("Toothpick Triangles"), Piyush Shroff ("Maze Mat"), Mohammad Zarrin ("Dice Bingo"), Nathan Miller ("Star Battle"), and Ellen Couvillion and Weam Al-Tameemi ("Connect the Dots"). Representatives from the Pi Mu Epsilon[8] mathematics honor society and the Math Club—including Nav Sharma, Sumit Sah, and Austin Penrose—were also present.

The Julia Robinson Math Festival welcomed both preregistered attendees and walk-ins to guarantee broad community access, and the library's convenient location and ample parking made participation easy for local families. Ultimately, the event's success highlights the Texas State University SIAM Student Chapter's dedication to the promotion of mathematical engagement and appreciation throughout society. It exemplified the cooperative spirit of the Texas State mathematics community by inspiring a lifelong love of mathematics through interactive discovery.

Officers of the Texas State University SIAM Student Chapter gather for a group photo during the Julia Robinson Math Festival, which was held at the San Marcos Public Library this past April. From left to right: Piyush Shroff (advisor), Luisa Montiel (treasurer), Ashok Paudel (liaison), Eirian Whitson (president), Adrian Walker (incoming liaison), Kristan Beluso (vice president and incoming president), Ari Rider (incoming vice president), and Iván Ojeda-Ruiz (advisor). Photo courtesy of Ash Demian.

Eirian Whitson graduated from Texas State University with a degree in applied mathematics and will begin a Ph.D. program in mathematics at the University of Texas at Arlington in fall 2025. They were a founding member of the Texas State University SIAM Student Chapter, having served as inaugural vice president and later as president. Iván Ojeda-Ruiz is an associate professor of instruction at Texas State University who will begin a position as assistant professor of mathematics at Lamar University in fall 2025. He is a current advisor of the Texas State University SIAM Student Chapter.

[1] https://pmetexasrho.wp.txstate.edu/siam
[2] https://www.cose.txst.edu/cose-news/news-2025/julia-robinson-math-fest.html
[3] https://www.sanmarcostx.gov/3879/Library
[4] https://jrmf.org
[5] https://jrmf.org/puzzle
[6] https://pmetexasrho.wp.txstate.edu/math-club
[7] https://www.engineering.txst.edu/current-students/organizations/fsae.html
[8] https://pmetexasrho.wp.txstate.edu/math-honors-clubs-and-societies/pi-mu-epsilon

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Obituary: Peter David Lax

By Mac Hyman and Dave Levermore

Peter David Lax, a pioneering figure whose groundbreaking work profoundly shaped computational science and applied mathematics, passed away on May 16, 2025, at the age of 99. His death marks the end of an extraordinary career that established foundational principles in the mathematics of fluid dynamics, shock waves, scattering theory, integrable systems, and numerical methods for the solution of partial differential equations.

Biography

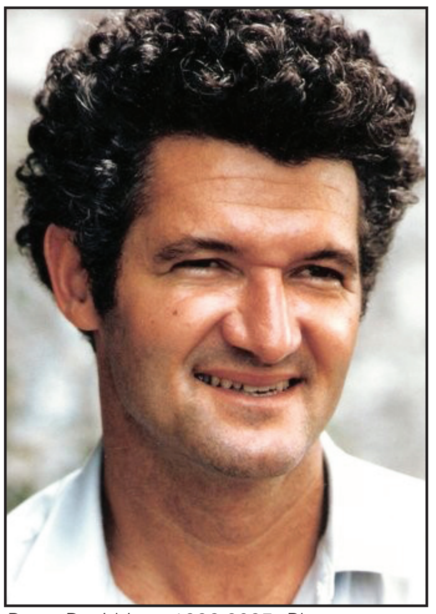
Born in Budapest, Hungary, on May 1, 1926, Peter showed mathematical promise from a young age. His family fled Nazi persecution and took the last boat from Lisbon to New York in November 1941, arriving just days after the attack on Pearl Harbor. This timing placed a teenage Peter in the U.S. during a transformative period for applied math. His talent quickly caught the attention of influential mathematicians — including John von Neumann, who became a major influence on Peter's career.

At 18 years old, Peter was drafted into the U.S. Army and assigned to the Manhattan Project at Los Alamos National Laboratory. This early introduction to interdisciplinary collaboration thoroughly shaped his mathematical perspective. *"It was the experience of being part of a scientific team—not just of mathematicians, but people with different outlooks—with the aim being not a theorem but a product,"* Peter later said. *"One cannot learn that from books; one must be a participant."*

The Los Alamos environment was intellectually electric. Peter even played tennis with Enrico Fermi, recalling with characteristic humor that *"I won six to four. He pointed out that the difference, two, was the square root of four, and therefore it was a random deviation."* Such anecdotes illustrate the blend of serious science and intellectual camaraderie that influenced Peter's approach to mathematics.

During this period, Peter's intellectual force was shaped by his close proximity to mathematical giants. *"People today have a hard time to imagine how brilliant von Neumann was,"* Peter once said. *"If you talked to him, after three words, he took over. He understood in an instant what the problem was and had ideas."* This exposure to mathematical prowess at a young age defined Peter's own approach to problem solving and collaboration.

After the war, Peter finished his education. He earned his bachelor's degree at New York University (NYU) in 1947 and completed his Ph.D. just two years later under the direction of Kurt Friedrichs. He remained at NYU's Courant Institute of Mathematical Sciences for his entire career and served as director from 1972 to 1980. Peter also maintained a connection with Los Alamos despite the distance, returning regularly as a consultant and summer researcher.



Peter David Lax, 1926-2025. Photo courtesy of New York University.

Research Contributions

As a whole, Peter's research significantly advanced our scientific understanding and computational capabilities in several critical areas of applied mathematics. In the 1950s, his work centered on hyperbolic systems of conservation laws and the mathematical theory of shock waves. The "Lax entropy condition" provided a crucial mathematical framework for the selection of physically relevant solutions to nonlinear conservation laws, resolving longstanding questions about uniqueness. This work guided Peter's formulation of the "Lax-Wendroff method" in 1960, which revolutionized the numerical computation of shock waves and became a foundational technique in computational fluid dynamics. His research with James Glimm in the 1960s further advanced the field. Peter's exceptionally well-written paper, "The Formation and Decay of Shock Waves," was published in *The American Mathematical Monthly* in 1972 and earned him the Chauvenet Prize in 1974; it continues to introduce scientists to the underlying mathematical theory in aerodynamics, weather prediction, and additional disciplines that involve fluid flow.

Peter's other contributions to numerical analysis were equally transformative. In 1954, the "Lax-Milgram lemma" offered a simple way to show both the well-posedness of certain linear problems and the stability of linear numerical methods for those problems. The "Lax equivalence theorem" in 1956 subsequently demonstrated the equivalence of convergence and stability for linear finite difference methods that are consistent with a well-posed linear differential equation. These techniques became cornerstones of modern numerical analysis.

Peter's famous 1957 study of the propagation of singularities for linear wave equations sparked the development of Fourier integral operators, a tool that proved both theoretically and practically useful. They comprised the setting for Lars Hörmander's characterization of singularity propagation in the 1960s; Bjorn Engquist and Andrew Majda also used them in 1977 to develop reflectionless boundary conditions for the numerical solution of wave equations over artificial domains.

The 1960s marked the start of Peter's decades-long collaboration with Ralph Phillips on scattering theory. Their work resulted in two books and has been applied to electromagnetic and acoustic waves, quantum mechanics, transport equations, and number theory. In the late 1960s, Peter introduced a mathematical formulation—soon to be known as "Lax pairs"—that provided a unifying framework for the emerging subject of integrable partial differential equations. When his colleague Dave McLaughlin once asked how he discovered this linear structure so quickly after learning about the complete integrability of the Korteweg-de Vries equation, Peter commented that *"For many years before, I had in my desk drawer calculations of relationships between unitary flows of commuting linear operators, abstractions waiting for an application."* This story is just one example of Peter's remarkable mathematical intuition and penchant for developing theoretical tools before their applications became clear.

Peter also clarified the relation between the Hamiltonian structure of these equations and the rich families of special solutions that they possess — i.e., solitons (special traveling wave solutions that maintain their shape), multi-soliton solutions, cnoidal waves, and hyperelliptic waves. These elegant approaches advanced pure math and influenced fields from fiber optics to quantum physics.

In the late 1970s, Peter initiated an investigation into the global characterization of the zero-dispersion limit of the Korteweg-de Vries equation — a study that inspired many works on similar limits for other integrable and near-integrable equations.

Peter's exceptional contributions were recognized with numerous prestigious awards, including the AMS-SIAM Norbert Wiener Prize in Applied Mathematics[1] in 1975, the National Medal of Science in 1986, the Wolf Prize in Mathematics in 1987, and the Abel Prize in 2005. He was the first applied mathematician to receive the Abel Prize, an honor that reflected his unique ability to bridge pure mathematical theory with practical applications.

