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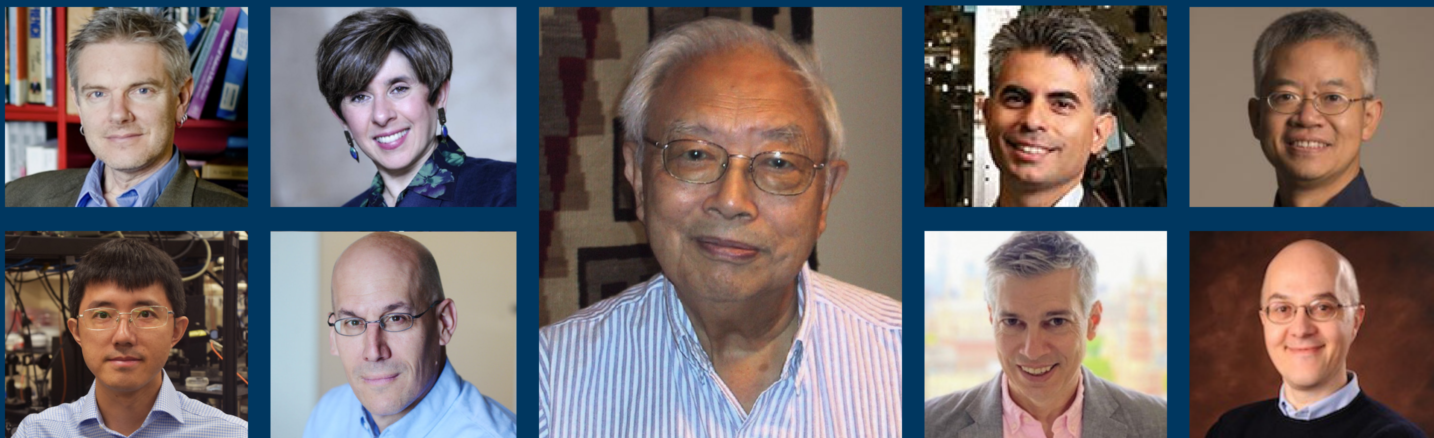
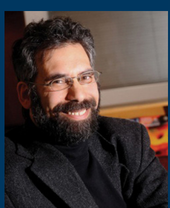
APAM NEWS

Applied Physics & Applied Mathematics Department
with Materials Science & Engineering
Columbia University in the City of New York





Dear APAM Community,

We are delighted to share the remarkable accomplishments of our students, faculty, scientists, and alumni as another exciting school year comes to a close. Despite the challenges of the past few years, the class of 2023 has thrived and excelled. We extend our congratulations to them, including our three undergraduate faculty award winners for excellence in Applied Mathematics, Applied Physics, and Materials Science. We wish them success in their future endeavors and welcome them as esteemed APAM alumni.

In this newsletter, we also celebrate the remarkable accomplishments of our faculty and research scientists, who have achieved scientific progress in a range of fields including advanced photonics, fundamental materials science, plasma physics, climate dynamics, and even the history of data science from "the age of reason to the age of algorithms." These achievements exemplify the exceptional intellectual diversity within APAM. Moreover, we showcase the numerous awards and honors bestowed upon our faculty, acknowledging their remarkable contributions to research and teaching.

Finally, this semester saw the passing of Professor *Emeritus* C.K. "John" Chu, one of the founding members of APAM and a lifelong champion for Applied Mathematics, the APAM Department, and Columbia Engineering. Together with family, friends, students, and colleagues, we came together to celebrate the life and legacy of Prof. Chu through a moving memorial service in St. Paul's chapel.

Thank you all for your continued support and dedication to the APAM community.

Best regards,

Marc Spiegelman
APAM Department Chair

Cover images, left-right (top row) Simon Billinge, Katayun Barmak, C.K. Chu, Carlos Paz-Soldan, Qiang Du (bottom row) Nanfang Yu, Alex Gaeta, Chris Wiggins, Lorenzo Polvani

Columbia Engineering Students Win Fusion-Energy Design Contest

Hari Choudhury, Priyansh Lunia, Haley Wilson, Matt Pharr, & Matt Tobin

A team of Columbia Engineering PhD students have been awarded $22,000 for winning a design contest that challenged university teams across the country to accelerate the commercialization of fusion energy. The Columbia team was composed of PhD students studying plasma physics in the APAM Department, and their work was supported by Columbia research scientist Dr. Oak Nelson.

By Hari Paul Choudhury

Fusion energy promises to be a sustainable, safe, and low-carbon method of electricity production that could play a key role in reducing global emissions of greenhouse gases. In the core of a fusion device, at temperatures so high that all gases ionise to form plasmas, light isotopes fuse together to form heavier elements, releasing energy in the process. This energy can then be converted into electricity. There are several different types of fusion devices being actively researched and built worldwide by both public and private organizations, all with the hope of proving commercial-viability of electricity production.

Of all the concepts, the tokamak, a doughnut-shaped machine that confines plasma using magnetic fields, has been proven to have the best fusion performance. The Columbia team studied a variation of the design of the traditional tokamak, known as the negative-triangularity tokamak, over the summer.

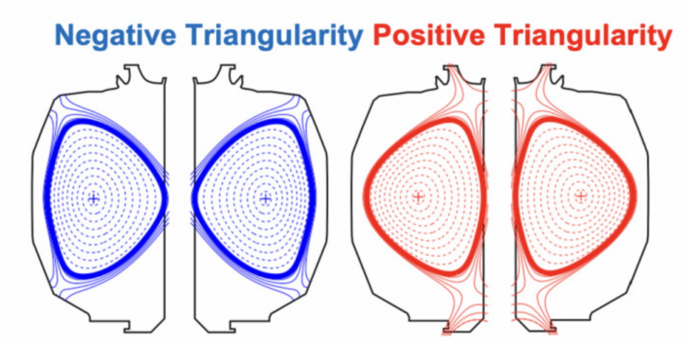


Figure: A poloidal cross-section of a tokamak plasma, showing in blue the negative triangularity shape, and in red, the more conventional positive triangularity shape.

In a tokamak, a series of electromagnetic coils produce magnetic fields that spiral around the inside of a doughnut-shaped vacuum vessel, and the plasmas confined typically have a 'positive-triangularity' shape, when viewed from a cross-section of the tokamak, see Figure 2, right-side. A different configuration of coils can change this cross-section to form a 'negative-triangularity' shape, see Figure 2, left. This new shape holds several advantages for confining the hot plasma compared to the traditional shape, and is the subject of an increasing amount of research and experimentation.

Over the summer, after completing a literature review of the topic, the student team modelled the confinement properties of this promising type of tokamak using a suite of software tools. In the process, the students laid the groundwork for a Fall semester class, APPH 9143, which took place in collaboration with MIT, that looks to design a commercially-viable negative-triangularity tokamak. The research conducted in the summer, alongside the work done in the Fall class by Columbia and MIT students, will help understand the feasibility of this mode of tokamak operation and whether it can accelerate the achievement of commercial fusion energy.

The summer research culminated in submitting a report on the potential of this type of tokamak design to ORFEAS, a philanthropic organization that created the design contest with the hope of accelerating progress in fusion energy. At the end of the summer, the team found out they had won the contest, along with a handful of other teams. All of the winning teams were invited out to the Massachusetts Institute of Technology for a weekend in October to meet each other, share their designs, and learn more about fusion energy.

The team have decided to use the prize money to expand Columbia's outreach efforts relating to fusion, hoping to take advantage of the university's unique location in the heart of New York City, with so many schools and students within a commuting distance. Ideas include building new demonstration equipment so high-school students can see examples of plasmas in the class room. The team hope to spread awareness about fusion energy, and, in particular, its far-reaching potential to provide clean, safe, carbon-free electricity.

Team members: Hari Paul Choudhury, Matthew Tobin, Haley Sunshine Wilson, Priyansh Lunia, & Matthew Pharr (Advised by Dr. Andrew Oak Nelson, Research Scientist). ORFEAS website: https://www.orfeasfusion.com/

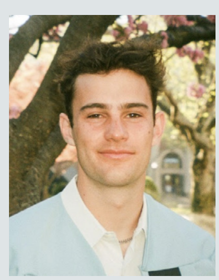
Class of 2023 Student Spotlights: Meet a few of our recent graduates and learn about their future plans.

Akshay Choudhry
BS '23 Applied Math

Future Plans: MPhil in Machine Learning/ Machine Intelligence at the University of Cambridge

Sadi Gulcelik
BS '23 Applied Math

Future Plans: Stay in NYC, work at Bridgewater, part-time master's at Columbia Computer Science



William O'Brien
BS '23 Applied Math

Future Plans: Machine Learning at JPMorgan; will apply to grad schools for computational biology

Plasma Students Receive CSGF & NSF Awards

Amelia Chambliss and Jacob Halpern, have been awarded Department of Energy Computational Science Graduate Fellowships (DOE CSGF). Another incoming student, Rohan Lopez, has received an NSF graduate fellowship.

Prof. Elizabeth Paul said, "It is an honor for the Plasma Lab to have such an excellent group of incoming graduate students. Both the CSGF and NSF fellowships are extremely competitive, and we are looking forward to the research we will do together in the coming years."

Amelia Chambliss is a rising second year PhD student working with Prof. Paul's group on the theory and numerical modeling of energetic ions in fusion plasmas. Because of her enthusiasm for fusion energy and poise as a young scientist, Amelia was chosen to speak at the White House Summit on "Developing a Bold Decadal Vision for Commercial Fusion Energy" in 2022. Prof. Paul said, "It is evident that Amelia is already considered a young leader in fusion energy sciences, and I look forward to guiding her through her continued development as a computational scientist."

Rohan Lopez is an incoming first year PhD student from Pomona College. Prof. Paul said, "I met Rohan last summer while he was an intern at Princeton Plasma Physics Laboratory, where he was developing costing models for high temperature superconducting (HTS) magnets. Rohan expressed enthusiasm for my research, and we began discussions on how his expertise could be used in my group to develop HTS technology for stellarator experiments. Rohan's command of both theoretical and laboratory physics will be used for the design of a new on-campus stellarator experiment."

Jacob Halpern is an incoming first year PhD student from Purdue University. Jacob shows immense promise as a young researcher, with internship experience at the Princeton Plasma Physics Laboratory and Naval Research Laboratory. He has received several national awards, including the Astronaut Scholarship Foundation Scholar, and has already published several journal articles. He will be jointly supervised by Prof. Elizabeth Paul and **Prof. Carlos Paz-Soldan**. Prof. Paz-Soldan said, "I'm delighted to be able to work with Jacob. His clear enthusiasm and capability will be a tremendous asset to the Columbia Plasma Physics Lab and I look forward to welcoming him to the program."

2023 Graduate Student Research Symposium

The first APAM Graduate Student Research Symposium took place on April 21st. There were 17 presentations from graduate students across three APAM programs: Applied Physics (AP), Applied Mathematics (AM), and Materials Science (MS). The day began with opening remarks by **Prof. Marc Spiegelman, Prof. Katayun Barmak, Prof. Shanyin Tong,** and **Andrew Bishop**, the representative of AMPS (the Association of Applied Math, Applied Physics, Materials Science, and Medical Physics Students). Three presentation sessions (AP, AM, and MS) covered a broad range of topics, including nonlinear optics, plasma physics, quantum mechanics, atmospheric sciences, electrochemical energy storage, and nanomaterials. Every presentation was excellent and followed by a few great questions from the audience. The faculty judges also provided useful feedback for every participant and selected a winner for each session.

Congratulations to our award recipients: **Richard Oliver**, Best Presentation in Applied Physics; **Zirui Xu**, Best Presentation in Applied Mathematics; **Luke Holtzman**, Best Presentation in Materials Science; and **Yuan Xu**, Audience Choice Award.

Overall, the symposium was a great success, highlighting the research being conducted by our graduate students and fostering a sense of intellectual enthusiasm among the department. We hope to see the symposium become a long-standing tradition in the future.

We would like to thank the help of the faculty judges: **Prof. Elizabeth Paul, Prof. Carlos Paz-Soldan, Prof. Saskia Mordijck, Prof. Marc Spiegelman, Prof. Michael Weinstein, Prof. Yuan Yang,** and **Prof. Ismail C. Noyan**. We also would like to thank **Prof. Katayun Barmak** for providing helpful materials to prepare the events. The event was organized by **Shanyin Tong**, Assistant Professor of Applied Mathematics, and members of the AMPS symposium organizing committee: **Andrew Bishop**, 5th year PhD student in Applied Physics; **Julia Hestenes**, 4th year PhD student in Materials Science; and **Han Yong Wunrow**, 2nd year PhD student in Applied Mathematics.

