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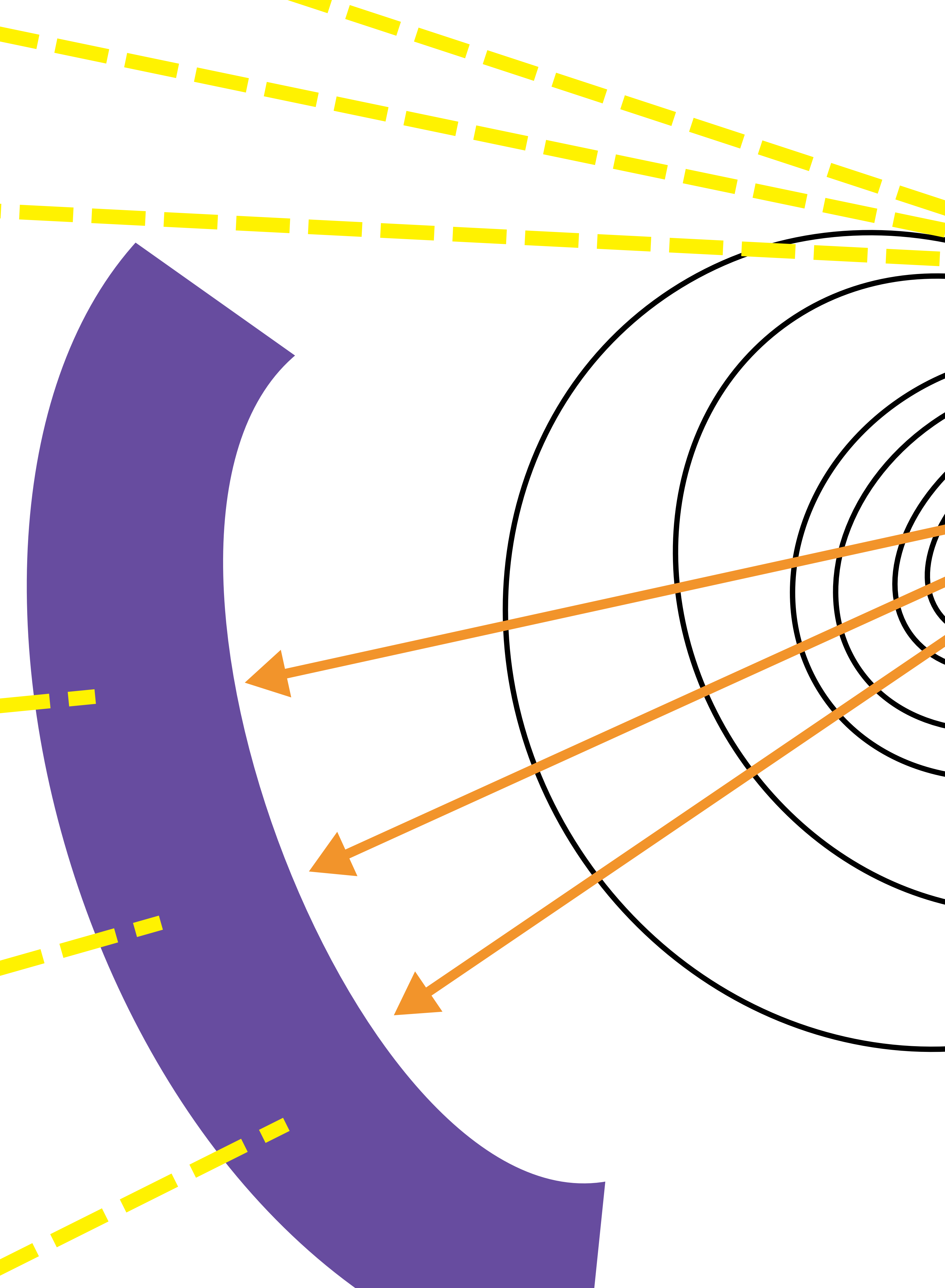
DEPARTMENT OF PHYSICS
MASSACHUSETTS INSTITUTE OF TECHNOLOGY



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Cover designs adapted from figures in Prof. Ronald Garcia Ruiz's (exterior covers) and Prof. Kiyo Masui's (inner covers) features.