Mentorship and Education

Throughout his career, Peter served as an exceptional mentor. He advised at least 55 doctoral students and currently has more than 850 academic descendants.[2] Peter's

See **Peter David Lax** *on page 5*

[1] https://www.siam.org/programs-initiatives/prizes-awards/joint-prizes/ams-siam-norbert-wiener-prize

[2] https://www.mathgenealogy.org/id.php?id=13415

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continuum model; a possible extension also includes energy [3]. Statistical averages of the DEM solutions determine the stress tensor and forcing terms in these equations, creating a mathematically consistent multiscale framework with particle interactions that collectively inform continuum-scale dynamics while respecting conservation laws. For example, the mass and momentum equations are given by

$$\frac{\partial\langle\rho\rangle}{\partial t}+\nabla\cdot(\langle\rho\mathbf{v}\rangle)=0,$$

$$\frac{\partial\langle\rho\mathbf{v}\rangle}{\partial t}+\nabla\cdot(\langle\rho\mathbf{v}\otimes\mathbf{v}\rangle)=\text{ocean drag}.$$

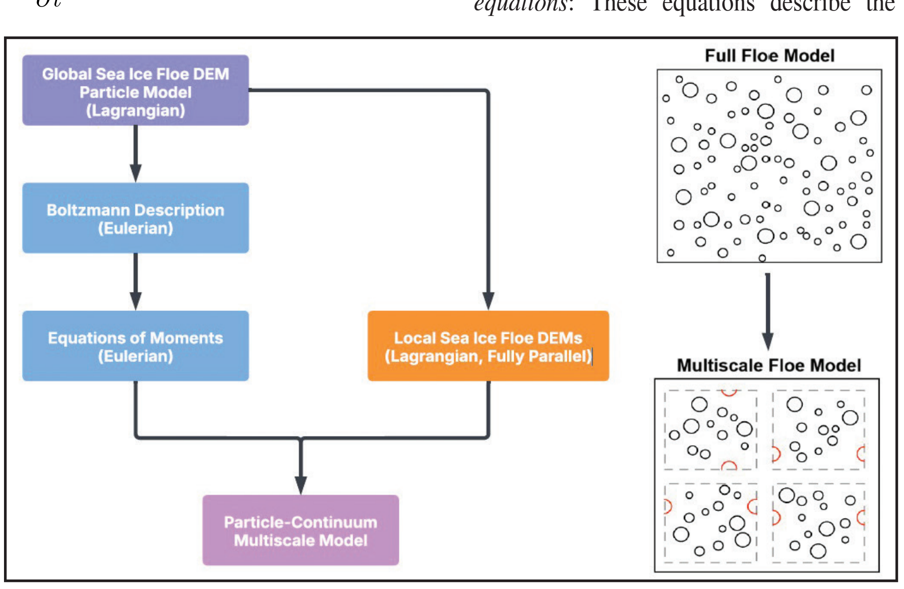

Figure 2. *A schematic of the particle-continuum multiscale model. The model architecture couples local discrete element method (DEM) simulations (fine scale) with continuum moment equations (coarse scale). Figure adapted from [4].*

The Hybrid Model

Our novel particle-continuum multiscale model addresses the fundamental tradeoff between continuum models that lack small-scale detail and DEM models that lack large-scale efficiency. It contains the following components:

- *Fine-scale local DEM simulations*: All grid cells in the continuum model run an independent DEM simulation with periodic boundary conditions. The model tracks floe properties (e.g., size, velocity, and rotation) within each grid cell and facilitates the use of parallel computing in every cell, which significantly improves computational efficiency.
- *Coarse-scale continuum moment equations*: These equations describe the evolution of averaged physical quantities of floes over time.
- *Two-way coupling*: The continuum model guides the motion of each DEM component, and DEM statistics feed back into the continuum model.

Broader Impacts

As Arctic sea ice becomes increasingly fragmented, our research provides an essential toolkit for the modeling and prediction of floe dynamics in MIZ regimes — a critical capability for climate adaptation, marine navigation, and policy decisions. The paradigm-shifting multiscale framework is similarly impactful beyond sea ice applications and constitutes a unique tool for the simulation of diverse natural systems where particle and continuum physics interact, from granular avalanches to planetary ice-ocean interfaces.

This work's mathematical foundations establish a rigorous pathway for multiscale modeling's application to realistic scenarios. For instance, it facilitates coupling between models and advanced DEM formulations that explicitly resolve floe shape evolution and fracture dynamics [6]. The framework has already inspired additional innovations, notably serving as the basis of a novel hybrid Eulerian-Lagrangian data assimilation algorithm for fragmented sea ice [2].

By bridging particle- and continuum-scale physics, our multiscale modeling framework can resolve high-resolution, large-scale simulations that were previously intractable. Ultimately, our study paves the way for next-generation Earth system models and beyond.

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Quanling Deng is a lecturer at the Australian National University. He is broadly interested in the fields of computational and applied mathematics. Samuel N. Stechmann is a professor at the University of Wisconsin-Madison. His research interests are in applied and computational mathematics. Nan Chen is an associate professor at the University of Wisconsin-Madison. His work covers general applied mathematics, atmospheric and ocean science, and data science.

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executed freehand drawing that is not usually intended as a finished work." Similarly, a sketch of a matrix is an approximation that preserves, to an extent, the matrix's essential features. While the term is visually evocative (I picture M.C. Escher's *Drawing Hands*,[4] a seemingly impossible sketch of two hands drawing each other), I do find it somewhat unfortunate, especially since it is the subject of several puns of algorithms that claim to be "sketchy."

We can sketch a matrix from the left or right (see Figure 1, on page 1). Suppose that we have an $m\times n$ matrix A. In low-rank approximations, sketching with an $n\times k$ random matrix X from the right yields a sketch $Y=AX$ that preserves the number of rows. If rank A is sufficiently low, then column space Y might be a good approximation to that of A. On the other hand, least squares solvers require that the sketch preserve the number of columns, so we sketch from the left: $Y=SA$, where S is an $r\times m$ random matrix. The choice of random matrix X or S is quite important, and ongoing research is actively seeking random matrices that balance the cost of sketching with the accuracy of the approximation. For concreteness, we can take the random matrix to a standard Gaussian matrix — i.e., a matrix with independent and identically distributed normal random variables that have zero mean and unit variance. This action typically yields the strongest theoretical guarantees. Several excellent surveys on sketching are available in the literature [2-5, 7].

Randomization for the Solution of Linear Systems

Kressner shared many success stories of randomization in surrogate model construction, linear system solutions, time integration, families of matrices, and subset selection. While each topic is fascinating in its own right, I will focus on his work with linear systems. This subject also prompted the largest number of audience questions at CSE25.

In scientific computing, we must often solve large linear systems $Au=b$, where the size of matrices A can be in the millions or billions. These problems arise in the context of numerical solutions to partial differential equations (PDEs). Kressner explored the solution of sequences of linear systems $A_i u_i = b_i$ for $i=1,\dots,n$, where the coefficient matrices A_i have dimension $d\times d$ and change only slightly from system to system. Such linear systems might arise from the discretization of time-dependent PDEs with variable time stepping. The development of direct and iterative solvers for large linear systems remains an important area of research. Several existing iterative solvers—such as the conjugate gradient method or the generalized minimal residual method (GMRES)—can generate sequences of iterates to approximate a linear system's solution.

When solving sequences of linear systems, we must consider the reuse of information from one linear system solution to another. Potential approaches include constructing an intelligent initial guess (sometimes called *warm starting*), extracting a solution basis from the previous iteration (i.e., recycling and augmented methods), or reusing/updating a preconditioner [6].

Kressner presented an approach [1] that somewhat used randomization to generate a good initial guess. The main idea is quite simple. Suppose that we solved $m-1$ linear systems and collected the solutions into a so-called *snapshot matrix* $U=[u_1 \ \dots \ u_{m-1}]$. In many cases, the snapshot matrix has rapidly decaying singular values and can be well approximated by a low-rank matrix — a key idea in reduced order modeling, e.g., proper orthogonal decomposition (POD). We can sketch the solution to the first m system as $Y=UX$, where X is a random matrix. To generate a new initial guess, we must then consider an approximation of the form Yz, where z is a solution to the linear least squares problem

$$\min_z \|A_m Y z - b_m\|_2$$

for the optimal solution z_m^*. Next, we can seed an iterative method like GMRES with the initial guess Yz_m^*. Computing $A_m Y$ and solving the least squares problem requires computational effort, though Kressner argued that doing so is often much cheaper than existing methods to accelerate linear solvers. He also maintained that orthogonalizing Y—as in POD or randomized singular value decomposition—is unnecessary.

[4] https://en.wikipedia.org/wiki/Drawing_Hands

To demonstrate, Kressner presented numerical results from an application in plasma physics. He considered the simulation of plasma turbulence in the outermost plasma region of a tokamak fusion reactor, where the plasma comes in contact with the surrounding external solid walls (see Figures 2 and 3). This application, which has multiscale physics in space and time, requires the solution of a sequence of linear systems that arise from discretized fluid equations coupled with Maxwell's equations for electromagnetics. The aforementioned method [1] led to a $3\times$ speedup in wall-clock time as compared to the baseline approach (see Figure 4). In other applications that involve elliptic PDEs, this technique can produce $10\times$ speedups in wall-clock time.

Kressner also discussed iterative methods for large linear systems that arise from kernel matrices in system identification. The linear system is $(I+K)u=b$, where K is a kernel matrix and I is the identity matrix. Kressner suggested augmenting b with a few (fictitious) random vectors as $B=[b,x]$, where X contains random vectors, and solving the block system $(I+K)U=B$. He contends that this approach is more beneficial—despite increasing the computational cost per iteration—because the addition to the right side implicitly preconditions the system, which intuitively leads to improved convergence.

The talk itself was well received by the CSE25 audience. If we measure a presentation's popularity by the number of photos that attendees take of slides, Kressner's fast-paced delivery meant that phone and tablet cameras were active throughout the session. Kressner—mindful of the Friday morning audience—kept the analysis to a minimum, included compelling graphics, and provided profound insight into randomization. He addressed a truly impressive number of RandNLA applications that spoke to his oeuvre.

Outlook

Kressner concluded with randomization's outlook in scientific computing, noting the myriad opportunities for researchers in RandNLA. From a theoretical perspective, randomization can benefit from new ideas in high-dimensional probability and random matrix theory. As the field matures, it will need robust software that can handle the current demands of data science and scientific computing. The impact of numerical linear algebra libraries—such as LAPACK[5]—on science and engineering cannot be overstated, and the development of a similar library for RandNLA is ongoing [5]. Another important direction involves the adaptation of existing algorithms to new applications and the creation of novel algorithms based on the challenges and needs of modern use cases. While it may be impossible (or in my case, undesirable) to completely eliminate randomness from our lives, in scientific computing we can at least embrace it gracefully.

[5] https://www.netlib.org/lapack

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[6] Soodhalter, K.M., de Sturler, E., & Kilmer, M.E. (2020). A survey of subspace recycling iterative methods. *GAMM-Mitteilungen, 43*(4), e202000016.

[7] Woodruff, D.P. (2014). Sketching as a tool for numerical linear algebra. *Found. Trends Theor. Comput. Sci., 10*(1-2), 1-157.

Arvind K. Saibaba is an associate professor of mathematics at North Carolina State University. He earned his Ph.D. from Stanford University's Institute of Computational and Mathematical Engineering in 2013.