2023 Undergraduate Award Winners

Marc Spiegelman, APAM Chair, presented awards to three outstanding seniors at the 2023 APAM Senior Dinner and Award Ceremony. Each winner was selected by the APAM faculty in recognition of their excellent academic achievements.

David Qian Liu, Applied Physics Faculty Award Winner
Our Applied Physics Faculty Award winner is an excellent student in a superb class of applied physics seniors. The award winner took many challenging courses in Applied Physics with A's and A+ in many of his courses. Prof. Venkataraman in particular, praised their performance in Quantum Physics of Matter (and she has very high standards). In addition to courses, our award winner has been heavily involved in research at Columbia, working with Prof. Nanfang Yu on a DARPA research project on creating novel night-vision goggles using nonlinear upconversion in resonant metasurfaces. David helped elucidate the image formation properties of the night-vision goggles by deriving a "nonlinear Snell's law", which basically predicts that when converting an infrared scene to one that is visible to our eyes, the scene will be demagnified and distorted. This is an important new result and, hopefully, one of many as our award winner will continue his studies as a Ph.D. student here at Columbia in Applied Physics.

Sadi Gulcelik, Applied Mathematics Faculty Award Winner
Our Applied Math Faculty Award winner is a dedicated and talented graduating senior, with a wealth of experience and accomplishments. He currently holds a 4.08 GPA with 145 points and is an inveterate problem solver. His senior seminar project team successfully extended and tested the "Gravitational Model" of International migration, using advanced Bayesian methods and low-dimensional embedding techniques to visualize their results in Python. Moreover, they correlated migration patterns with the Economist's Democracy Index, adding another layer of complexity and depth to their analysis. This insightful, creative, and challenging project exemplifies this major's dedication to pushing the boundaries of knowledge and making a meaningful impact in their chosen fields. Having lived and worked between Turkey and the U.S., he is now poised to join Bridgewater after completing his degree at Columbia. In addition to his new role, he will be pursuing a part-time MS Express in Computer Science at Columbia to further enhance his skills.

Liam Andrew Hayes, Frances Rhodes Prize in Materials Science
This year's awardee is a polymath, working on a dual degree program (4+1) with a BS in materials science and BA in the college in Archaeology where they hope to make an impact at the intersection of both fields. In preparation, they did their senior design project with the Kawashima Group in the Department of Civil Engineering on concrete, both a significant source of CO_2 to the atmosphere and critical in mitigating climate change (as well as being a mainstay of future archaeology). They will be returning to Columbia in the Fall to finish the Archaeology Degree at Columbia College and will likely be applying to graduate school in Fall 2024 where their combined expertise in Materials Science and Archaeology will make them extremely competitive.

(left-right) David Qian Liu, Sadi Gulcelik, Prof. Marc Spiegelman & Liam Andrew Hayes

Congratulations Graduates!

October 2022 MS: Brandt Ange (AM-CVN), Lu Chen (MSE), Xuanjing Chu (MSE), Yifan Jin (AM), Lek Heng Lee (AM-CVN), Celine Raton (AP), Cole Sandvold (MSE), Jialiang Sun (AM), Yingbin Xia (MSE), Zetong Zhuang (MSE)

October 2022 MPhil: Andrew Bishop (AP-SS/OP), William Boyes (AP-PP), Boting Li (AP-PP,) Mark Mathis (AP-SS/OP), Ivan Mitevski (AM-Atmos)

October 2022 PhD: Wei Cao (MSE), Wen Ding (AM), Kuang Huang (AM), Zeyu Hui (MSE), Jonathan Karp (AP)

February 2023 BS: Ji Eun Kim (AM), David King (AM), Matthew Stafford (AP)

February 2023 MS: AlBatool Abaalkhail (AP), Jason Bram (AM-CVN), Chloe Bullard (MSE), Zhiyue Cao (AM), Haoyang Chen (AP), Muqing Chen (AM), Yen Pang Chen (MSE), Yi Chen (AM), Yizhi Chen (AM), Ziheng Chen (MSE), Hari Choudhury (AP), Ivan Chukhryaev (AP), Nicholas Coupey (MP), Nigel DaSilva (AP), Zhihao Dong (AM), Guangzheng Du (AP), Hui Fang (MSE), Yikai Gong (MSE), Huaiqian Guo (MSE), Yanjun Guo (MSE), Amol Gupta (AM), Dion Ho (AM), Nicolas Holt (AM), Yuxin Hu (MP), Hong Jun Kim (MSE), Sonya Kin (MP), Jingyang Kong (MSE), Aryeh Krischer (AP), Hannah Kwon (AM), Yen-Po Louis Lee (MP), Huaijin Li (MSE), Keyue Liang (MSE), Dongping Lin (MSE), Kaishun Lin (AM), Zhengyan Lin (AP), Zhi Lin (AP), Yibin Phoebe Ling (MP), Chun Wei Liu (AP), Priyansh Lunia (AP), Guobin Miao (MSE), Kristina Nabayan (MSE), Shankrith Natarajan (AM), Mohammad Nehmeh (MP), Chinh Nguyen (MP), Paul Nicholas (MP), Ilgaz Ozkurt (AM), Yinxi Pan (AM), Matthew Pharr (AP), Daniel Piatigorski (MP), Miheer Prakash (AM), Benjamin Reilly (MSE), Jianqing Shen (AM), Haoyuan Shi (MSE), Juanlang Shi (AM), Yuelai Shi (AM), Dennis Shpits (AM), John Stone (MP), Audrey Shu (AM), Matthew Sisson (AM), Nathan Soedjak (AM), Jacob Solomon (AP), John Stone (MP), Keyuan Su (AM), Xiao Arianna Tan (MP), Jiaqin Tang (AM), Nicole Tansey (MSE), Matthew Tobin (AP), Zirui Tong (AM), Jackson Turner (AM), Dawei Wang (AM), Hanlin Wang (AM), Jinxiao Wang (MSE), Qiuyang Wang (AM), Yifan Wang (AM), Tianqi Wei (AM), Zujin Wen (AP), Haley Wilson (AP), Tenzin Worden (AM), Jiahao Wu (AP), Meng-Jou Serena Wu (MP), Yini Xu (AM), Jitong Yan (MSE), Yunbo Yang (AM), Haochen Zhao (MSE), Chengyu Zhu (MSE)

February 2023 MPhil: Sasaank Bandi (MSE), Isabelle Bunge (AM), Jonah Chaban (AM), Yinan Dong (MSE), Todd Elder (AP), Patrick Orenstein (AM), Yi Fang Wang (AP)

February 2023 PhD: Michael Carter (MSE), Yocheved Ungar (AP)

May 2023 BS: Yamini Ananth (AM), Juan Baek (MatSci), Fatima Begum (MatSci), Kaitlyn Brown (AM), Ethan Burkley (MatSci), Miguel Caro (AP), Melody Chang (AM), Cara Chen (AM), Akshay Choudhry (AM), Alex Chung (AM), Malachi William Coleman (AM), Antonio Foglia (AM), Chenghan Guan (AM), Sadi Gulcelik (AM), Liam Hayes (MatSci), Nicolas Hortiguera (AM), Yang Hsu (AM), Andrew Jin (AM), Peter Jin (AM), William Kim (AP), Abhiram Kolluri (AM), Xianchang Kuang (AM), Olivia Girling Lease (AM), Ethan Levitt (AP), Xinyi Li (AM), Zhiyuan Li (AM), Jinghuan Lin (AM), Vivian Lin (AM), Zaikang Lin (AM), Chunhui Liou (AM), Andrew Liu (AM), Qian Liu (AP), Vivian Liu (AM), Andrew Loevinger (AP), Wo Long (AM), Samuel Lossef (MatSci), Serena Luo (AP), Morgan McNulty (AM), Kairui Miao (AM), Julia Moncayo von Hase (AM), William O'Brien (AM), Arianna Pahlavan (AM), Patrick Park (AP), Olivia Pfetsch (AM), Syed Saam Rasool (MatSci), Yanling Shen (AM), Reuben Solnick (AM), Margot Szamosszegi (MatSci), Yutaro Tanaka (AM), Austin Tao (AM), Mitchell Thomas (AM), Silvia Toderas (AM), Jacob Vider (AP), Jafar Vohra (AM), Emily Wang (AM), Timothy Wang (AM), Ruihan Wu (AM), Yu Xiang (AM), Zixuan Xu (AM), Yihao Yu (AM), Xinyi Zhan (AM), Jinpai Zhao (AM), Zezheng Zhu (AP)

May 2023 MS: Faisal Alharbi (MP), Garrett Beals (AP), Yunong Chen (AM), Joseph Halligan (AM), Megan Handa (AM-CVN), Zenan Jin (AM), Muhe Li (AM), Xinyi Lu (AM), Yue Ma (AM), Amanda McAdams (AM-CVN), Christopher Myung (AM-CVN), Casey O'Neill (AM-CVN), Jeet Parekh (MP), Jayoung Park (MSE), Jared Spang (AM), Ethan Tucker (AP-CVN), Jack Vogelgesang (AP-CVN), Jiahao Xu (AM), Zhenghao Yang (MSE), Ruiwen Zhang (MSE), Ruiyu Zhang (AM)

May 2023 MPhil: Rian Chandra (AP–PP), Vahe Gharakhanyan (MSE), Julia Hestenes (MSE), Huaiyu Li (AM), Stephanie Malek (MSE), Matthew Patrick (MSE), Yumou Wei (AP-PP), Qi Zhang (MSE)

May 2023 PhD: Philip Dinenis (AM), Heqing Huang (AP-SS/OP), Songsheng Tao (AP-SS/OP), Zhen Zhang (AP-SS/OP)

AM: Applied Math |AP: Applied Physics | MatSci: Materials Science | MP: Medical Physics |MSE: Materials Science & Enginering | Atmos: Atmospheric Science |PP: Plasma Physics | SS/OP: Solid State/Optical Physics | CVN: Columbia Video Network

Student Spotlight: Max Zhao BS '23

Meet one of our newest graduates, **Max Zhao**, BS' 23 Applied Mathematics. More students spotlights are available online.

What is a highlight from your time at Columbia Engineering?
"I had a great time working on research that I was so passionate about with **Professor Kyle Mandli** during the summer of my junior year. Afterward, I presented my work at the undergraduate research symposium."

The most important thing has Columbia Engineering taught you?
"Being versatile and curious. Always seeking for opportunities, and never being afraid to ask questions."

What are your future plans?
"I'm going to UT Austin to start my PhD studies in computational science, engineering, and mathematics."

APAM Alumni Updates

Dr. Xiaochuan Tian (PhD 2017, Applied Mathematics) was named a 2023 Sloan Fellow. In addition, she also recently received an NSF Career Award. Dr. Tian earned her Ph.D. in Applied Mathematics from Columbia University in 2017 where she worked with Professor Qiang Du. She is currently an Assistant Professor in the Department of Mathematics at UC San Diego. She works in numerical analysis and the focus of her work is on the analysis and computation of non-local models, as well as both applied and fractional PDEs and multiscale modeling.

Congratulations to APAM Alumni, **Anjali Verma** (SEAS 2021) and **Jane Pan** (SEAS 2021). These two scholars, along with 35 other Columbia undergraduates, have received National Science Foundation-Graduate Research Fellowship Program (NSF-GRFP) awards which support graduate study in STEM/Social Science fields. For a full list of winners, please see: **https://bit.ly/3O3BzBA**

Lucas Vargas Zeppetello (BS 2016, Applied Physics) presented a talk on "Why is Soil Moisture Not Decreasing," for the Ocean and Climate Physics (OCP) lecture series at the Lamont-Doherty Earth Observatory (LDEO) on January 20, 2023. He is currently an Environmental Fellow at Harvard University's Center for the Environment where he works with Professor Peter Huybers in the Department of Earth and Planetary Sciences. Through collaboration with Professors Kaighin McColl and Missy Holbrook, he is working to understand novel soil moisture observations and how they relate to ecosystem dynamics and land surface climate variability.