Message from the Department Head

DEAR MIT PHYSICS COMMUNITY MEMBERS,

This issue of *physics@mit* includes three major feature articles. **Professor Kiyoshi Masui** discusses fast radio bursts: enigmatic, brief flashes of cosmic radio emission observed from all over the sky. **Professor Ronald Garcia Ruiz** discusses laser spectroscopy of short-lived radioactive nuclei, and how this innovative technique can be used to probe a major open question in fundamental physics. Third, **Prof. Lindley Winslow, Associate Department Head**, profiles the career of the late **Prof. Vera Kistiakowsky** (1928–2021), who became the first woman appointed to the MIT Physics faculty in 1971.

Many of our alumni will remember senior lecturer **Dr. Peter Dourmashkin**, who has retired after 40 years of teaching freshman physics at MIT, including 24 years co-leading the Department's TEAL (Technology Enabled Active Learning) classes for 8.01 and 8.02. At the same time, we welcome three new faculty members to the Department: **Profs. Kevin Burdge** (Astrophysics), **Brooke Russell** (Particle Physics), and **Shu-Heng Shao** (High Energy and Particle Theory). In addition, six of our current faculty received promotions this year, including awards of tenure to **Profs. Phil Harris** (Particle Physics), **Erin Kara** (Astrophysics), and **Maxim Metlitski** (Condensed Matter Theory). On a sad note, we mourn the passing of four retired faculty members: **Profs. Hale Bradt** (Astrophysics), **Lee Grodzins** (Nuclear Physics), **Earle Lomon** (Theoretical Physics), and **Daniel Kleppner** (Atomic Physics), as well as retired senior research scientist **Dr. Edwin Taylor**, a long-time member of our Physics Education Group.

This year, we received over 2,000 applications to our PhD program for the first time, a record for the Department. We extended 67 offers of admissions, and 40 students accepted our offer. We will have a total of around 300 graduate students in our program. We also have approximately 200 undergraduate Physics majors.

As I write this, significant cuts to federal funding for basic research in science are being considered in Washington. Robust federal support for science, awarded through competitive review, has been foundational to our mission for decades, enabling both breakthrough discoveries and the training of the next generation of researchers. I believe such support is in the national interest. In the long term, the Department will have to adapt to whatever funding equilibrium eventually emerges. However, we worry about the short-term risk to current students, postdocs, and junior faculty working on projects whose federal support might be abruptly reduced or canceled in mid-stream.

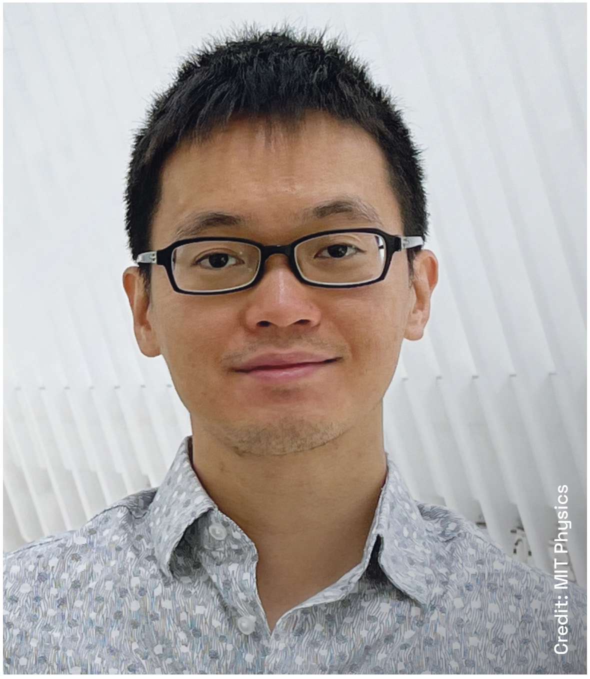

Credit: Steph Stevens

In recent years, we have been very lucky to be able to recruit—and retain—some of the best physicists in the world to be our students, postdocs, and faculty. It is a testament to the Department's positive, stimulating, and collaborative environment and to the support that the Department has been able to offer. The tools that help enable this support—graduate fellowships, postdoctoral fellowships, junior faculty startups, senior faculty retentions—are largely funded through gifts from our alumni, parents, and friends. This generous support has always been critical to our recruitment success and our strength as a department. It is more important than ever today. Gifts in any amount to our Physics Unrestricted Fund (#2657500) or our Alumni Fellowship Fund (#2738023) are helpful. Please consider supporting the Physics Department! For more information, please contact our Senior Director of Development, **Erin McGrath Tribble**, at 617-452-2807, or *emcgrath@mit.edu*.