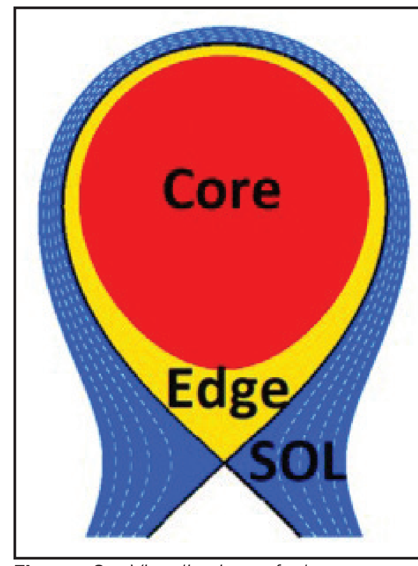


Figure 3. *Visualization of the scrape-off layer (SOL): the outermost plasma region in the tokamak between the last closed flux surface and the external solid wall. Figure courtesy of Maurizio Giacomin.*

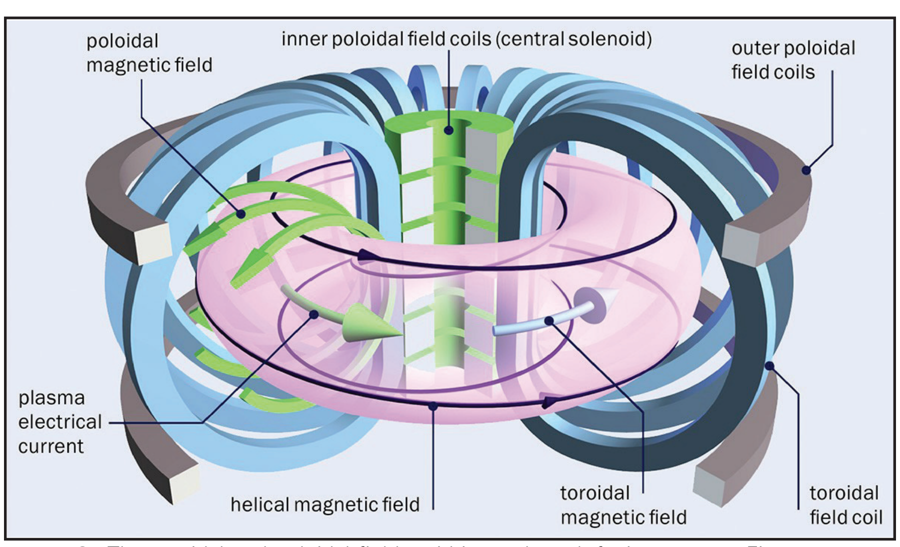


Figure 2. *The toroidal and poloidal fields within a tokamak fusion reactor. Figure courtesy of the UK Atomic Energy Authority.*

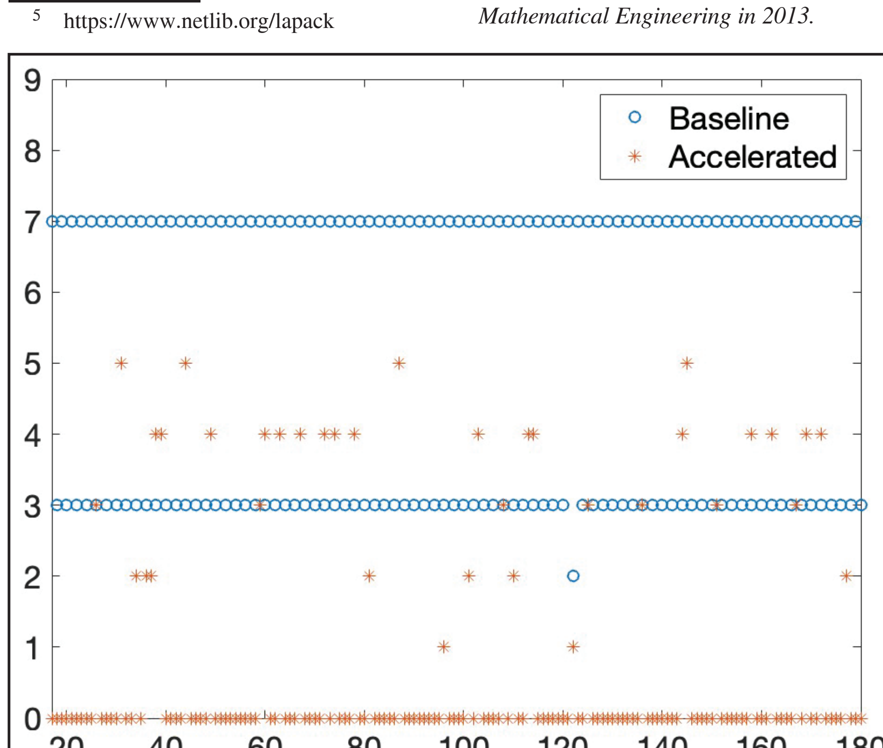


Figure 4. *Plot of the number of generalized minimal residual method iterations on a total of 180 linear systems, with respect to the baseline method. A 3x speedup was observed in wall-clock time. See [1] for additional details. Figure courtesy of Margherita Guido.*

Peter David Lax

Continued from page 3

approach to education emphasized the connections between theory and application, encouraging students to think broadly about the potential impact of mathematical ideas. Former student Michael Ghil recalls a defining moment during his thesis defense; when Ghil proudly announced a proof that confirmed three steady-state solutions to his climate model, Peter looked at him and asked, *"Why do you need a proof? Don't you believe it?"* Ghil had indeed shown him careful numerical solutions to that effect.

Peter had a cherished tradition for commemorating his students' achievements. The "true" Ph.D. diploma was "the bottle of champagne happily imbibed after the successful defense and bearing on its label the signatures of Peter and the other Ph.D. committee members," Ghil remembers fondly. This tradition reflected Peter's belief in celebrating both fine work and civilized life.

The impact of Peter's mentorship often extended far beyond formal academic relationships. Upon meeting Peter for the first time at a 1981 seminar in Stanford, Calif., Eitan Tadmor was stunned when Peter immediately invited him to stay in his New York apartment — an invitation that included Tadmor's three-year-old daughter. This anecdote was unsurprising to Peter's son, James. "My parents were like that," he said. "My friends refer to their apartment as Hotel Lax." This hospitality became legendary among the mathematical community.

Peter's personal warmth and generosity extended to chance encounters as well. Walter Strauss recalls bringing his 12-year-old son to lunch at NYU's Courant Institute, where Peter unhesitatingly offered half of his chocolate bar to the boy. These types of small gestures expressed his fundamental kindness and belief that mathematics should be part of the larger human community.

Peter's approach to problem solving—which combined rigorous mathematics with physical intuition and computational methods—epitomized an interdisciplinary spirit. His remarkable textbooks on linear algebra and functional analysis reflect this paradigm. His first calculus textbook, coauthored with Samuel Burstein and Anneli Lax (Peter's first wife and also an accomplished mathematician), published in 1976 and aimed to infuse mathematical education with computational perspectives. Peter once modestly described this book as *"enormously unsuccessful"* and later rethought his approach, producing two new calculus textbooks with Maria Shea Terrell. Beyond the realm of calculus, Peter's 1973 SIAM monograph, *Hyperbolic Systems of Conservation Laws and the Mathematical Theory of Shock Waves*,[3] became an influential text that educated generations of applied mathematicians.

Community Leadership

Peter was director of the Courant Institute from 1972 to 1980, vice president of the American Mathematical Society (AMS) from 1969 to 1971, and AMS President from 1977 to 1980. He served on the Mathematical Association of America's Board of Governors from 1966 to 1967 and the U.S. National Science Foundation's (NSF) National Science Board from 1980 to 1986.

As computers grew increasingly powerful, Peter embraced their potential and developed numerical schemes that later became standard approaches for the solution of complex physical problems. In the early 1980s, he led the influential "Lax Report," which identified critical gaps in supercomputing capabilities at U.S. universities and argued for increased computational resources for scientific research. This advocacy shaped national policies on scientific computing infrastructure, such as the creation of the NSF supercomputer centers.

Peter's dedication to his community extended well beyond academic pursuits. When demonstrators attempted to bomb the CDC 6600 computer center at Courant during student protests in 1970, Peter rushed into the building despite the danger. *"I could smell smoke,"* he later recalled. *"Two of my younger colleagues jumped in and stepped on it, while the rest of us went to the machine room and removed the flammable liquids that were hung on the machine."* When his wife Anneli asked if he was crazy for risking his life, Peter replied that *"I was so mad I didn't think."* His quick actions helped save the computer that was crucial to the institute's research.

Legacy and Remembrances

A longtime SIAM member,[4] Peter was a perfect embodiment of SIAM's mission. His work exemplified the power of mathematical analysis to solve real problems, and his advocacy for computational resources aligned with SIAM's commitment to advance computational science.

Colleagues remember Peter's unique style during mathematical discussions. "He was famous for napping while listening to a lecture," Strauss noted. "But at the end, he would nevertheless often come up with an incisive comment or question." This apparent contradiction sometimes epitomized Peter's deep understanding of a topic before the lecture began. At other times, it captured his mathematical intuition and remarkable ability to absorb ideas even while somewhat distracted.

During his nearly century-long life, Peter witnessed the transformation of applied mathematics from a relatively narrow field to a wide discipline that touches virtually every aspect of modern science and technology. His contributions played a crucial role in this evolution, demonstrating how mathematical analysis illuminates complex physical phenomena and how computational approaches can extend the reach of mathematical methods.

When former student Charles Epstein struggled during a summer at Los Alamos in 1982, Peter consoled him with characteristic humor. *"I had hoped that you would relive the glory days of my youth,"* he said. *"But I guess you can only build the hydrogen bomb once."* This quip highlighted Peter's sense of history and his realization that each generation of mathematicians must find their own great challenges.

As SIAM and the broader applied math community reflect on Peter's legacy, we recognize that he not only solved critical mathematical problems but also helped to shape the very landscape of modern computational science. His vision of mathematics as a powerful tool for comprehending and addressing real-world problems remains at the heart of SIAM's mission and the daily work of applied mathematicians worldwide.

Having known Peter for more than 50 years as his students and colleagues, we can both personally attest that he taught us how to see mathematics as a force to understand the world. He showed us—and society as a whole—how to maintain intellectual rigor while remaining grounded in questions that matter.

Peter is survived by his son, James; two stepchildren from his second marriage; three grandchildren; and two great-grandchildren. He was preceded in death by his first wife, Anneli Cahn Lax; their son, John; and his second wife, Lori Berkowitz. We extend our deepest condolences to Peter's family, colleagues, and the many mathematicians whose work and lives he influenced. His contributions will continue to shape applied mathematics for generations to come.