We'd love to hear from you! Please send your news and address updates to apam@columbia.edu

Polvani Named Fellow of the American Association for the Advancement of Science

Professor Lorenzo Polvani has been named a Fellow of the American Association for the Advancement of Science (AAAS) in the Section on Atmospheric & Hydrospheric Sciences.

Polvani is the Maurice Ewing and J. Lamar Worzel Professor of Geophysics in the Department of Applied Physics and Applied Mathematics, Professor of Earth & Environmental Sciences, and Senior Research Scientist at the Lamont Doherty-Earth Observatory, Columbia University.

Polvani's research encompasses many aspects of atmospheric and climate dynamics, including the physical response of the climate system to increasing concentrations of carbon dioxide, the chemistry and dynamics of the stratosphere, Arctic and Antarctic climate change, and past and future climate impacts related to the Montreal Protocol. He is particularly interested in quantifying and distinguishing the effects of anthropogenic forcings from natural climate variability. He also retains an interest in geophysical fluid dynamics, and occasionally dabbles in planetary atmospheres.

Polvani earned Bachelor and Master degrees in Physics from McGill University, and a Doctorate in Physical Oceanography from the MIT/Woods Hole Joint Program in 1988. He was an Instructor in Applied Mathematics at MIT before joining Columbia University, where he has been teaching for over 25 years. He has received several teaching awards including the Best Teacher of the Year from the Department of Earth and Environmental Science, the Great Teacher Award from the Society of Columbia Graduates, and the Distinguished Faculty Teaching Award from the Columbia School of Engineering and Applied Science's Alumni Association. He is a Fellow of the American Geophysical Union and the American Meteorological Society.

Scholz Elected to National Academy of Engineering

Originally published by Columbia Engineering

Christopher H. Scholz, Professor *Emeritus* of Applied Physics and Applied Mathematics, has been elected to the U.S. National Academy of Engineering (NAE). Scholz is an expert on earthquakes who was among the first to combine geological engineering and physics to understand the processes behind tectonic plates and the formation of earthquakes. He is author of the authoritative text, "The Mechanics of Earthquakes and Faulting" (2002), as well as more than 250 papers. He received the Murchison Medal from the Geological Society of London in 2005 and the Harry Fielding Reid Medal from the Seismological Society of America in 2016. Scholz earned a BS in Geological Engineering from the University of Nevada in 1964 and a PhD in Rock Mechanics from MIT in 1967.

The NAE is part of the National Academies of Science, Engineering, and Medicine, dedicated to advancing the technological welfare of the nation through education, research, and recognizing the superior contributions made by engineers.

The Digital Twin of NYC, Smart City Project Named Winner in IDC Smart Cities North America Awards

By Liana Rhee, Originally published by the Columbia Data Science Institute

Columbia University's The Digital Twin of New York, Smart City Project, has been named a winner in IDC Government Insight's sixth annual Smart Cities North America Awards in the transportation category. Led by an interdisciplinary team from Columbia University's Fu Foundation School of Engineering and Applied Science and the Data Science Institute, the project created a digital twin of New York City, leveraging sensing data and machine learning, to optimize traffic flows while enhancing traffic safety. The Smart Cities North America Awards (SCNNA) were created to acknowledge the achievements of North American states and municipalities in implementing Smart Cities projects and to foster the sharing of best practices to accelerate Smart City development in the region. The award will be presented to the Columbia University team led by associate professor of civil engineering and engineering mechanics Sharon Di; professor of applied mathematics, **Qiang Du** (pictured above); and professors of electrical engineering, Zoran Kostic and Gil Zussman, along with student and postdoctoral research collaborators. The team will be honored at Smart Cities Connect being held May 16-18, 2023, at the Colorado Convention Center in Denver, CO.

SCNAA recipient projects exemplify novel and best practices in leveraging technology and innovation to foster sustainable growth and economic development to meet the needs and expectations of diverse communities.

"Our annual Smart Cities North America Awards recognize the best of the best among smart city initiatives and, unlike anything else in the industry, provide a blueprint for government officials looking to execute similar projects," said Ruthbea Yesner, Vice President, IDC Government Insights and Smart Cities and Communities Strategies. "We congratulate the winners on their unwavering dedication to executing compelling projects from start to finish – leveraging cutting-edge technology to offer sustainable, new services and economic opportunities and enhancing the lives of citizens."

About the Digital Twin Project: The Digital Twin Project is an initiative aimed at addressing the challenge of traffic congestion and fatalities in urban areas through the use of cutting-edge technology. By creating a virtual replica of New York City, referred to as a digital twin, the project will enable traffic managers to continuously monitor traffic patterns and swiftly adapt to any changes in real time. The team will leverage both roadside infrastructure and in-vehicle sensors to continuously learn and dynamically update as the traffic environment changes. This approach incorporates domain knowledge on traffic congestion to enhance predictions and ensures the system is trained using data collected from COSMOS, a city-scale wireless testbed, located in West Harlem as part of the NSF PAWR program. The Digital Twin project will provide a foundation for the recently-funded NSF Center for Smart Streetscapes (CS3) which will work to develop a rich ecosystem of streetscape applications such as road safety and traffic efficiency, built upon real-time, hyper-local intelligence to advance livable, safe and inclusive communities.

The Digital Twin Project aims to benefit cities and communities in Harlem by integrating the digital twin into traffic management systems to improve road safety, enhance operational efficiency, reduce congestion, and lower emissions. To address the lack of guidelines on building a digital twin for a city, the project also prioritizes education and community outreach.

The Project is co-funded by the National Science Foundation (NSF) and Federal Highway Administration (FHWA) and has engaged with the New York City Office of Technology and Innovation. The project has also benefited from close collaboration with a European startup, Kentyou, funded by the NGI Atlantic program, and received additional funding for the US-India collaboration from the NSF and the Indian Technology Innovation Hubs (TIHs) supported by the Indian Department of Science and Technology. **https://bit.ly/3ppnTGy**

Barmak Named 2023 Fellow of ASM International Society

The Board of Trustees of ASM International has elected **Katayun Barmak**, the Philips Electronics Professor at Columbia University, a Fellow of the ASM International Society.

The honor of Fellow recognizes her "distinguished contributions in the field of materials science and engineering and develops a broadly based forum for technical and professional leaders to serve as advisors to the Society," stated Sandy Robert, CAE, Executive Director of ASM International.

Professor Barmak's citation reads: *"For seminal contributions to the study of solid-state reactions, phase transformations, microstructure evolution and structure-property relations in metallic films for electronic and magnetic applications."*

Barmak holds the Philips Electronics Chair in the School of Engineering and Applied Science at Columbia University. She is a Professor of Materials Science and Engineering in the Department of Applied Physics and Applied Mathematics (APAM). She served as the Materials Program Director in APAM from 2013-2019.

Prior to her appointment to the Faculty at Lehigh University in 1992, she spent three years at IBM T. J. Watson Research Center and IBM East Fishkill development laboratory working on materials, structures and processes for field effect and bipolar junction transistors. She joined Carnegie Mellon University in 1999 and moved to Columbia University in 2011.

She received the National Young Investigator (NYI) award in 1994 and the Creativity Award in 2001, both from the US National Science Foundation. She was the recipient of an IBM Materials Research Community Visiting Scientist Award, IBM T. J. Watson Research Center, 2004 (one of only two faculty awards made worldwide), and a Deutsche Forschungsgemeinschaft Fellowship in 1994.

A major focus of her research is the study metallic films and nanowires. In addition to coauthoring a number of book chapters, she has co-edited and has authored three chapters in the book *Metallic Films for Electronic, Magnetic, Optical and Thermal Applications: Structure, Processing and Properties*. She has authored more than 200 peer reviewed publications and holds four patents.

Barmak will receive the ASM Fellow Award at IMAT'23 in Detroit, MI. ASM International, formerly known as the American Society for Metals, is an association of materials-centric engineers and scientists.

Spiegelman Receives Great Teacher Award from Society of Columbia Graduates

Marc Spiegelman is the recipient of the Society of Columbia Graduates' Great Teacher Award in Columbia College for the 2022/2023 academic year. He will receive the award during the Great Teacher Award Event held during the Columbia Reunion Weekend on Saturday June 3rd.

Spiegelman is the Arthur D. Storke Memorial Professor of Earth & Environmental Sciences, a Professor of Applied Physics & Applied Mathematics, and Chair of the Department of Applied Physics & Applied Mathematics at Columbia Engineering. He was named a Fellow of the American Geophysical Union (AGU) in 2022 and was the recipient of the Columbia Engineering Alumni Association's 2020 Distinguished Faculty Teaching Award, the 2004 Edward and Carol Kim Award for Faculty Involvement from Columbia Engineering, and the DEES Outstanding Teaching Award in 1998 and 2002.

Gaeta Wins Optica's Stephen D. Fantone Distinguished Service Award

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Optica has selected **Alexander Gaeta**, as the 2023 recipient of the Stephen D. Fantone Distinguished Service Award.

The announcement on Optica's website stated that Gaeta was, "*recognized for his role as founding editor-in chief of Optica and his commitment to excellence in the optics and photonics community."*

"Gaeta received his Ph.D. in 1991 in Optics from the University of Rochester. He is the David M. Rickey Professor in the Department of Applied Physics and Applied Mathematics at Columbia University. He was on the faculty of the School of Applied and Engineering at Cornell University from 1992-2015 and served as its Director from 2012-2014. He recently co-founded Xscape Photonics, Inc. and is currently the CEO.

Gaeta has made pioneering contributions to the fields of quantum and nonlinear photonics. These include key advances to nonlinear wave propagation that provided critical understanding to self-focusing and filamentation of ultrashort laser pulses, the generation of slow light via stimulated scattering, and nonlinear processes in photonic crystal fibers. He and his group have also performed seminal research in nonlinear nanophotonics that enabled photonic-chip dispersion engineering, optical frequency combs, generation of quantum states of light, and all-optical signal processing.

He holds 10 patents, has published more than 300 papers in quantum and nonlinear optics, and is a Thomson Reuters Highly Cited Researcher. He served as the founding Editor-in-Chief of *Optica* and was the Chair of the Optica Publications Council from 2021-2022. He is a Fellow of Optica, the American Physical Society, and IEEE. He also received the 2019 Charles H. Townes Medal.

Established in 1973, the Distinguished Service Award is presented to individuals who, over an extended period of time, have served the Society in an outstanding way, especially through volunteer participation in its management, operation, or planning in such ways as editorship of a periodical, organization of meetings, or other service to the Society. The award was created in memory of Stephen M. MacNeille and was named in honor of Stephen D. Fantone in 2013. It is endowed by the American Optical Corporation and contributions from individual members."

Billinge Named Swiss Society for Crystallography Flack Lecturer

Simon Billinge was named the Flack Lecturer for the 2023 Howard Flack Lecture Series of the Swiss Society for Crystallography SGK/SSCr from November 6-10, 2023.

The 2023 Howard Flack Lecture Series will focus on local order and pair distribution function analysis with Professor Simon Billinge as the invited Flack Lecturer. As a materials scientist, Simon uses and advances crystallographic techniques to study local-structure property relationships across many different materials used for energy, catalysis, environmental remediation, and pharmaceuticals.

The Howard Flack Lecturer Award is conferred annually by the Swiss Society for Crystallography on a scientist who is making or has made significant recent contributions to the field of structural science or involving the use of structural science in the chemical, biological, physical, medicinal or materials sciences. The awardee is then normally invited for a week-long tour of Switzerland to present seminars as part of The Howard Flack Lecture Series at several Swiss institutions and research facilities. Learn more at: **swiss-crystallography.ch**

Materials Scientists and Mathematicians Challenge Central Hypothesis in Grain Growth Modelling for Thin Films

The recently published manuscript by **Professor Katayun Barmak** (APAM Department, Columbia University), Professor Yekaterina Epshteyn (Department of Mathematics, University of Utah), and graduate student **Matthew Patrick** (APAM Department, Columbia University) [M. Patrick et al., *Acta Materialia* 242 (2023) 118476] challenges the commonly used assumption that grain growth in thin films is governed by a force balance at grain triple junctions known as the Herring equation, where geometries are determined by boundary energy anisotropy alone. These novel experimental findings could lead to a significant reformulation of existing grain growth models.

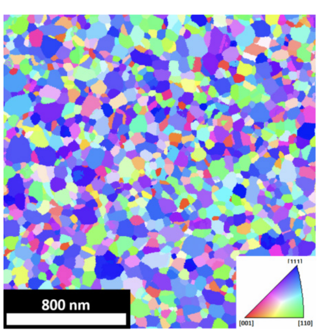
The vast majority of metals and alloys used in engineering applications, from structural components to microchip interconnects, are polycrystalline in nature. This means that they are composed of many small crystals, each made of an identical material, but with their atoms arranged in lattices of different orientations. These small crystals join together at planar defects known as grain boundaries. The grain and grain boundary structure of materials has a profound impact on their properties and performance, from ductility to electrical resistivity, and so an understanding of how their structure evolves in time is a critical tool in designing the next generation of materials.

Grain boundaries are non-equilibrium defects that have some associated excess energy (GBED) which is a function of their crystallographic character (GBCD). These boundaries meet at points known as triple junctions. It has long been accepted that the angles between boundaries at these junctions are dominantly determined by a force balance known as the Herring equation, where the forces are assumed to be proportional to the energies associated with each boundary. This can be thought of as analogous to tensions in three wires, joined at a single point. A tighter tension (higher boundary energy) would be associated with a more acute dihedral angle. This idea has been incorporated into many theoretical models of microstructural evolution. It has also been used to experimentally determine relative energies of boundaries in bulk materials by measuring the angles at the triple junctions of boundaries with known crystallographic character and then solving the Herring equation. This method has been applied to a variety of metals and ceramics, showing strong agreements with theoretical boundary energies calculated using molecular dynamics (MD), and revealing a strong inverse correlation between populations of boundaries and their associated energies.

In the thin metallic films examined in the new work, the GBCDs exhibited inverse correlations with the MD-computed energy distributions, indicating that the systems are selecting the lowest energy boundaries as expected. Surprisingly, however, when the geometries at triple junctions were used to solve the Herring equation, the relative energies did not inversely correlate with populations of grain boundaries and did not correlate with theoretical energies. Thus, in these spatially constrained systems, the conventional Herring equation cannot be used to describe the system's behavior, since the GBED should be dependent only on the material in question. It follows that the evolution of the microstructure of these materials, and in particular the geometry of triple junctions, are governed by a more complex interplay of factors that might include surface energies, strain energies, and other energy reduction pathways which drive the formation and evolution of the materials' structure.

The new findings come at a time when other widely employed assumptions about grain boundary behavior including bedrock models like curvature-driven grain growth, are being re-examined. The behavior of triple junctions is of increasing interest to the grain-growth modeling community, given that these features are convenient microstructural markers, and so the energetic and kinetic factors dictating junction dynamics are highly relevant. By challenging an important assumption about grain growth, this paper advances the study of grain boundary network structure and its evolution and invites the development of more predictive models to help unravel some of the mysteries of grain growth.

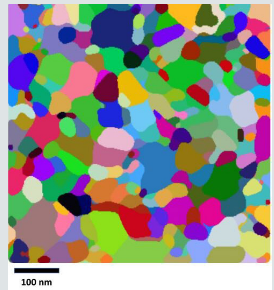
Barmak and Epshteyn's research was funded by the Division of Mathematical Science and the Division of Materials Research of the National Science Foundation.



Crystal orientation map of an aluminum thin film in the sample normal direction. The orientation key is given on the right and is labelled with the Miller indices of three crystal directions at its corners.

New Research is Helping Scientists Better Understand How Microstructures Change

By Lehigh University



The microstructure for an Al film. A representative microstructure for an Al film that was annealed for 150 min at a temperature T = 400 °C. Grain colors reflect crystallographic orientations. Credit: Lehigh University

The orientations of these infinitesimally small separations between individual "grains" of a polycrystalline material have big effects. In a material such as aluminum, these collections of grains (called microstructures) determine properties such as hardness.

New research is helping scientists better understand how microstructures change, or undergo "grain growth," at high temperatures.

A team of materials scientists and applied mathematicians developed a mathematical model that more accurately describes such microstructures by integrating data that can be identified from highly magnified images taken during experiments. Their findings are published in *Nature: Computational Materials*.

The research team included Jeffrey Rickman, Class of '61 Professor of Materials Science & Engineering at Lehigh University; **Katayun Barmak**, Philips Electronics Professor of Applied Physics and Applied Mathematics at Columbia; Yekaterina Epshteyn, Professor of Mathematics at the University of Utah; and Chun Liu, Professor of Applied Mathematics at the Illinois Institute of Technology.

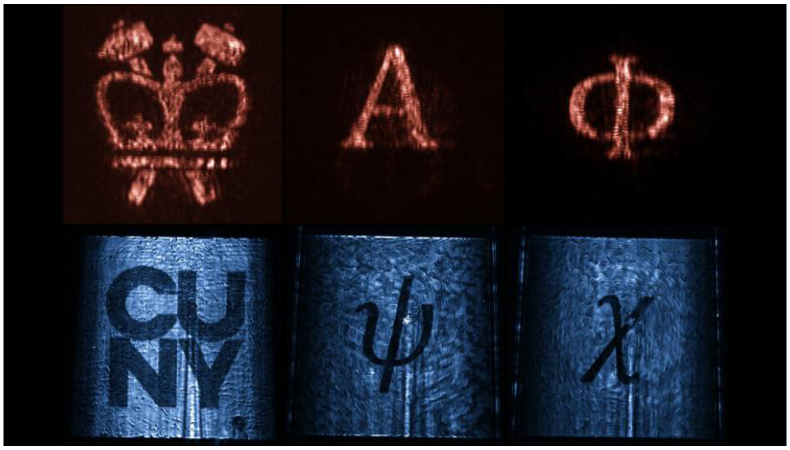
"Our model is novel because it is given in terms of features that can be identified from experimental micrographs, or photos that reveal the details of microstructures at a length scale of nanometers to microns," Rickman said. "Because our model can be related to these experimental features, it is a more faithful representation of the actual grain growth process."

The researchers conducted crystal orientation mapping on thin films of aluminum with columnar grains and used a stochastic, marked point process to represent triple junctions, points where three grains and grain boundaries meet in the structure. Their model is the first to integrate data on the interactions and disorientations of these triple junctions to predict grain growth.

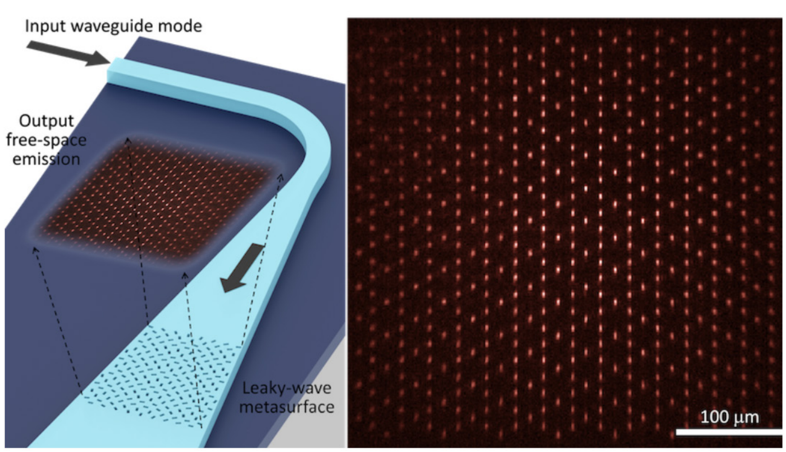
Predicting grain growth is key to the creation of new materials and is a pivotal area of study in materials science. As a result, many models of grain growth have been developed. However, the project's direct link between the mathematical model and the experimental micrographs is highly distinctive.

According to Rickman, linking the model directly to features that can be tracked during experiments will benefit computational materials scientists who model the kinetics of grain growth. "Ultimately, this research provides a way to better understand how grain growth works and how it can be used to inform the development of new materials," Rickman said. **DOI: 10.1038/s41524-023-00986-w**

Leaky-wave Metasurfaces: A Perfect Interface Between Free-space & Integrated Optical Systems



Left two figures: Two holographic images produced by a leaky-wave metasurface at two different distances from the device surface. Right four figures: Four distinct holographic images produced by a single leaky-wave metasurface at two different distances from the device surface and at two orthogonal polarization states. Credit: Heqing Huang, Adam Overvig, and Nanfang Yu/Columbia Engineering



Left: Schematic showing the operation of a leaky-wave metasurface. Right: A 2D array of optical spots forming a Kagome pattern that is produced by a leaky-wave metasurface. Credit: Heqing Huang, Adam Overvig, and Nanfang Yu/Columbia Engineering

New class of integrated nanophotonic devices--a world record in simultaneous control of all four optical degrees of freedom--can convert light initially confined in an optical waveguide to an arbitrary optical pattern in free space.

By Holly Evarts, Originally published by Columbia Engineering

Researchers at Columbia Engineering have developed a new class of integrated photonic devices--"leaky-wave metasurfaces"--that can convert light initially confined in an optical waveguide to an arbitrary optical pattern in free space. These devices are the first to demonstrate simultaneous control of all four optical degrees of freedom, namely, amplitude, phase, polarization ellipticity, and polarization orientation--a world record. Because the devices are so thin, transparent, and compatible with photonic integrated circuits (PICs), they can be used to improve optical displays, LIDAR (Light Detection and Ranging), optical communications, and quantum optics.

"We are excited to find an elegant solution for interfacing free-space optics and integrated photonics--these two platforms have traditionally been studied by investigators from different subfields of optics and have led to commercial products addressing completely different needs," said Nanfang Yu, associate professor of applied physics and applied mathematics who is a leader in research on nanophotonic devices. "Our work points to new ways to create hybrid systems that utilize the best of both worlds--free-space optics for shaping the wavefront of light and integrated photonics for optical data processing--to address many emerging applications such as quantum optics, optogenetics, sensor networks, inter-chip communications, and holographic displays."

Bridging free-space optics and integrated photonics

The key challenge of interfacing PICs and free-space optics is to transform a simple waveguide mode confined within a waveguide--a thin ridge defined on a chip--into a broad free-space wave with a complex wavefront, and vice versa. Yu's team tackled this challenge by building on their invention last fall of "nonlocal metasurfaces" and extended the devices' functionality from controlling free-space light waves to controlling guided waves.

Specifically, they expanded the input waveguide mode by using a waveguide taper into a slab waveguide mode--a sheet of light propagating along the chip. "We realized that the slab waveguide mode can be decomposed into two orthogonal standing waves--waves reminiscent of those produced by plucking a string," said Heqing Huang, a PhD student in Yu's lab and co-first author of the study, published in *Nature Nanotechnology*. "Therefore, we designed a 'leaky-wave metasurface' composed of two sets of rectangular apertures that have a subwavelength offset from each other to independently control these two standing waves. The result is that each standing wave is converted into a surface emission with independent amplitude and polarization; together, the two surface emission components merge into a single free-space wave with completely controllable amplitude, phase, and polarization at each point over its wavefront." **(Continued on page 9)**

About the Study

Heqing Huang, Adam C. Overvig, Yuan Xu, Stephanie C. Malek, Cheng-Chia Tsai, Andrea Alu, and Nanfang Yu, "Leaky-wave metasurfaces for integrated photonics," *Nature Nanotechnology* (2023). **https://doi.org/10.1038/s41565-023-01360-z**

The study was supported by the National Science Foundation (grant no. QII-TAQS-1936359 (H.H., Y.X., and N.Y.) and no. ECCS-2004685 (S.C.M., C.-C.T., and N.Y.)), the Air Force Office of Scientific Research (no. FA9550-16-1-0322 (N.Y.)), and the Simons Foundation (A.C.O. and A.A). S.C.M. acknowledges support from the NSF Graduate Research Fellowship Program (grant no. DGE-1644869). A.C.O., S.C.M., and N.Y. are listed as inventors in a US non-provisional patent application no. 17/110,846; in addition, H.H., Y.X., A.C.O., A.A., and N.Y. are listed as inventors in a US provisional application no. 63/342,475. Both were filed by Columbia University and are related to the technology reported in this article. The remaining authors declare no competing interests.