Many of Peter's quotes in this tribute were courtesy of a 2014 video and article[5] that were part of the Simons Foundation's "Science Lives" series.

Mac Hyman is the emeritus Evelyn and John Phillips Distinguished Chair in Mathematics at Tulane University and a Past President of SIAM. Dave Levermore is an emeritus professor in the Department of Mathematics and the Institute for Physical Science and Technology at the University of Maryland, College Park. He is a former SIAM Vice President for Science Policy.

[3] https://epubs.siam.org/doi/10.1137/1.9781611970562

[4] https://history.siam.org/oralhistories/lax.htm

[5] https://www.simonsfoundation.org/2014/04/10/peter-lax

Maps of the Moon

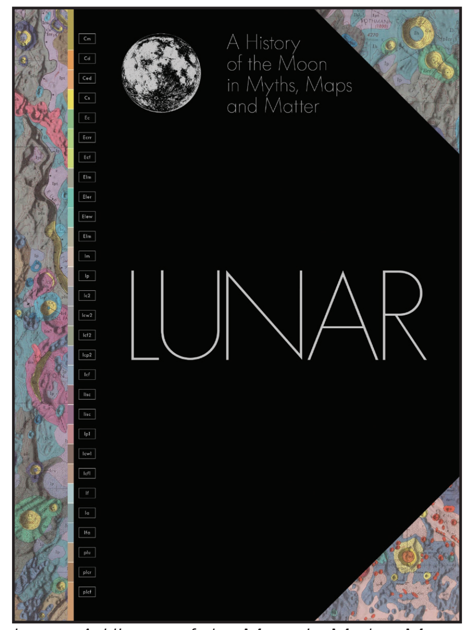
Lunar: A History of the Moon in Myths, Maps, and Matter. *Edited by Matthew Shindell. The University of Chicago Press, Chicago, IL, November 2024. 256 pages, $65.00.*

BOOK REVIEW
By Ernest Davis

The topographical maps from the U.S. Geological Survey[1] (USGS), an agency within the U.S. Department of the Interior,[2] have been admired for decades by map enthusiasts and hikers alike. Printed on a scale of 1:24,000 (one inch to 2,000 feet), these beautiful maps[3] are full of detail and marked with contour lines and physical benchmarks. They serve as delightful guides for an afternoon hike, fascinating subjects of study for a rainy day indoors, and suitable art pieces for framing and hanging on a wall.

However, the USGS maps are not limited to the U.S. or even planet Earth. Since 1961, USGS has also created maps of some of the solid heavenly bodies:[4] planets Mercury, Venus, Mars, and Pluto; asteroids Ceres and Vesta; the four Galilean moons of Jupiter; four of Saturn's large moons; Triton, the large moon of Neptune; and above all, our own Moon.

Between 1962 and 1974, the USGS Astrogeology Science Center[5] produced a series of 44 maps that cover most of the surface of the near side of the Moon. The maps portray the region from 70° East to 70° West and 64° South to 64° North; the parts that are closest to the edge are omitted, presumably because scientists cannot observe them in sufficient detail from Earth. Each map is hand drawn on a 1:1,000,000 scale and in a head-on perspective (rather than from an Earth-based view). I would hence estimate that each map is about 25×20 inches. Geological features are color coded, and every map is embedded in a larger, 35×45-inch sheet with a great deal of text and graphical information: keys to the cartographic conventions, paragraphs of detailed geological information, and references to the literature.



Lunar: A History of the Moon in Myths, Maps, and Matter. Edited by Matthew Shindell. Courtesy of the University of Chicago Press.

These maps form the core of *Lunar: A History of the Moon in Myths, Maps, and Matter,* a new book that is produced by USGS and edited by Matthew Shindell. This large tome (14.5×10.5 inches and 256 pages) is beautifully manufactured and lavishly illustrated. Each map is reproduced twice. First, the entire large map sheet is rendered as a half-page (9×5 or 9×6-inch) facsimile. At this scale, the map text is approximately a four-point font; squinting, straining, and holding the book close to my nose, my 68-year-old eyes can barely make it out. Second, each map is allotted its own two-page spread. The map itself is printed on the right page at about half of its original size (around 10.5×9 inches), while the remainder of that page and the entire left page are filled with explanatory texts and relevant images: photographs from lunar orbiters, a list of notable manned and unmanned landings, and so on. Many further details are displayed separately in enlarged form. I will note that the colors in the printed book are less attractive than in the online version; for instance, the deep blue in the top left of Figure 1 is an unattractive muddy green in the physical copy.

In addition to the reproductions of the USGS lunar maps and discussions about their content and history, the book includes 31 two- to four-page essays on Moon-related topics that range from histories of science and the lunar landings to the Moon's role in myth, religion, literature, and art. Each essay is lavishly illustrated; in all, the book must contain at least a thousand separate images, most of them remarkable and many of them beautiful. The authors of the vignettes are distinguished experts in their fields and comprise planetary scientists, historians, and popular science writers. These essays are interspersed with the maps and arranged in rough chronological order.

My favorite essay, at least in terms of the accompanying illustrations, is also the most frivolous. In the late 19th and early 20th centuries—once photography became popular and comparatively affordable—a fad emerged for visiting cards that featured a photograph of the card's owner posed with a stylized crescent moon. The essay in question includes reproductions of 21 examples from an unidentified private collection (see Figure 2, on page 8).

All in all, though, the exact point and intended audience of *Lunar* is unclear. A reader who wishes to learn about the Moon's geology will find the account frustrating, as the book includes a lot of detail but does not provide a clear overall picture of what has been going on inside of the Moon for the last 4.6 billion years. A reader who hopes for an atlas would do better to consult the current USGS lunar maps—all

See **Maps of the Moon** *on page 8*

[1] https://www.usgs.gov
[2] https://www.doi.gov
[3] https://www.usgs.gov/products/maps
[4] https://www.usgs.gov/special-topics/planetary-geologic-mapping/search-usgs-sim-and-i-series-maps
[5] https://www.usgs.gov/centers/astrogeology-science-center

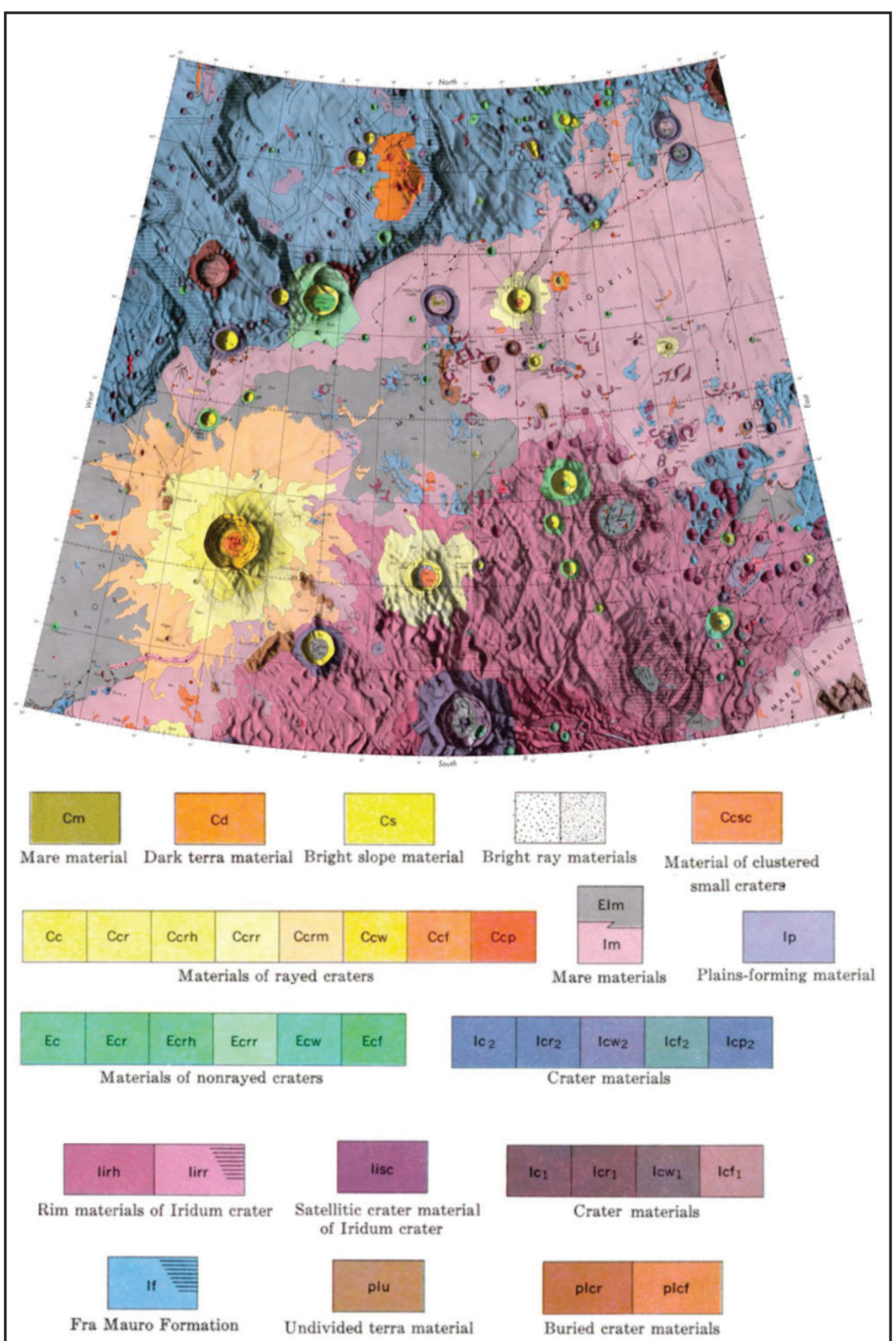


Figure 1. *Geological map of the Moon's J. Herschel quadrangle (48° to 64° North, 20° to 50° West), accompanied by a color key. Figure adapted from a U.S. Geological Survey map that was compiled by G.E. Ulrich.*

Falling Into a Trap

MATHEMATICAL CURIOSITIES
By Mark Levi

Some years ago, I asked my class to prove that if the solution to the baby problem

$$\dot{x}=a(t)x,\ \ x(0)=1 \qquad (1)$$

is exponentially small, i.e.,

$$x(t)\le e^{-t}\ \text{ for all }\ t>0, \qquad (2)$$

then with a tiny addition to the right side:

$$\dot{y}=a(t)y+e^{-t^2},\ \ y(0)=1, \qquad (3)$$

the solution will remain small: $y(t)\to 0$ as $t\to\infty$. Surely e^{-t^2} cannot make much of a difference.