From quantum optics to optical communications to holographic 3D displays (continued from page 8)

Yu's team experimentally demonstrated multiple leaky-wave metasurfaces that can convert a waveguide mode propagating along a waveguide with a cross-section on the order of one wavelength into free-space emission with a designer wavefront over an area about 300 times the wavelength at the telecom wavelength of 1.55 microns. These include:

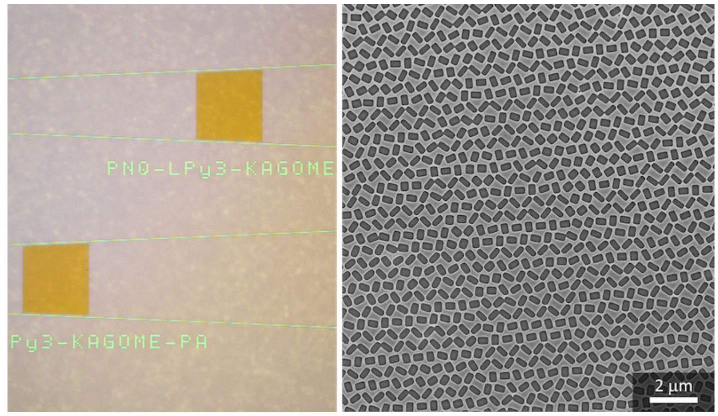
A leaky-wave metalens that produces a focal spot in free space. Such a device will be ideal for forming a low-loss, high-capacity free-space optical link between PIC chips; it will also be useful for an integrated optogenetic probe that produces focused beams to optically stimulate neurons located far away from the probe.

A leaky-wave optical-lattice generator that can produce hundreds of focal spots forming a Kagome lattice pattern in free space. In general, the leaky-wave metasurface can produce complex aperiodic and three-dimensional optical lattices to trap cold atoms and molecules. This capability will enable researchers to study exotic quantum optical phenomena or conduct quantum simulations hitherto not easily attainable with other platforms, and enable them to substantially reduce the complexity, volume, and cost of atomic-array-based quantum devices. For example, the leaky-wave metasurface could be directly integrated into the vacuum chamber to simplify the optical system, making portable quantum optics applications, such as atomic clocks, a possibility.

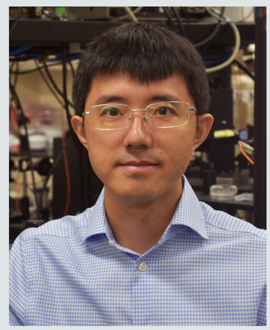
A leaky-wave vortex-beam generator that produces a beam with a corkscrew-shaped wavefront. This could lead to a free-space optical link between buildings that relies on PICs to process information carried by light, while also using light waves with shaped wavefronts for high-capacity intercommunication.

A leaky-wave hologram that can displace four distinct images simultaneously: two at the device plane (at two orthogonal polarization states) and another two at a distance in the free space (also at two orthogonal polarization states). This function could be used to make lighter, more comfortable augmented reality goggles and more realistic holographic 3D displays.

Device fabrication was carried out at the Columbia Nano Initiative cleanroom, and at the Advanced Science Research Center NanoFabrication Facility at the Graduate Center of the City University of New York.



Left: Photo of two leaky-wave metasurfaces for generating Kagome lattices. Right: SEM image of a portion of a leaky-wave metasurface, which is composed of nano-apertures etched into a polymer layer on top of a silicon nitride thin film. Credit: Heqing Huang, Adam Overvig, and Nanfang Yu/ Columbia Engineering



"Our work points to new ways to create hybrid systems that utilize the best of both worlds--free-space optics for shaping the wavefront of light and integrated photonics for optical data processing--to address many emerging applications such as quantum optics, optogenetics, sensor networks, inter-chip communications, and holographic displays."

- **Nanfang Yu**, Associate Professor of Applied Physics

Next steps: Yu's current demonstration is based on a simple polymer-silicon nitride materials platform at near-infrared wavelengths. His team plans next to demonstrate devices based on the more robust silicon nitride platform, which is compatible with foundry fabrication protocols and tolerant to high optical power operation. They also plan to demonstrate designs for high output efficiency and operation at visible wavelengths, which is more suitable for applications such as quantum optics and holographic displays.

Widely tunable and narrow-linewidth chip-scale lasers from near-ultraviolet to near-infrared wavelengths

Professor **Michal Lipson's** group's paper, "Widely tunable and narrow-linewidth chip-scale lasers from near-ultraviolet to near-infrared wavelengths," was published in *Nature Photonics*.

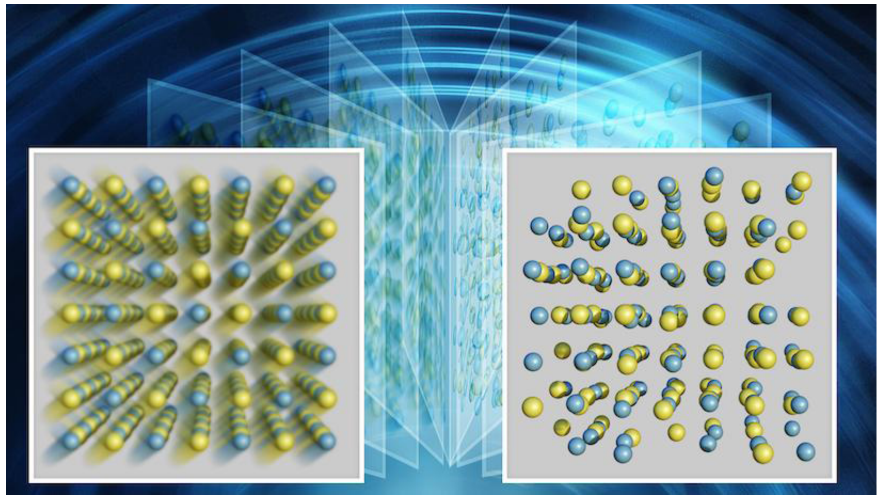
The Lipson Group reported, "In this work, led by the PhD candidate Mateus Corato Zanarella under the supervision of Prof. Michal Lipson, our team demonstrated the first tunable and narrow-linewidth chip-scale lasers for wavelengths shorter than red, down to record-short 404 nm (near-ultraviolet). By combining micrometer-scale silicon nitride resonators and commercial Fabry-Perot laser diodes, we built inexpensive lasers that fit on a fingertip with performance only previously achieved in large and expensive state-of-the-art benchtop lasers. Our integrated platform enables lasers of colors from near-ultraviolet to near-infrared in a single photonic chip, with coarse tuning up to 12.5 nm, mode-hop-free fine tuning up to 33.9 GHz, intrinsic linewidths down to a few kHz, fiber-coupled powers up to 10 mW, tuning speeds up to 267 petahertz/s, and side-mode suppression ratios above 35 dB. Our chip-scale lasers stand out as powerful tools for the next generation of visible-light technologies, with impactful consequences in fields such as quantum information, laser displays, biosensing, underwater ranging, and visible-light communications."

Their work was also the cover story of the April '23 issue of the *Laser Focus World Magazine*! See **https://www.laserfocusworld.com/magazine/62263**

New "Camera" with Shutter Speed of 1 Trillionth of a Second Sees through Dynamic Disorder of Atoms

Speeding up a camera shutter a million million times enables researchers to understand how materials move heat around and is a major step in advancing sustainable energy applications

By Holly Evarts, Originally published by Columbia Engineering



At slow shutter speeds, the atomic structure of GeTE looks ordered but blurred. Faster exposures reveal a clear intricate pattern of dynamic displacements. Credit: Jill Hemman/ORNL, U.S. Dept. of Energy

Researchers are coming to understand that the best performing materials in sustainable energy applications, such as converting sunlight or waste heat to electricity, often use collective fluctuations of clusters of atoms within a much larger structure. This process is often referred to as "dynamic disorder."

Dynamic disorder: Understanding dynamic disorder in materials could lead to more energy-efficient thermoelectric devices, such as solid-state refrigerators and heat pumps, and also to better recovery of useful energy from waste heat, such as car exhausts and power station exhausts, by converting it directly to electricity. A thermoelectric device was able to take heat from radioactive plutonium and convert it to electricity to power the Mars Rover when there was not enough sunlight.

When materials function inside an operating device, they can behave as if they are alive and dancing--parts of the material respond and change in amazing and unexpected ways. This dynamic disorder is difficult to study because the clusters are not only so small and disordered, but they also fluctuate in time. In addition, there is "boring" non-fluctuating disorder in materials that researchers aren't interested in because the disorder doesn't improve properties. Until now, it has been impossible to see the relevant dynamic disorder from the background of less relevant static disorder.

New "camera" has incredibly fast shutter speed of around 1 picosecond: Researchers at Columbia Engineering and Université de Bourgogne report that they have developed a new kind of "camera" that can see the local disorder. Its key feature is a variable shutter speed: because the disordered atomic clusters are moving, when the team used a slow shutter, the dynamic disorder blurred out, but when they used a fast shutter, they could see it. The new method, which they call variable shutter PDF or vsPDF (for atomic pair distribution function), doesn't work like a conventional camera--it uses neutrons from a source at the U.S. Department of Energy's Oak Ridge National Laboratory (ORNL) to measure atomic positions with a shutter speed of around one picosecond, or a million million (a trillion) times faster than normal camera shutters. The study was published February 20, 2023, by *Nature Materials*.

"It's only with this new vsPDF tool that we can really see this side of materials," said Simon Billinge, professor of materials science and applied physics and applied mathematics. "It gives us a whole new way to untangle the complexities of what is going on in complex materials, hidden effects that can supercharge their properties. With this technique, we'll be able to watch a material and see which atoms are in the dance and which are sitting it out."

New theory on stabilizing local fluctuations and converting waste heat to electricity: The vsPDF tool enabled the researchers to find atomic symmetries being broken in GeTe, an important material for thermoelectricity that converts waste heat to electricity (or electricity into cooling). They hadn't previously been able to see the displacements, or to show the dynamic fluctuations and how quickly they fluctuated. As a result of the insights from vsPDF, the team developed a new theory that shows just how such local fluctuations can form in GeTe and related materials. Such a mechanistic understanding of the dance will help researchers to look for new materials with these effects and to apply external forces to influence the effect, leading to even better materials.

Research team: Billlinge's co-lead on this work with Simon Kimber, who was at the University of Bourgogne in France at the time of the study. Billinge and Kimber worked with colleagues at ORNL and the Argonne National Laboratory (ANL), also funded by the DOE. The Inelastic neutron scattering measurements for the vsPDF camera were made at ORNL; the theory was done at ANL.

Next steps: Billinge is now working on making his technique easier to use for the research community and applying it to other systems with dynamic disorder. At the moment, the technique is not turn-key, but with further development, it should become a much more standard measurement that could be used on many material systems where atomic dynamics are important, from watching lithium moving around in battery electrodes to studying dynamic processes during water-splitting with sunlight. See video: **Revealing Atomic Structures with a "Neutron" Camera, https://bit.ly/3pnHmaE**

Kimber, S.A.J., Zhang, J., Liang, C.H. et al. Dynamic crystallography reveals spontaneous anisotropy in cubic GeTe. *Nat. Mater.* 22, 311–315 (2023). https://doi.org/10.1038/s41563-023-01483-7

Billinge on Building the Materials Science Lab of the Future

Simon Billinge co-chaired the virtual Materials with Long Range Order Workshop from November 16-17, 2022. The workshop, sponsored by the National Science Foundation (NSF), was part of the "Materials Laboratories of the Future: Instrumentation and Infrastructure to Accelerate the Unification of the Materials Innovation Infrastructure" workshop series. It focused on "materials with long-range order, such as bulk crystals, epitaxial films, 2-dimensional materials, Van der Waals solids, and other materials science topics." To learn more, see **https://bit.ly/42x5vue**

Montreal Protocol Is Delaying First Ice-Free Arctic Summer

New research shows that the 1987 global treaty, designed to protect the ozone layer, has postponed the occurrence of the first ice-free Arctic by as much as 15 years

By Holly Evarts, Originally published by Columbia Engineering

When scientists discovered a hole over Antarctica in 1985, countries across the globe got together and wrote a treaty designed to protect the ozone layer, which shields the Earth--and us--from harmful levels of ultraviolet radiation. The resulting Montreal Protocol, the only United Nations treaty ratified by every country in the world, was signed in 1987 and entered into effect in 1989, when little was known about its impact on the global climate. Its purpose was to reduce atmospheric concentrations of ozone-depleting substances (ODSs), materials commonly used in products such as refrigerators, air conditioners, fire extinguishers, and aerosols. For more than 50 years, it has been an important mitigation treaty, affecting many aspects of the global climate.

New study shows that the treaty's impact goes as far as the Arctic: A new study led by climate researchers at Columbia Engineering and the University of Essex demonstrates that the treaty's impact reaches all the way into the Arctic: its implementation is delaying the occurrence of the first ice-free Arctic by as much as 15 years, depending on the details of future emissions. The study was published by the *Proceedings of the National Academy of Sciences* (*PNAS)*.

"The first ice-free Arctic summer–with the Arctic Ocean practically free of sea ice–will be a major milestone in the process of climate change, and our findings were a surprise to us," said the study's co-author **Lorenzo Polvani,** Maurice Ewing and J. Lamar Worzel Professor of Geophysics in the Department of Applied Physics and Applied Mathematics and professor of earth and environmental sciences. "Our results show that the climate benefits from the Montreal Protocol are not in some faraway future: the Protocol is delaying the melting of Arctic sea ice at this very moment. That's what a successful climate treaty does: it yields measurable results within a few decades of its implementation."

Impact of ODSs: Polvani noted that the rapid melting of Arctic sea ice is the largest and clearest signal of anthropogenic climate change. Current projections indicate that the first ice-free Arctic summer will likely occur by 2050, owing largely to increasing carbon dioxide concentrations in the atmosphere. However, other powerful greenhouse gases have also contributed to Arctic sea ice loss, notably ODSs. When ODSs became strictly regulated by the Montreal Protocol In the late 1980s, their atmospheric concentrations began to decline in the mid-1990s.

Polvani and his co-author Mark England, Royal Commission for the Exhibition of 1851 Senior Research Fellow at the University of Exeter and a former PhD student with Polvani, were particularly interested in exploring the impact of ODSs because their molecules, while a lot less common in the atmosphere, are tens of thousands of times more powerful at warming the planet than carbon dioxide.

Analysis of new climate model simulations: The researchers analyzed new climate model simulations and found that the Montreal Protocol is delaying the first appearance of an ice-free Arctic summer by up to 15 years, depending on future CO2 emissions. They compared the estimated warming from ODS with and without the Montreal Protocol under two scenarios of future CO2 emissions from 1985–2050. Their results show that if the Montreal Protocol had not been enacted, the estimated global mean surface temperature would be around 0.5 °C warmer and the Arctic polar cap would be almost 1 °C warmer in 2050.

"This important climate mitigation stems entirely from the reduced greenhouse gas warming from the regulated ODSs, with the avoided stratospheric ozone losses playing no role," said England. "While ODSs aren't as abundant as other greenhouse gasses such as carbon dioxide, they can have a real impact on global warming. ODSs have particularly powerful effects in the Arctic, and they were an important driver of Arctic climate change in the second half of the 20th Century. While stopping these effects was not the primary goal of the Montreal Protocol, it has been a fantastic by-product."

Continued monitoring is critical: Since the mid-1990s, the Montreal Protocol has successfully reduced atmospheric concentrations of ODSs and there are signs that the ozone layer has started to heal. But recent research has suggested a slight rise in ODS concentrations from 2010-20, and England and Polvani stress the importance of staying vigilant.

Mark R. England and Lorenzo M. Polvani, "The Montreal Protocol is delaying the occurrence of the first ice-free Arctic summer," *Proceedings of the National Academy of Sciences* (PNAS), May 22, 2023, 120 (22) e2211432120, https://doi.org/10.1073/pnas.2211432120

Sobel Presents Distinguished Lectures

Adam Sobel, Professor of Applied Physics and Applied Mathematics and of Earth and Environmental Sciences, was invited to present a talk at the Graduate Students' Distinguished Visiting Lecture in the Department of Atmospheric Science at the University of Washington on May 10th. His talk was titled, "Climate Risk Science: An Applied Field in Need of Synthesis and Theory".He also presented the lecture, ""Climate Risk Science, Fundamental and Applied," at the NASA Goddard Space Flight Center's (GSFC) Scientific Colloquium on May 3rd.

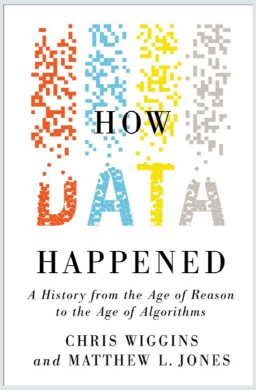
Sobel studies the dynamics of climate and weather phenomena, particularly in the tropics. In recent years he has become particularly interested in understanding the risks to human society from extreme weather events and climate change.

His research spans basic and applied prediction and risk assessment, and uses observations, theory, and numerical simulations with models spanning a hierarchy in complexity. He is author or co-author of over 150 peer-reviewed scientific articles; a popular book, *Storm Surge*, about Hurricane Sandy; and numerous op-eds. He is particularly interested in the interactions between turbulent deep convection and large-scale atmospheric dynamics, as these are key to the qualitative and quantitative understanding and prediction of many modes of atmospheric behavior, including extreme precipitation events. He has developed novel methods for diagnosing these interactions, connecting high-resolution explicit simulations of cloud systems to simple theoretical representations of large-scale dynamics in order to extract essential mechanisms and understand the connections between weather and climate. In another line of work, with colleagues in both academia and the insurance industry, Sobel has been developing hybrid statistical-dynamical models, combining mechanistic understanding with inference from observational data, to assess the risk of rare but extremely damaging extreme weather events, particularly tropical cyclones, tornadoes, and hail.

Sobel has received the Meisinger Award (2010) and Louis J. Battan Author's Award (2014) from the American Meteorological Society, the Ascent Award from the Atmospheric Sciences Section of the American Geophysical Union (2014), and the Lamont-Doherty Award for Excellence in Mentoring (2010).

New Faculty Book by Chris Wiggins & Matthew Jones - How Data Happened: A History from the Age of Reason to the Age of Algorithms

A sweeping history of data and its technical, political, and ethical impact on our world.



About the book

From facial recognition—capable of checking people into flights or identifying undocumented residents—to automated decision systems that inform who gets loans and who receives bail, each of us moves through a world determined by data-empowered algorithms. But these technologies didn't just appear: they are part of a history that goes back centuries, from the census enshrined in the US Constitution to the birth of eugenics in Victorian Britain to the development of Google search.

Expanding on the popular course they created at Columbia University, Chris Wiggins and Matthew L. Jones illuminate the ways in which data has long been used as a tool and a weapon in arguing for what is true, as well as a means of rearranging or defending power. They explore how data was created and curated, as well as how new mathematical and computational techniques developed to contend with that data serve to shape people, ideas, society, military operations, and economies. Although technology and mathematics are at its heart, the story of data ultimately concerns an unstable game among states, corporations, and people. How were new technical and scientific capabilities developed; who supported, advanced, or funded these capabilities or transitions; and how did they change who could do what, from what, and to whom?

Wiggins and Jones focus on these questions as they trace data's historical arc, and look to the future. By understanding the trajectory of data—where it has been and where it might yet go—Wiggins and Jones argue that we can understand how to bend it to ends that we collectively choose, with intentionality and purpose.

About the authors

Chris Wiggins (pictured above) is an associate professor of applied mathematics in the APAM Department at Columbia University and the Chief Data Scientist at The New York Times. At Columbia he is a founding member of the executive committee of the Data Science Institute, and of the Department of Systems Biology, and is affiliated faculty in Statistics. He is a co-founder and co-organizer of hackNY, a nonprofit which since 2010 has organized once a semester student hackathons and the hackNY Fellows Program, a structured summer internship at NYC startups.

Matthew L. Jones studies the history of science and technology, focused on early modern Europe and on recent information technologies. A Guggenheim Fellow for 2012-13 and a Mellon New Directions fellow for 2012-15, he is writing on book on computing and state surveillance of communications, and is working on Data Mining: The Critique of Artificial Reason, 1963-2005, a historical and ethnographic account of "big data," its relation to statistics and machine learning, and its growth as a fundamental new form of technical expertise in business and scientific research.

Timeline of Wiggins' Recent Talks & Interviews

March 21, 2023: Prof. Chris Wiggins' and Matthew L. Jones' book, *How Data Happened: A History from the Age of Reason to the Age of Algorithms,* was published by W. W. Norton & Company, ISBN: 978-1-324-00673-2.

March 27, 2023: The book was featured in *The New Yorker* in the article, "The Data Delusion," by Jill Lepore. https://www.newyorker.com/magazine/2023/04/03/the-data-delusion

March 27, 2023: A book launch party was hosted at Columbia University (see page 13 for details)

March-April 2023: Wiggins was interviewed on numerous podcasts including *Talks at Google*, *The Sunday Show* by Tech Policy Press; *Keen On* hosted by Andrew Keen; Wondery's *The Iron Age*, *The Local Maximum* with Max Sklyar; *The Data Exchange* with Ben Lorica; *CDO Matters Podcast* with Malcolm Hawker; and *Future Hindsight* with Mila Atmos.

April 13, 2023: "Entre Nous: Data's Human History with Chris Wiggins and Matthew Jones" was a conversation between Chris Wiggins, Matthew Jones, and Alice McCrum at the American Library in Paris, co-sponsored by Columbia Global Centers and the Institute for Ideas and Imagination as part of the Entre Nous conversation series

April 25, 2023: A portion of the book was published online in the Big Think article, "The wild evolution of data science and how to unpack it
Data scientists first gained prominence by making us click on ads — now the profession spans a multiverse." https://bigthink.com/the-future/the-wild-evolution-of-data-science-and-how-to-unpack-it/

May 3, 2023: Prof. Wiggins and Prof. Matt Jones spoke at Harvard University's Science Book Talk: *Chris Wiggins & Matthew L. Jones, "How Data Happened: A History from the Age of Reason to the Age of Algorithms,"* hosted by the Harvard Division of Science, Harvard Library, and Harvard Book Store.

May 4, 2023: Prof. Wiggins spoke at the United Nations (UN) in New York. He was invited by the University for Peace (UPEACE) to be a panelist for the official side event for at the UN World Press Freedom Day on Data collection and distribution processes as enablers of human rights. This side event was part of the UPEACE Global Center for Peace Innovation public engagement series.

May 10, 2023: Prof. Wiggins was a keynote speaker at Development Data Partnership Day 2023 at the World Bank headquarters in Washington, DC.

Data, Truth, & Power

Columbia professors & co-authors dive into "How Data Happened: A History from the Age of Reason to the Age of Algorithms" at recent book launch & panel discussion.

By Beatrice Mhando
Originally published by Columbia Engineering

Above (right-left): Chris Wiggins and Matthew Jones. Below: Julia Angwin moderated the discussion during the book launch party on March 27th. Credit: Timothy Lee

Despite the rain pouring down on a Monday afternoon, the atmosphere inside Columbia's Brown Institute for Media Innovation was nothing short of electric. Data enthusiasts of all ages engaged in spirited conversations, eagerly awaiting a panel on Mar. 27 with **Chris Wiggins** (pictured above) and **Matthew Jones**. The discussion centered around their new book, *How Data Happened: A History from the Age of Reason to the Age of Algorithms*. The book, an extension of their popular class, "Data: Past, Present and Future", offers not only a comprehensive analysis of the development of data, but also delves into its significant impact on our political and personal lives, from shaping our understanding of truth to redefining our political landscape.

The book's genesis can be traced back 10 years when Chris Wiggins, an associate professor of applied mathematics at Columbia Engineering, attended a lecture by Matthew Jones, Barker Professor of Contemporary Civilization at Columbia, on the history of machine learning. "I was very intrigued, in part because I was working in machine learning, but I wasn't trained as a machine learner," Wiggins shared during the panel, moderated by renowned data journalist Julia Angwin. "So I went to his lecture, which was great. And then, the summer after that, we ended up - thanks to Mark Hansen and friends here [at the Journalism School] - teaching a class together in 2014."

The class, which commenced three years after their collaboration began, aimed to foster digital capabilities by incorporating data and computer science into other disciplines. "We came together and tried to create a class that would appeal at once to students coming from technical backgrounds or students coming from more humanistic backgrounds," Jones explained. "And really, that class has developed from a small seminar to a large lecture and eventually became the foundation for the book."

While it is widely believed that data is an unbiased, objective numerical tool, Wiggins and Jones challenge this notion by using history to illustrate how data wields considerable power in shaping our perception of the absolute truth. "It was a realization for me, and I think for many other technologists over the last, let's say, 6 or 7 years, that data and data science rearranges power," Wiggins acknowledged. "Something we've talked about in class is how much of the history was shaped by people who had some interest, created some new capabilities, and every one of those capabilities rearranged power."