When reading the first submitted assignment a week later, I found a mistake. The next homework was wrong as well. Prior to reading the third submission, I started to think — something, I soon realized, I should have done more of before assigning the problem. I realized that not only $y\to 0$ may fail, but even more surprisingly, $y(t)$ may be unbounded.

How Can a Tiny Addition Have Such a Big Effect?

Figure 1 illustrates the mechanism of possible unboundedness; let's first concentrate on interval $[0,3]$. To simplify the problem, replace e^{-t^2} in (3) with a function $b(t)\le e^{-t^2}$, chosen to be constant and positive on $[1,2]$ and vanishing elsewhere. The solution of

$$\dot{z}=a(t)z+b(t),\ \ z(0)=1 \qquad (4)$$

satisfies $z(t)\le y(t)$, and so it is enough to produce an example of $a(t)$ for which z is unbounded. To that end, let us specify $a(t)$ by letting it be piecewise constant with values $-A$, 0, and $A-3$ on the three intervals in Figure 1, showing the graphs of $x(t)$ and $z(t)$. This choice of a is dictated by the wish to make $x(t)$ approach 0 very closely before it returns to e^{-t}. Incidentally, the "-3" in $A-3$ guarantees that $x(t)\le e^{-t}$.

With a large enough A, $z(3)$ can be arbitrarily large — this can be seen via an explicit calculation that I omit, or from the discussion in the next paragraph. By extending this construction to the intervals $[3n,3n+3]$, we get $z(3n)\to\infty$ for $n\to\infty$. And since $z(t)\le y(t)$, we have $y(3n)\to\infty$. Incidentally, $y(3n+1)\to 0$ so that y oscillates between 0 and ∞ as $t\to\infty$.

Here is a heuristic argument for the unboundedness of $z(t)$. Think of a stock market in which one dollar that we invest at $t=0$ oscillates between nearly 0 and e^{-t}. Even a tiny investment when the stock is near 0 can increase the value by an arbitrarily large factor if the dip is sufficiently deep; this factor propagates to the time the market "recovers" (see Figure 1). Cyclical repetition leads to times of ever higher rises that alternate with ever deeper declines.

Mark Levi (levi@math.psu.edu) is a professor of mathematics at the Pennsylvania State University.

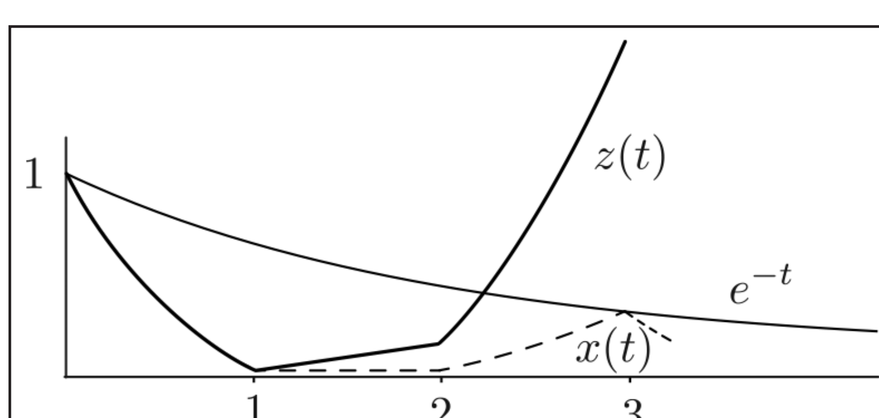


Figure 1. *The solution to (1) (dotted line) decays over $[0,1]$ to a very small value over $[1,2]$ and "recovers" over $[2,3]$. An arbitrarily small addition $b(t)$ during $[1,2]$ increases the solution (solid line) by a large factor. This increase propagates to $t=3$ so that $z(3)$ can be made arbitrarily large. Figure courtesy of Mark Levi.*

Rough Volatility in Financial Mathematics

By Jim Gatheral

The following is a brief description from one of the editors of Rough Volatility,[1] which was published by SIAM in 2023. The book—the first to offer a comprehensive investigation of the subject—seeks to advance reader understanding of rough volatility models by exploring their motivation and introducing a toolbox for computation and practical implementation. It is meant for researchers and graduate students in quantitative finance, quantitative analysts, and finance professionals.

More than a decade has passed since the publication of the first two working papers on *rough volatility*. While researchers had previously hypothesized that fractional volatility models might account for the observed power law behavior of implied volatility smiles, these models initially lacked econometric validation. Moreover, their non-Markovian nature raised serious concerns about computational tractability.

The two aforementioned foundational papers directly addressed these challenges and now comprise the first two chapters of *Rough Volatility*, edited by Christian Bayer, Peter Friz, Masaaki Fukasawa, Jim Gatheral, Antoine Jacquier, and Mathieu Rosenbaum. The remaining eight chapters trace the field's rapid development, providing an in-depth view of the sustained research activity that has transformed rough volatility into a robust and versatile modeling paradigm.

Overview and Contents

Chapter 1, titled "Volatility is Rough," presents the empirical case for rough volatility, noting that log volatility behaves like a fractional Brownian motion with a Hurst parameter H that is significantly less than $\frac{1}{2}$. The text introduces the rough fractional stochastic volatility (RFSV) model (under the physical measure $\mathbb{P}$) as a parsimonious framework that matches observed autocorrelation structures and scaling laws.

Chapter 2, "Pricing Under Rough Volatility," constructs a dynamical pricing model called the *rough Bergomi model* from the RFSV model by changing measure from $\mathbb{P}$ to the pricing measure $\mathbb{Q}$. Notably, the history of the Brownian motion that drives the volatility process can be inferred from the forward variance curve — an object that we can extract from option prices. The highly parsimonious rough Bergomi model generates SPX smiles that closely align with observed data (see Figure 1).

FROM THE SIAM BOOKSHELF

Chapter 3—a reprint of the 2020 paper "No-arbitrage Implies Power-law Market Impact and Rough Volatility"—builds an economic argument for rough volatility in the framework of Hawkes processes given some basic assumptions, including absence of arbitrage, linearity of permanent impact, and the existence of market impact with a transient component.

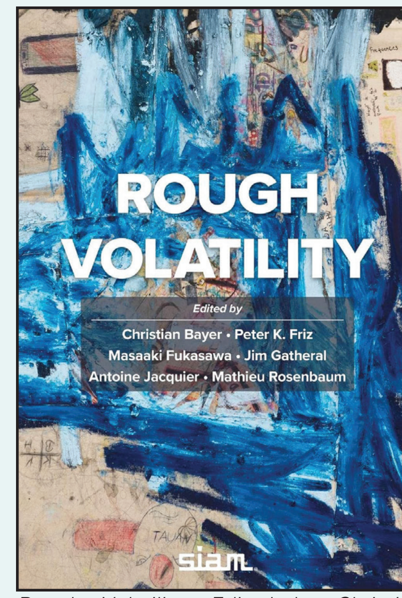
Chapter 4 explores the rough Heston model: a natural fractional extension of the classical Heston model. The rough model preserves the classic model's analytical tractability with a characteristic function that can be expressed in terms of the solution of a fractional version of the classical Riccati ordinary differential equation (ODE). As with the rough Bergomi model, the rough Heston model generates highly realistic smiles. Chapter 4 also touches briefly on the *quadratic* rough Heston model, which—though less tractable than its non-quadric counterpart—can jointly fit SPX and VIX smiles.

The rough Heston model is a member of the much larger class of rough affine models that are discussed in chapter 5. The characteristic function of such models has a representation in terms of the solution of a Riccati-Volterra equation, a natural generalization of the classical Riccati ODE. Chapter 6 then addresses hedging under rough volatility, illustrating through a simple example the improved hedging performance of strategies based on rough models.

The hybrid simulation scheme is key to the practical implementation of rough volatility models. Chapter 7, a reprint of the 2017 article "Hybrid Scheme for Brownian Semistationary Processes," presents this scheme in detail, applying it to a generalized version of the rough Bergomi model; extended versions can be used to simulate many other rough volatility models.

Chapter 8 explores asymptotic expansions for implied volatility under rough models in various regimes. This chapter is invaluable to researchers, as it pulls together various asymptotic results from the vast rough volatility literature *with consistent notation*.

Chapters 9 and 10 offer a flavor of the types of mathematical development that have been inspired by rough volatility. Chapter 9, "The Forest Expansion of Forward Variance Models," introduces the forest expansion: a combinatorial representation of characteristic functions for forward variance models as infinite sums over binary trees. Because rough volatility models are non-Markovian, the traditional tools of stochastic analysis do not apply. Subsequently, chapter 10—based on the 2020 article "Regularity Structure for Rough Volatility"—develops a strong approximation theory for rough volatility that is motivated by the work of Martin Hairer, which earned him the Fields Medal in 2014.



Rough Volatility. Edited by Christian Bayer, Peter Friz, Masaaki Fukasawa, Jim Gatheral, Antoine Jacquier, and Mathieu Rosenbaum. Courtesy of SIAM.

Intended Audience

Rough Volatility is a comprehensive reference on a growing discipline that lies at the intersection of stochastic analysis, financial modeling, and numerical computation. It is an ideal resource for graduate students, researchers, and practitioners with an interest in volatility modeling and market microstructure. While the field of rough volatility continues to evolve, this book provides a solid foundation and will remain a key reference point amidst future developments. The inclusion of empirical studies, calibration results, and numerical methods ensures its enduring relevance in both theory and practice.

Finally, the cover design by Colombian artist Oscar Murillo (winner of the 2019 Turner Prize) adds a touch of visual sophistication, making the volume equally at home on a coffee table or a bookshelf, and a perfect gift.

Enjoy this passage? Visit the SIAM Bookstore[2] to learn more about Rough Volatility[3] and browse other SIAM titles. And be sure to stop by the SIAM books booth at the upcoming ***2025 SIAM Conference on Financial Mathematics and Engineering[4]****—which will take place from July 15-18 in Miami, Fl.—for the opportunity to purchase Rough Volatility and other texts at special conference prices.*

Jim Gatheral is the Presidential Professor of Mathematics at Baruch College of the City University of New York, where he teaches in the Master of Science in Financial Engineering program. He serves as co-editor-in-chief of Quantitative Finance and is the author of The Volatility Surface: A Practitioner's Guide, which published in 2006. In 2021, he and Mathieu Rosenbaum were jointly named "Quant of the Year" by Risk.net.

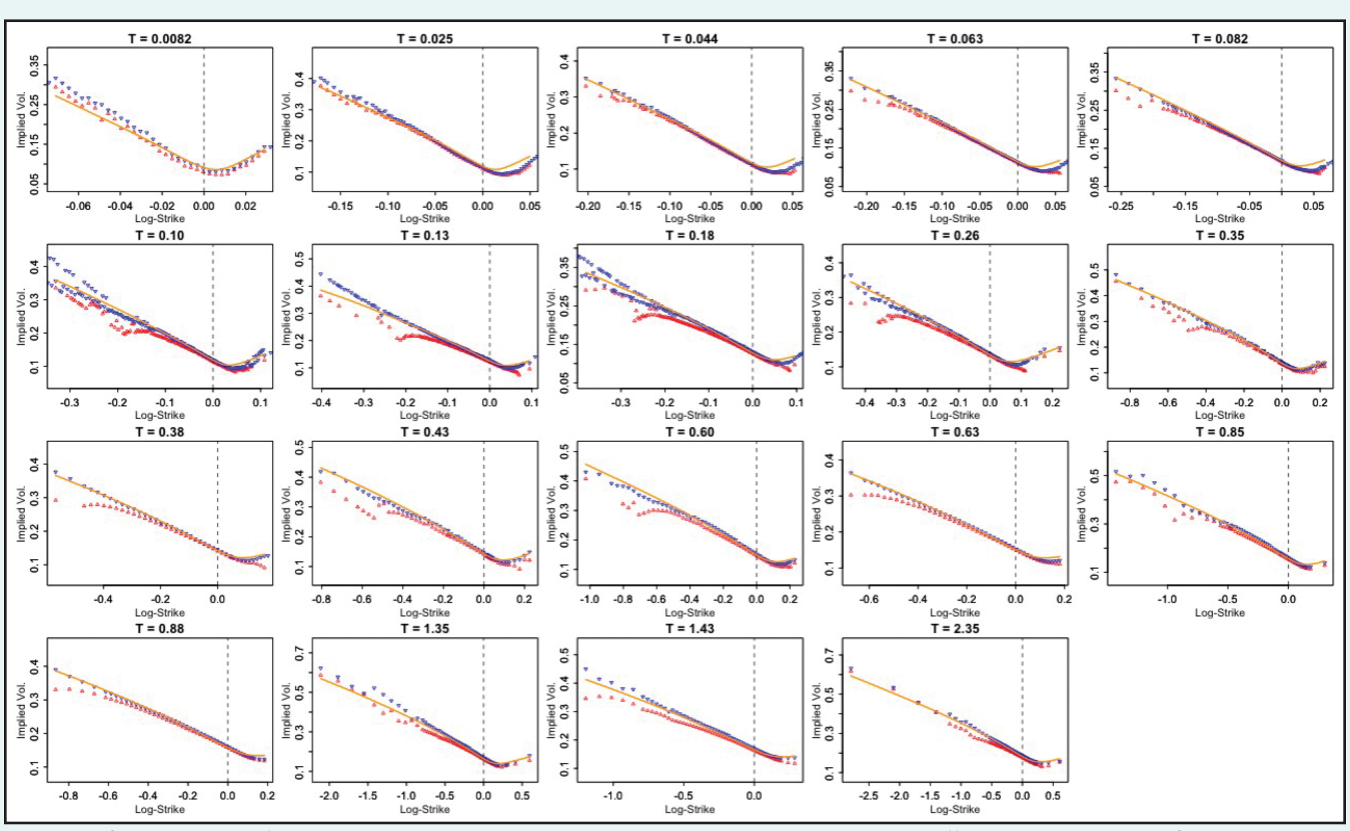


Figure 1. *SPX smiles as of August 14, 2013. Red and blue points represent observed bid and offer implied volatilities. Orange curves are generated from a simulation of the rough Bergomi model. Figure courtesy of Rough Volatility.*

[1] https://epubs.siam.org/doi/book/10.1137/1.9781611977783

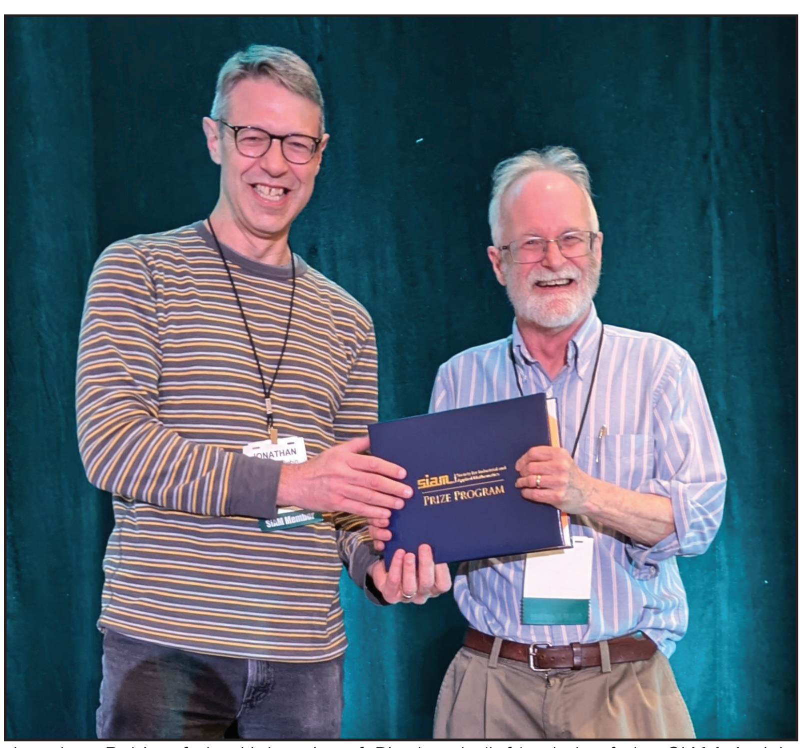
[2] https://epubs.siam.org/bookstore

[3] https://epubs.siam.org/doi/book/10.1137/1.9781611977783

[4] https://www.siam.org/conferences-events/siam-conferences/fm25

Photos From the 2025 SIAM Conference on Applications of Dynamical Systems

During the 2025 SIAM Conference on Applications of Dynamical Systems, which took place in Denver, Colo., this past May, Gary Froyland of the University of New South Wales (right) accepts the 2025 J.D. Crawford Prize from Jonathan Rubin of the University of Pittsburgh, chair of the SIAM Activity Group on Dynamical Systems. The J.D. Crawford Prize honors researchers for recent outstanding contributions to a topic in nonlinear science; Froyland was recognized for his work on the spectral analysis of climate dynamics via operator-theoretic approaches that advance the theory of complex fluid flow. SIAM photo.



Jonathan Rubin of the University of Pittsburgh (left), chair of the SIAM Activity Group on Dynamical Systems, congratulates Bard Ermentrout of the University of Pittsburgh for his receipt and delivery of the Jürgen Moser Lecture at the 2025 SIAM Conference on Applications of Dynamical Systems, which was held in Denver, Colo., this past May. Ermentrout was honored for his "broad and seminal contributions to mathematical biology, including pioneering work on mathematical and computational neuroscience, dynamical systems, and pattern formation." His accompanying lecture was titled "Not Just Another Pretty Phase: The Use of Phase Models in Neuroscience and Biology." SIAM photo.

The illustrious Red Sock Award at the 2025 SIAM Conference on Applications of Dynamical Systems, which was held in Denver, Colo., this past May, recognized outstanding poster presentations by students and postdoctoral researchers. From left to right: awardees Juan Patiño-Echeverria of the University of Auckland, Laura Pinkney of the University of Leeds, and Anna Thomas of the University of Pittsburgh hold the coveted accessories for which the prize is named. Recipient Twinkle Jaswal of Illinois State University is not pictured. SIAM photo.

The poster session and dessert reception at the 2025 SIAM Conference on Applications of Dynamical Systems, which took place this past May in Denver, Colo., promoted spirited discussions about a wide variety of research applications. Throughout the evening event, roving judges evaluated the presentations of students and postdoctoral researchers to select the winners of the Red Sock Award, who were announced the next day. SIAM photo.

Read more about prize recipients at the 2025 SIAM Conference on Applications of Dynamical Systems at https://go.siam.org/qukbxd.

Check out the hashtag #SIAMDS25 on social media to view more photos and posts from the meeting.

Maps of the Moon

Continued from page 6

of which are accessible online—or examine one of the several atlases of the Moon that are already available in print. The maps in this book are 50 to 60 years old and have been superseded in terms of both cartography and geology. Even a reader with a historical interest in these particular maps will generally have more success with the online versions. Many of the cartographical notations go unexplained in the main text and must be deciphered by working through the tiny facsimile on the reproduced map.

The far side of the Moon and the edges of the near side—that is, the parts of the surface that were not included in the original set of maps—get a particularly short shrift; *Lunar* only acknowledges them in one two-page essay with two small photographs and no maps of any kind. A book that seriously wanted to present lunar geography would hardly omit two thirds of the Moon's surface in this way.

The illustrations that complement the nonmap essays are marvelous, but the relatively brief texts often feel too short for the subjects that they attempt to cover. It is unsatisfying to read an article about scientific theories of the tides that jumps from Pierre-Simon Laplace to the present day with no mention of Lord Kelvin's tide-predicting machine; or an article about the history of literary fantasies of life on the Moon with no reference to Cyrano de Bergerac's 1657 *The Other World: Comical History of the States and Empires of the Moon*; or an article about lunar astronomy with only a brief, dismissive comment on the lunar distance method of determining longitude—invented by Tobias Mayer and Nevil Maskelyne and refined by Nathaniel Bowditch—which was in practical use for close to a century.