"We begin the book at the end of the 18th century because that's when there's an explosion of the idea that somehow numerical data is more reliable; it might be more appropriate for understanding not just the natural world, like the movement of planetary bodies, but the economic world, the social world, the political world," Jones added. "And the explosion of that idea, from the 19th century to the present, is one of the great transformations in how we even understand the world."

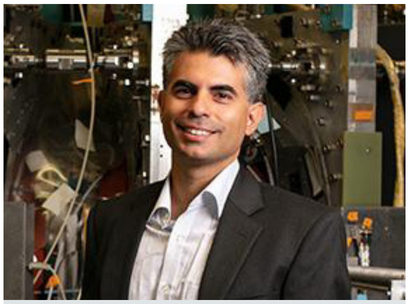
The book encourages readers to become critical thinkers when it comes to data by understanding how it is embedded in particular power dynamics that affect our daily lives, such as socio-economic relationships.

"Data comes from a Latin word that means 'to give'," said Wiggins, "and I liked the fact that it means given, because it speaks to the way that data doesn't really invite critique, right?"

Rather than presenting data as merely quantitative versus qualitative, the authors explore the inherent "unquestioned truthiness" people often associate with numbers and the belief that having numbers makes an argument more valid than one without them.

"We want to invite people to question by looking at things historically," Wiggins said. "Part of what the book poses is: How do we maintain some critical abilities around data?"

Following the thought-provoking panel discussion, Wiggins and Jones participated in a lively question-and-answer session with an enthusiastic and packed audience. Afterwards, the two authors signed copies of their new book, leaving attendees inspired and eager to dive into its pages.



"Our campaign consisted of several experiments each targeting an important part of tokamak plasma physics, and our team benefited from great expertise on all fronts," said Prof. Paz-Soldan. "We were able to gather data to push the limits of the plasma's behavior in this unique configuration, and to understand how all the pieces fit together into a successful fusion reactor operating regime. It was an honor to help realize the campaign."

Carlos Paz-Soldan
Associate Professor of Applied Physics

Paz-Soldan Collaborates with DIII-D National Fusion Facility on Negative Triangularity Experiments

Reprinted with permission from General Atomics

The DIII-D National Fusion Facility has completed an innovative month-long fusion research campaign utilizing a plasma configuration known as "negative triangularity." The campaign was organized and conducted to explore the potential benefits of using this configuration to improve exhaust handling and particle confinement as a means of making future fusion energy plants more efficient and cost effective.

The campaign was a global collaboration and included the participation of researchers from 15 institutions. It produced the highest-powered negative triangularity experiments in the history of the U.S. fusion research program. Initial data from this work appear very encouraging and full results will be released in the summer of 2023 after further analysis.

The DIII-D National Fusion Facility: DIII-D is an Office of Science scientific user facility, operated by General Atomics (GA) for the U.S. Department of Energy. Its mission is to pioneer the science and innovative technology that will enable the development of fusion as an energy source. DIII-D is the largest operating magnetic fusion research facility in the United States and one of the most flexible tokamaks in the world, which allows it to run innovative experiments and research campaigns that cannot be conducted anywhere else.

Fusion is the process that powers the stars and offers the potential for nearly limitless clean, safe energy. It occurs when two light nuclei combine to form a new one, releasing vast amounts of energy that can be used to generate electricity. Researchers can achieve fusion using a tokamak, a device that uses heat, magnetic fields, and microwaves to create and contain a plasma of charged particles. When enough heat is added, the plasma reaches fusion conditions.

Positive vs. Negative Configurations: To achieve fusion conditions relevant for energy production, DIII-D's plasma must be heated to temperatures exceeding 100 million degrees Celsius—approximately ten times the temperature at the center of the sun. DIII-D generates these conditions inside a vacuum vessel that has a D-shaped cross-section. When operating with a standard configuration, the plasma inside the DIII-D tokamak takes the same "D" shape as the vacuum vessel. This is known as "positive triangularity" and is the configuration used in nearly every experiment at the DIII-D National Fusion Facility.

By comparison, the cross-section of a plasma configured in a "negative triangularity" appears mirrored, closely resembling a backwards "D". Due to their shape within the fusion machine, plasmas in negative triangularity are less likely to impact the inner walls of the tokamak, potentially offering significant benefits for the design of future fusion power plants.

To prevent the harsh conditions within the tokamak from damaging the inner walls, DIII-D must channel excess heat away from the edge of the plasma. Using the machine's magnetic fields, this heat exhaust is guided into a region known as the divertor, where it is efficiently dispersed, cooled, and vented. The divertor is a permanently installed component on DIII-D and is positioned for a standard plasma configuration.

Because negative triangularity plasmas place heat exhaust outside of the installed divertor region, DIII-D's interior required a special modification. To enable the research campaign at DIII-D, the research team completed an engineering project to design and install special armor tiles to provide sufficient protection and create a temporary divertor region.

Designed to be one of the most flexible research tokamaks in the world, DIII-D is uniquely capable of accommodating changes to its interior and plasma configurations. Once the armor was in place, the campaign was able to run for four weeks in January and February 2023. The full month of experiments produced 178 run hours (22 percent of the 800 planned run hours throughout the calendar year).

International Collaboration: Participants joined the research campaign from eight universities, four national laboratories, GA, and several international institutions, including the Swiss Federal Institute of Technology Lausanne, Germany's Max Planck Institute for Plasma Physics, and Japan's National Institute for Fusion Science.

"The negative triangularity research team deserves a lot of credit for their planning and execution of this research campaign," said Dr. Richard Buttery, Director of the DIII-D National Fusion Facility. "As an Office of Science user facility, our goal is to deliver cutting-edge science for the world. This collaboration is a perfect illustration of what we can do when we bring different voices together from around the world to tackle a specific challenge."

The research team was led by Dr. Kathreen Thome, a GA Scientist stationed at DIII-D, and **Prof. Carlos Paz-Soldan**, Associate Professor of Applied Physics at Columbia University's School of Engineering. Prof. Paz-Soldan recently served as the co-lead for a collaboration between Columbia University and the Massachusetts Institute of Technology (MIT), facilitating a graduate-level fusion reactor design course in which students designed fusion reactors leveraging negative triangularity for electricity production.

"In my entire time working at DIII-D, I have never seen the research team come together like this," said Dr. Thome. "From our incredible engineers who made this campaign possible, to our world-class operations and science groups, this was an international team effort from top to bottom. It was truly special to be part of it. I know the entire team is very excited to dive into the results."

"Our campaign consisted of several experiments each targeting an important part of tokamak plasma physics, and our team benefited from great expertise on all fronts," said Prof. Paz-Soldan. "We were able to gather data to push the limits of the plasma's behavior in this unique configuration, and to understand how all the pieces fit together into a successful fusion reactor operating regime. It was an honor to help realize the campaign."

Dr. Max Austin, a DIII-D Scientist affiliated with the University of Texas-Austin, served as the deputy research lead. "This campaign was unique. Everyone involved contributed their own individual expertise, and it was great to see the team work together to solve challenges in real time and ensure successful experiments," said Dr. Austin. **https://bit.ly/42tCQ9m**

First 'Worlds at Waste' Conference Takes an Interdisciplinary Look at Water in South Asia

Adam Sobel, Professor of Applied Physics and Applied Mathematics and of Earth and Environmental Sciences, presented at *The Worlds at Waste: The Crisis of Water in the Subcontinent* workshop on April 7, 2023. The purpose of the workshop, as outlined on the event announcement, was "to reflect on recent climate events that have caused massive displacement in southern Pakistan, northeastern and southwestern India and Bangladesh. It aims to bring together scientists and social scientists to help look through the lens of historical pasts, politics, and an embedded presents."

Sobel, who presented his work on urban floods, reflected on the role that convenings like these play on climate science. "I think what climate science needs is more engagement with the human issues that our science hinges upon," he said. "So much about climate is inextricable from all these other local, global, geopolitical, economic and cultural issues, because everything exists within a planet that has a climate. It's easy for our science to get separated from all of that. So, it's good to have events where we have interdisciplinary conversations. It's a cliché, but it's not easy to do it." (reported in the Columbia's Climate School's, *State of the Planet*). To learn more, see: **https://bit.ly/3nUhp23**

Sobel was also featured in the recent article, "Why hurricanes feel like they're getting more frequent" (NPR) **https://n.pr/3O7PyX6**

Topological Insulators Let Molecular Wires Grow Longer

Research that extends distance that current travels along organic molecules and opens a path to new types of tiny electronics (from Professor **Latha Venkataraman** and colleagues) was featured by Chemical & Engineering News. "Scientists have long dreamed of making molecular electronics, building one-dimensional strings atom by atom to create new circuits even smaller than today's tiniest silicon structures. Shrinking silicon circuits has led to vast increases in computer chip power, and molecular wires could be the next advance. One hurdle has been that molecular wires become insulating and stop carrying current after a very short distance, shorter than the length they'd need to be for most practical devices. Now, scientists have shown they can overcome that limit, making wires that carry current along more useful lengths." (by Neil Savage, C&EN)

Liang Li, Shayan Louie, Austin M. Evans, Elena Meirzadeh, Colin Nuckolls, and Latha Venkataraman, "Topological Radical Pairs Produce Ultrahigh Conductance in Long Molecular Wires," ***J. Am. Chem. Soc.*** **2023, 145, 4, 2492–2498. January 23, 2023, https://doi.org/10.1021/jacs.2c12059**

Workshop on Computational Quantum Thermodynamics

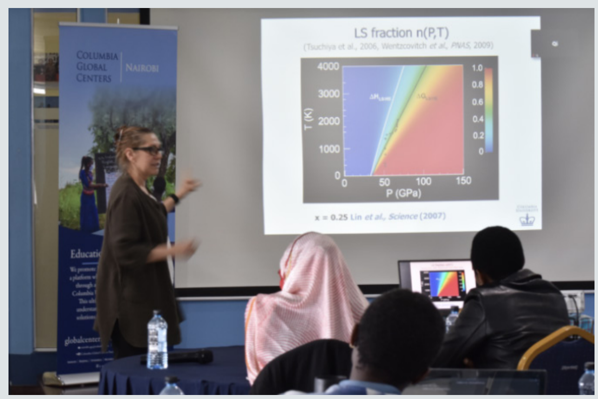
Organized by Professors Renata Wentzcovitch, George Amolo, and Michael Atambo, Columbia Global Center in Nairobi and Technical University of Kenya

Renata Wentzcovitch, a Professor of Materials Science and Engineering in the Department of Applied Physics and Applied Mathematics and the Department of Earth and Environmental Sciences, Lamont-Doherty Earth Observatory at Columbia University, in collaboration with Professors George Amolo and Michael Atambo from the Technical University of Kenya led the Workshop on Ab initio Quantum Thermodynamics. The workshop also counted on the contribution of Dr. Pietro Delugas from the Scuola Internazionale Superiore di Studi Avanzati, SISSA, from Trieste, Italy. He led the lectures of the Quantum ESPRESSO, the software used for ab initio computations. Prof. John Perdew from Temple University also gave two lectures on the fundamentals of Density Functional Theory and its cutting-edge applications. Lectures on methods for quantum thermodynamics and thermoelasticity were given by Zhen Zhang, Chenxing Luo, and Qi Zhang from Columbia University.

Fifteen material physicists from Kenya and Tanzania attended the workshop hosted by the Columbia Global Center in Nairobi. Funding was provided by the US-Africa Initiative in Electronic Structure (USAfrI), one of the inaugural Innovation Fund Awards of the American Physical Society. USAfri aims to create a platform for exchange between African and U.S. physicists with opportunities to have a major impact on African research and education.

The workshop aimed to introduce computational approaches based on ab initio methods to compute complex materials' thermodynamic and thermoelastic properties at extreme pressure and temperature conditions. These techniques have proved predictive at the extreme conditions of planetary interiors, such as Earth's interior, where pressure and temperature reach 3.6 Mbar and over 6,000 K at its very center. Only such approaches can investigate in detail materials properties that can shed light on the nature of such interiors. These materials simulation approaches have transformed the field of Computational Mineral Physics and its Geophysics Applications. Despite their reach, these techniques apply to ordinary materials in cryogenic and ambient conditions where they are more easily validated.

This workshop fostered the development of collaborations between U.S. and African scientists and students while leveraging the position of the Columbia Global Center in Nairobi. More details about the workshop can be found at **http://mineralscloud.com/events/2022/workshop-thermodynamics**



Professor Renata Wentzcovitch lecturing on spin crossovers in iron bearing phases at extreme conditions

Conference participants (left to right) 1st row: Stephen Chege, Kiptiemoi Korir, Leah Wairimu, Perpetua Wanjiru, Gladys King'ori, Carolyne Bakasa, George Amolo, Mariamu Ali, Renata Wentzcovitch, Catherine Pascal. 2nd Row: Bill C. Oyomo, Charles Rotich, Michael O. Atambo

Celebrating the Life & Legacy of C.K. "John" Chu (1927-2023)

Friends, family, alumni, and colleagues joined together for a memorial service and reception on Saturday, April 29, 2023, to celebrate the life and legacy of **Chia-Kun (John) Chu**, the Fu Foundation Professor *Emeritus* of Applied Mathematics at Columbia Engineering.

The event featured reflections from colleagues including **Shih-Fu Chang**, Dean of the Fu Foundation School of Engineering and Applied Science; **Marc Spiegelman**, Chair of the APAM Department; **Gerald Navratil**, the Edison Professor of Applied Physics in the APAM Department; and **David Keyes**, the Founding Dean of Mathematical and Computational Sciences at KAUST. Reflections and memories were also shared by two of Professor Chu's former students, **Ralph Izzo PhD '81** and **Yurij Baransky PhD '87** as well as members of the Chu family, including **Barbara Chu**, **Beatrix Chu**, and **Benjamin Eckersley**. Family members also shared eulogies from **Martin Goldstein, MD**, and **Sin-Ming Shaw, PhD '71**. Special musical offerings provided by **Dr. Yeou-Cheng Ma**, violin, and **Christopher Johnson**, organ.

Professor Chu's work in fluid dynamics, magnetohydrodynamics, and shock waves garnered him international recognition while his zeal for his life's work prompted him to work tirelessly to create a home for applied mathematics at Columbia University. He is one of only seven mathematicians to receive an Honorary Doctor of Science Degree in Columbia's 252-year history.

Professor Chu was born in Shanghai in 1927. He graduated in 1944 from St. John's University High School, where the curriculum was half Chinese and half English. He was accepted at St. John's University but decided to take the entrance examination for Chiaotung (now Jiaotong) University, the national science and engineering university.

In 1959, he became the first Chinese student to receive a PhD from Courant Institute. He taught at Pratt Institute and NYU Engineering before joining the Columbia Engineering and Applied Science faculty in 1963 as a visiting research scientist in the plasma physics laboratory. He was granted tenure at Columbia and was named a full professor in 1968. He was one of the original nine members of the faculty of the Department of Applied Physics and Nuclear Engineering; he served as the chair of the Plasma Physics Committee from 1966-1967, 1970-1971, and 1974-1977; and was chair of the Applied Mathematics Committee from 1978-2003. He also served as Chair of the Department of Applied Physics and Nuclear Engineering from 1982-1983, 1985-1988, and 1995-1997.

In 1999, he was named Fu Foundation Professor of Applied Mathematics. As a theoretician working with plasma physics, he was delighted when then dean Peter Likins asked him to form a new program in applied mathematics as a successor to the Mathematical Methods program already functioning well under Prof. Morton Friedman. Its first home was in Applied Physics and, in 1997, the name of the department was changed to Applied Physics and Applied Mathematics, fully recognizing the program. Professor Chu was key in promoting the endowment that established the Fu Foundation School of Engineering and Applied Science. This endowment spurred the expansion of the School, and its rise in prominence.

He was named a John Simon Guggenheim Foundation Fellow from 1971-1972, a Fellow of the American Physical Society in 1971, and Fellow of the Japan Society Promotion of Science in 1979. He was listed in Who's Who in America in 1983 and was a Sherman Fairchild Distinguished Scholar at Caltech in 1984. He was named an Advisory Professor at Shanghai Jiao Tong University in 1985, an Honorary Research Professor at the Institute of Mechanic from the Academia Sinica in 1988, the Wei Lun Foundation Lecturer at the Chinese University of Hong Kong in 1991, and an Honorary Professor of Mechanical Engineering at Hong Kong University in 1993. He received Columbia University's Great Teacher Award in 1985.

Professor Chu, whose advice and guidance helped hundreds of students for more than four decades, retired in 2003 but he continued to maintain contact with most of his 24 PhD students and many of his former undergraduate students. He was awarded an Honorary Doctor of Science Degree from Columbia University in 2006 and was recognized by the Asian Columbia Alumni Association (ACAA) at their 20th Anniversary Gala in 2016.

Professor Marc Spiegelman

Dean Shih-Fu Chang

Dr. Ralph Izzo '81

Dr. Yurij Baransky '87

Barbara Chu and Dr. Yeou-Cheng Ma
Photo credits: Barbara Alper

Videos and photos are available online at:
https://www.apam.columbia.edu/memorial-service-professor-ck-chu

In Memoriam: Maurice V. “Moe” and Dolores Cea

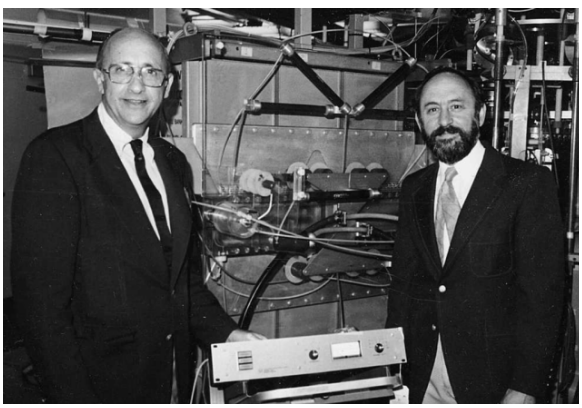
A Tale of Two Columbia Families by Christine Cea

Train. Ferry. Train. For 43 years **Maurice V. “Moe” Cea** commuted from his home on Staten Island to Columbia University – more than an hour and a half. And, yet he rarely missed a school play, a dance recital, a track meet, or a family dinner. Dedicated and devoted. That was Moe. Dedicated to his work at the School of Engineering’s Plasma Physics Laboratory, to its students and its faculty. Devoted to his family: **Dolores**, his wife of 62 years; daughter **Christine** (Barnard ’83, Columbia Graduate School of Arts and Sciences ‘85); son **Steven** (Columbia College ’85); and son **Robert** (Columbia College ’86, Columbia Business School ’97), who was named after Plasma Laboratory Founder **Dean Robert “Bob” Gross**; and five grandchildren.

To all who knew them, Moe and Dolores were good people and good to people. Moe, Manager of the Plasma Laboratory until his retirement in 1999, passed away in September 2022 and Dolores, facility manager for the Columbia Department of Mathematics from 1988–2005, in December 2022. In aggregate, the Cea family spent 75 years working and studying at Columbia, educations made possible by Moe’s years of service to and status as an Officer of the University. Moe worked on the first tokamak, which began as a series of experiments that continue to present day and are now achieving unprecedented breakthroughs.

Born in the Bronx to Italian immigrants, Moe grew up in Brooklyn. A “club king” who loved Latin dances, he met Dolores West Side Story-style at a school dance. A consummate sportsman, as a teenager he became hooked on his lifelong love of fishing on the piers of Coney Island and played roller hockey in the streets of Bensonhurst. Moe was the Physical Training champion at his Army Basic Training camp and played baseball while serving in post-war Korea. He ran the NYC Marathon six times and took Christine for Daddy-Daughter dates to see the Lions play (and mostly lose) at Bakers Field. The family spent their summer vacations camping – and fishing – all across America.

And how much did Moe love to laugh. He never met a pun he didn’t like and had a revolving repertoire of what are now called “Dad jokes” and guffaw-inducing stories. When thinking about Moe, you can’t help but hear his laugh. Moe believed in “better” – the better nature of people and how to make his and other lives better through learning, nutrition, respect for others, personal growth, and optimism. As a student once wrote to him: “Moe, you could hold a conversation on just about anything.”



Dean Robert Gross and Maurice “Moe” Cea

Upon his retirement, tributes poured in:

Robin Motz, who along with Bob Gross, Ben Eastlund, Ben Miller and Moe, worked together in the basement of the Mudd building, recalled that “the graduate experimental students did a lot of running around, while you tried to ‘keep the faith,’ and supervise the building of everything with calm reassurance.”

Raed Kombargi (Ph.D. Applied Physics, MA Philosophy, MS all from Columbia) wrote “you have taught me, and many others before me, technical skills, but more important than that, you have showed us through your actions how to be caring human beings. And at the end, that is all that matters. If I had to summarize your qualities, I would say that having known you made me a better person.”

Phil Efthimion (B.S., Columbia University; M.S., Columbia University; Ph.D., Columbia University) wrote how “it is hard to imagine the Plasma Physics Lab without you. So many of us alumni owe you a great amount of gratitude for your help when we were struggling to complete our experimental work. When we needed a hand or technical advice you were there to help. Not only because it was your job, but it was clear that you cared for the students. The plaque listing the Laboratory’s graduates is not just an indication of the Department’s growth and success, but it also a testament to your support and dedication.”

Thomas C. Marshall, the late Professor *Emeritus* of Applied Physics, thanked Moe for his “dedication to making the Plasma Laboratory not only a first-class place to do research, but also in making it a pleasant place to work as well, with a spirit of cooperation that all our students remember fondly. This is not just a happy coincidence; it is also rather uncommon, it just didn’t happen by accident, and you deserve credit for helping to make it happen.”

That was, and will always be, Moe: An uncommon common man who made things happen. Who cared. Who loved “the lab” and his family beyond measure. And, who made us all laugh – and better people.

Welcoming the New APAM Director of Career Placement

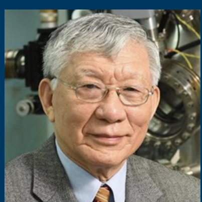
The Applied Physics and Applied Mathematics Department warmly welcomes a new staff member to our administrative team!

Emily-Anne McCormack is the Director of Career Placement for the APAM, Civil Engineering, and Mechanical Engineering Departments at Columbia Engineering. She works closely with students to provide a specialized approach to professional development while also leading industry outreach to develop mutually beneficial partnerships with companies who would like to engage with Columbia students.

Faculty Updates, continued

New Faculty Open Course: Pets, Politics and Pandemics

Prof. Simon Billinge launched a new open course on Coursera. The course description states, "This course is designed to be a fun and accessible introduction to the topic of systems theory. Systems theory describes a number of fundamental concepts that undergird a broad array of phenomena across many different social, political and natural arenas. It is from this broad applicability that the course derives its title: Pets (social), politics (political and economic) and Pandemics (natural). Despite being, hopefully, fun, the course has a serious intent as it aims to teach enough systems theoretical methods so that after taking the course the student can apply it to their own life to gain new insights into things they may have been studying already for a while. The material within this course can be applied across broad contexts, such as making difficult choices and communicating your ideas effectively to peers. After all, there are indeed strategies for navigating situations in life with the help of lessons from science. In the course, with the help of Professor Billinge's dogs, we will grapple with social justice, climate change, propaganda and disinformation, the origin of the unidirectionality of time and watch some relaxing views of birds flying around with nice music playing." Learn more at https://www.coursera.org/learn/pet-politics-and-pandemics



Chen Presents Short Course for World Voice Day

Dr. Julian Chengjun Chen recently gave a short course on The Transient Theory of Human Voice Production, to celebrate World Voice Day (April 16, 2023) at the Voice Study Centre in Bergholt, England, UK. World Voice Day is an annual celebration established by the Voice Committee of the American Academy of Otolaryngology - Head and Neck Surgery. The transient theory of human voice production and applications were detailed in Prof. Chen's monograph Elements of Human Voice (2017). According to ResearchGate, now it has 6035 reads and 14 citations. His monograph was intended to replace the 50+ year old orthodoxy, the source-filter theory of human voice production, with a transient theory of human voice production, initially formulated by Leonhard Euler in 1727. Dr. Chen's invitation to present a graduate-level course on the occasion of World Voice Day highlights his contributions to the academic community. Because the audience was likely not familiar with physics and mathematics, his entire presentation was made with graphics, rather than equations. Only high-school level mathematics and physics--the concept of energy conservation--were mentioned. A video of the presentation is available for anyone interested, including those outside of APAM: for example, students majoring in vocal music, physiology, or medicine. https://bit.ly/42RIpOr

Contact Us

We'd love to hear from you and stay connected! Follow us on social media and please send your news and updates to
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