My guess would be that the creators of *Lunar* started with a plan to publish the original maps as a celebration of the initial project, perhaps in honor of the 50th anniversary of its completion. Feasibly their second thought was that interest would be limited, so they decided to add the essays. The result is a volume that contains fascinating—albeit scattershot—content in the text and a treasure trove of Moon-related images, but not exactly a coherent book.

Ernest Davis is a professor of computer science at New York University's Courant Institute of Mathematical Sciences.

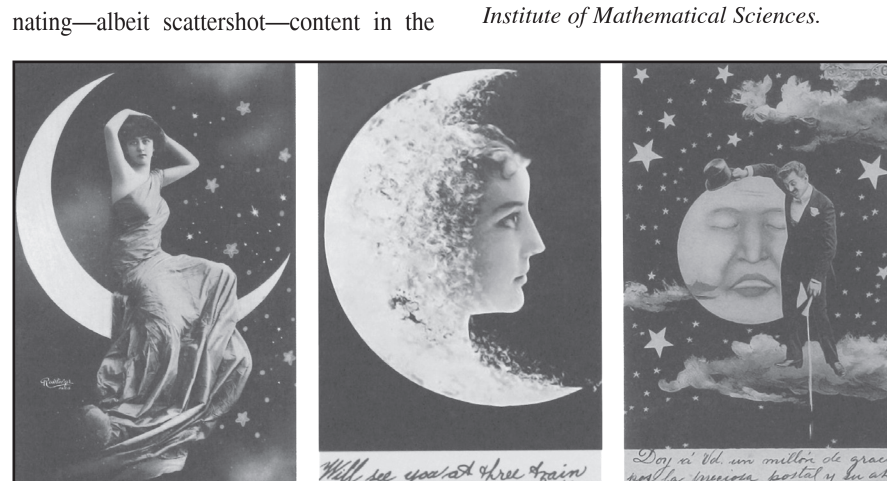


Figure 2. *Examples of a popular type of calling card from the late 1800s and early 1900s, which often included a posed photo of the card's owner with a stylized moon. Figure courtesy of Lunar: A History of the Moon in Myths, Maps, and Matter.*

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SUBMISSION DEADLINE
July 14, 2025

SIAM Symposium on Algorithm Engineering and Experiments (ALENEX26)

January 11–12, 2026 | Vancouver, Canada
siam.org/alenex26 | #ALENEX26

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siam.org/sosa26 | #SOSA26

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SUBMISSION DEADLINE
August 7, 2025

SIAM Conference on Parallel Processing for Scientific Computing (PP26)

March 3–6, 2026 | Berlin, Germany
siam.org/pp26 | #SIAMPP26

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SUBMISSION DEADLINES
July 31, 2025: Minisymposium Proposal Submissions
September 2, 2025: Contributed Lecture, Poster, Minisymposium Presentation Abstract, and Proceedings Paper Submissions

SIAM Conference on Uncertainty Quantification (UQ26)

March 22–25, 2026 | Minneapolis, Minnesota, U.S.
siam.org/uq26 | #SIAMUQ26

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August 25, 2025: Minisymposium Proposal Submissions
September 22, 2025: Contributed Lecture, Poster, and Minisymposium Presentation Abstract Submissions

Upcoming SIAM Events

SIAM Conference on Applied Algebraic Geometry
July 7–11, 2025
Madison, Wisconsin, U.S.
Sponsored by the SIAM Activity Group on Algebraic Geometry

SIAM Conference on Financial Mathematics and Engineering
July 15–18, 2025
Miami, Florida, U.S.
Sponsored by the SIAM Activity Group on Financial Mathematics and Engineering

The Third Joint SIAM/CAIMS Annual Meetings
July 28–August 1, 2025
Montréal, Québec, Canada

SIAM Conference on Control and Its Applications
July 28–30, 2025
Montréal, Québec, Canada
Sponsored by the SIAM Activity Group on Control and Systems Theory

SIAM Conference on Computational Geometric Design
July 28–30, 2025
Montréal, Québec, Canada
Sponsored by the SIAM Activity Group on Geometric Design

SIAM Conference on Applied and Computational Discrete Algorithms
July 30–August 1, 2025
Montréal, Québec, Canada
Sponsored by the SIAM Activity Group on Applied & Computational Discrete Algorithms

SIAM Conference on Mathematical and Computational Issues in the Geosciences
October 14–17, 2025
Baton Rouge, Louisiana, U.S.
Sponsored by the SIAM Activity Group on Geosciences

2nd SIAM Northern and Central California Sectional Conference
October 27–28, 2025
Berkeley, California, U.S.

SIAM Conference on Analysis of Partial Differential Equations
November 17–20, 2025
Pittsburgh, Pennsylvania, U.S.
Sponsored by the SIAM Activity Group on Analysis of Partial Differential Equations

Information is current as of June 25, 2025. Visit *siam.org/conferences* for the most up-to-date information.

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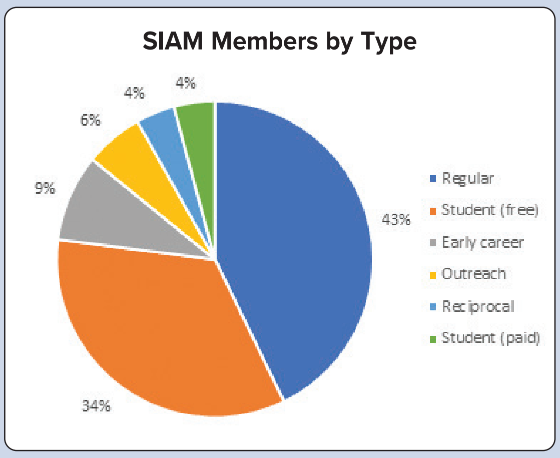
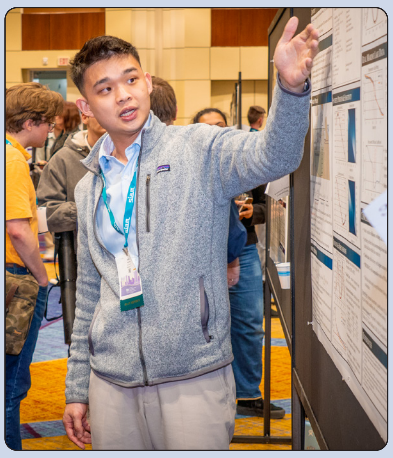
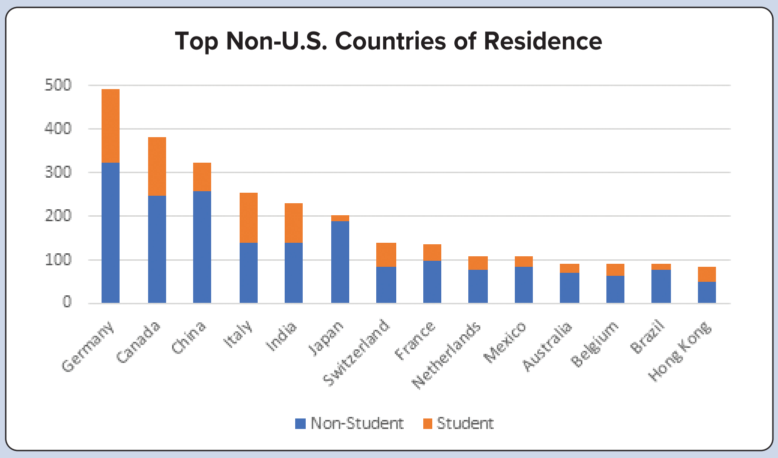
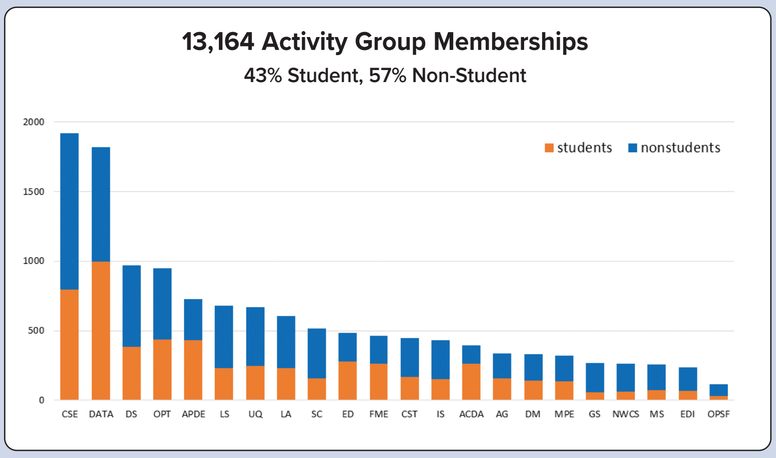
Annual SIAM Membership Report

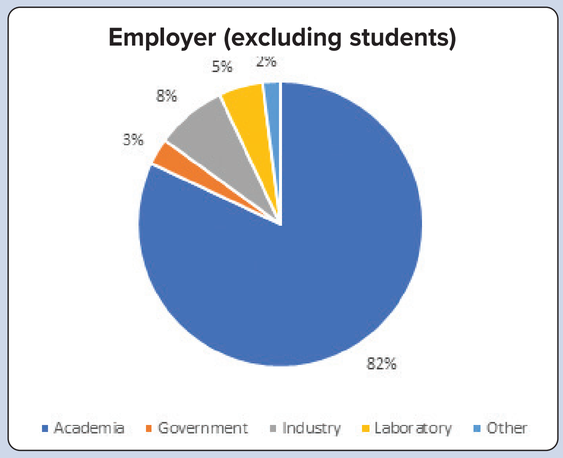
As of December 31, 2024, SIAM had 12,275 members from 95 countries and 226 active student chapters representing 29 countries. Thirty-six percent (36%) of SIAM members reside outside the United States. The charts on this page show information about SIAM members.

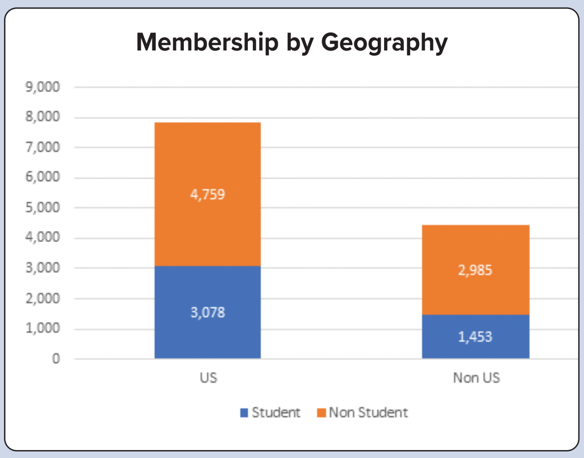


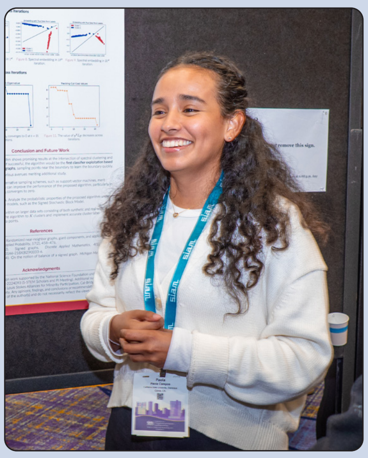


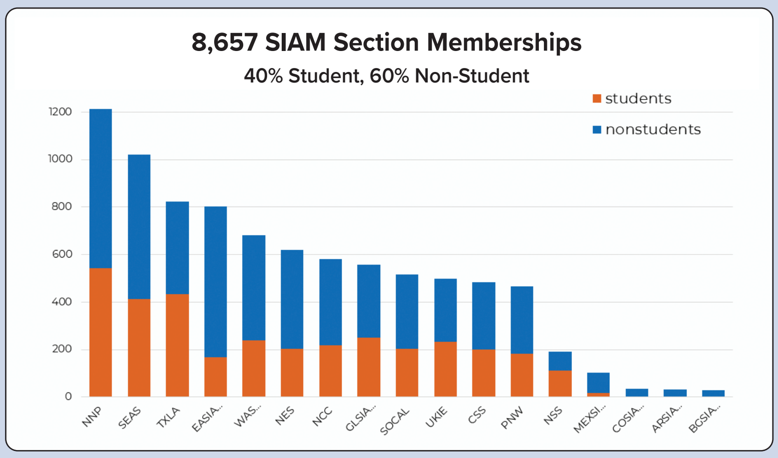












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SIAM-Simons Undergraduate Summer Research Program Seeks Mentors

The program seeks mentors for the summer 2026 cycle. Funding covers food, lodging, travel, and stipend for participants and stipend for mentors. Applications to be a mentor for two students for eight weeks open in July and close at the end of August. Visit ***siam.org/simons*** for more information.

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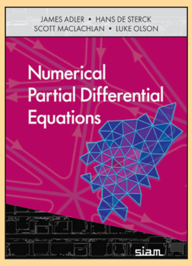

Numerical Partial Differential Equations

James H. Adler, Hans De Sterck, Scott MacLachlan, and Luke Olson

This comprehensive textbook focuses on numerical methods for approximating solutions to partial differential equations (PDEs). The authors present a broad survey of these methods, introducing readers to the central concepts of various families of discretizations and solution algorithms and laying the foundation needed to understand more advanced material. The authors include 100+ well-established definitions, theorems, corollaries, and lemmas and summaries of and references to in-depth treatments of more advanced mathematics when needed.

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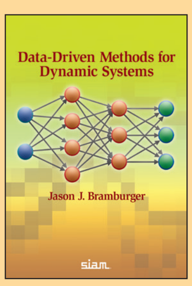

Data-Driven Methods for Dynamic Systems

Jason J. Bramburger

This book brings together modern computational tools to provide an accurate understanding of dynamic data. The techniques build on pencil-and-paper mathematical techniques that go back decades and even centuries. The result is an introduction to state-of-the-art methods that complement, rather than replace, traditional analysis of time-dependent systems. This book provides readers with methods not found in other texts as well as novel ones developed just for this book.

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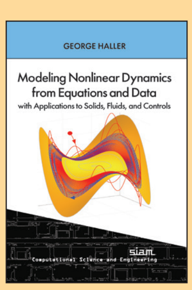

Modeling Nonlinear Dynamics from Equations and Data—with Applications to Solids, Fluids, and Controls

George Haller

This concise text introduces the emerging area of reducing complex nonlinear differential equations or time-resolved data sets to spectral submanifolds (SSMs). SSMs are ubiquitous low-dimensional attracting invariant manifolds that can be constructed systematically, building on the spectral properties of the linear part of a nonlinear system. SSM-based model reduction has a solid mathematical foundation and hence is guaranteed to deliver accurate and predictive reduced-order models under a precise set of assumptions. This book introduces the foundations of SSM theory to the novice reader; reviews recent extensions of classic SSM results for the advanced reader; and illustrates the power of SSM reduction on a large collection of equation- and data-driven applications in fluid mechanics, solid mechanics, and control.

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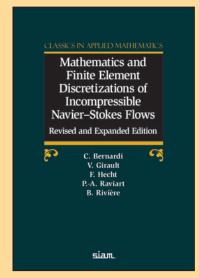

Mathematics and Finite Element Discretizations of Incompressible Navier–Stokes Flows *Expanded and Revised Edition*

Christine Bernardi, Vivette Girault, Frédéric Hecht, Pierre-Arnaud Raviart, and Beatrice Riviere

This revised and expanded edition of Girault and Raviart's 1986 textbook provides a thorough theoretical study of finite element methods for solving incompressible Navier–Stokes equations, which model flow of incompressible Newtonian fluids and are used in many practical applications. It focuses on efficient and widely used finite element methods that are well adapted to large-scale simulations. Readers will find rigorous proof of stability and convergence, analysis of practical algorithms, and a stand-alone chapter on finite element methods that is applicable to a large range of PDEs.

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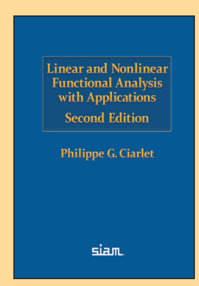

Linear and Nonlinear Functional Analysis with Applications *Second Edition*

Philippe G. Ciarlet

This new, expanded edition covers the fundamentals of linear and nonlinear functional analysis, includes numerous applications, and provides all the basic theorems with complete and detailed proofs. The author has added more than 450 pages of new material, more than 210 problems, and two entirely new chapters, one on locally convex spaces and distribution theory and the other on the Fourier transform and Calderón–Zygmund singular integral operators. The chapter on the "great theorems" of nonlinear functional analysis has been enlarged and split into two chapters.

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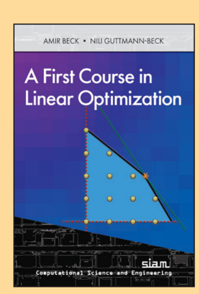

A First Course in Linear Optimization

Amir Beck and Nili Guttmann-Beck

This self-contained textbook provides the foundations of linear optimization, covering topics in both continuous and discrete linear optimization. It gradually builds the connection between theory, algorithms, and applications so that readers gain a theoretical and algorithmic foundation, familiarity with a variety of applications, and the ability to apply the theory and algorithms to actual problems. To deepen the reader's understanding, the authors provide many applications from diverse areas of applied sciences. The book also includes more than 180 exercises, most of them with partial answers and about 70 with complete solutions, as well as a continuous illustration of the theory through examples and exercises.

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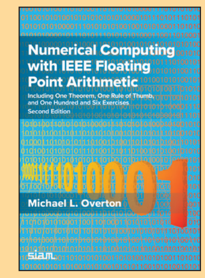

Numerical Computing with IEEE Floating Point Arithmetic *Including One Theorem, One Rule of Thumb, and One Hundred and Six Exercises, Second Edition*

Michael L. Overton

This book provides an easily accessible, yet detailed, discussion of computer arithmetic as mandated by the IEEE 754 floating point standard, arguably the most important standard in the computer industry. Although the basic principles of IEEE floating point arithmetic have remained largely unchanged since the first edition of this book was published in 2001, the technology that supports it has changed enormously. Every chapter has been extensively rewritten, and two new chapters have been added: one on computations with higher precision than that mandated by the standard and one on computations with lower precision than was ever contemplated by those who wrote the standard, driven by the massive computational demands of machine learning. It includes many technical details not readily available elsewhere, along with many new exercises.

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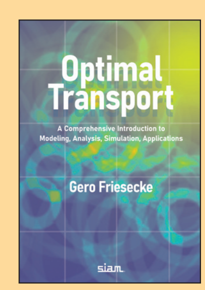

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Gero Friesecke

Optimal transport problems have been found to arise in many different fields of mathematics, science, and engineering, and in the last three decades interest in the subject has exploded. This accessible book begins with an elementary and self-contained chapter on optimal transport on finite state spaces that does not require measure theory or functional analysis. It builds up mathematical theory rigorously and from scratch, aided by intuitive arguments, informal discussion, and carefully selected applications. It is the first book to cover modern topics such as Wasserstein GANs and multimarginal problems and includes a discussion of numerical methods and basic MATLAB code for simulating optimal transport problems directly via linear programming or more efficiently via the Sinkhorn algorithm.

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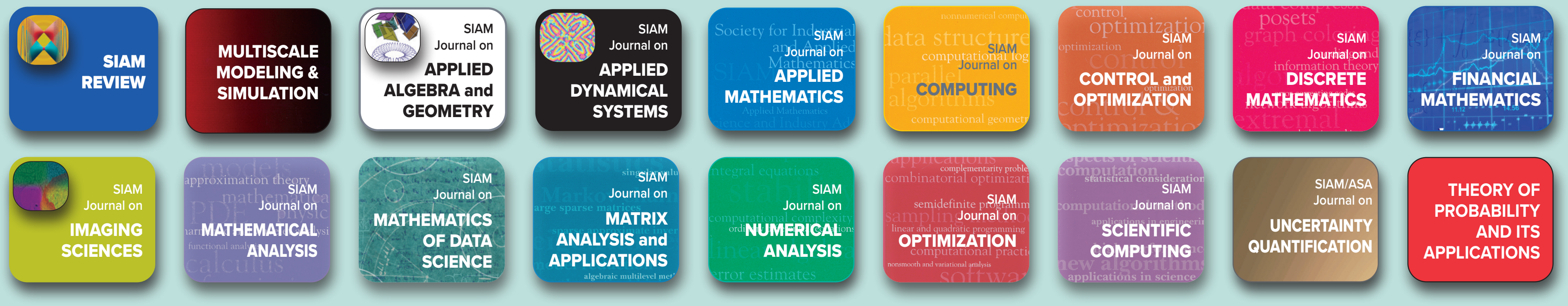

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