With best regards,

DEEPTO CHAKRABARTY
William A. M. Burden Professor of Astrophysics
Head, Department of Physics

New Faculty



July 2024

Shu-Heng Shao

Assistant Professor of Physics,
MIT Center for Theoretical Physics –
A Leinweber Institute

Research Interests

Shu-Heng Shao explores the structural aspects of quantum field theories and lattice systems. Recently, his research has centered on generalized symmetries and anomalies, with a particular focus on a novel type of symmetry without an inverse, referred to as non-invertible symmetries. These new symmetries have been identified in various quantum systems, including the Ising model, Yang-Mills theories, lattice gauge theories, and the Standard Model. They lead to new constraints on renormalization group flows, new conservation laws, and new organizing principles in classifying phases of quantum matter.

Biographical Sketch

Shu-Heng Shao was born and raised in Taiwan. He obtained his BS in physics from National Taiwan University in 2010 and his PhD in physics from Harvard University in 2016, under the direction of Prof. Xi Yin. He was then a five-year member of the Institute for Advanced Study at Princeton University before he moved to the Yang Institute for Theoretical Physics at Stony Brook University as an assistant professor in 2021. In 2024, he joined the MIT Physics faculty.

For a list of Prof. Shao's selected publications, as well as recent awards and honors, please visit his faculty web page at: *physics.mit.edu/faculty/shu-heng-shao/*.

July 2025

Kevin Burdge

Assistant Professor of Physics,
MIT Kavli Institute for Astrophysics and Space Research

Research Interests

Kevin Burdge is an observational astrophysicist focused on discovering and characterizing compact binary systems—pairs of stellar remnants such as white dwarfs, neutron stars, and black holes. These systems provide exceptional laboratories for exploring compact-object physics, accretion processes, stellar evolution, and explosive cosmic events, including Type Ia supernovae.

His research leverages next-generation observatories, including the Vera Rubin Observatory, the Nancy Grace Roman Space Telescope, and the upcoming Laser Interferometer Space Antenna (LISA), to discover and study large, diverse populations of compact binaries. By combining gravitational-wave detections with multi-wavelength electromagnetic observations, Burdge and his group aim to understand how these systems form, evolve, and influence their cosmic environments. His team has significantly expanded the known population of gravitational-wave sources detectable by LISA, identifying rare binary systems and exotic merger remnants that offer unique opportunities to test general relativity and models of binary evolution. This discovery-driven work is supported by innovative GPU-based algorithms developed by his group.

Burdge has also used Gaia astrometry to discover the first known black hole in a triple-star system and maintains a strong interest in X-ray binary systems. Additionally, he develops specialized astronomical instrumentation, such as the ultrafast "Lightspeed" camera for the Magellan telescopes, enabling rapid photometric studies of faint, fast astrophysical phenomena. He is pioneering time-domain research with the James Webb Space Telescope, investigating dense stellar environments like globular clusters and the Galactic center to uncover hidden populations of compact binaries. Burdge is a member of the science team for the Advanced X-ray Imaging Satellite (AXIS), where he led the design of a proposed Galactic-plane survey expected to reveal over a million new X-ray sources.

Biographical Sketch

Kevin Burdge is a first-generation college graduate, growing up in Heidelberg, Germany, as part of the U.S. military community stationed there. In 2010, following an internship at the Max Planck Institute for Nuclear Physics, he participated in the Research Science Institute at MIT, conducting research under the mentorship of MIT Physics professor Hong Liu. Inspired by this formative experience, he pursued undergraduate studies at MIT, earning his SB in physics in 2015. At MIT, Kevin discovered a passion for experimental astrophysics through his experience in Junior Lab with Profs. David Pritchard and Christoph Paus, and he completed his senior thesis under Prof. Peter Fisher.

In 2015, Kevin began his PhD studies in physics at the California Institute of Technology. Initially focused on quantum optics, his interests shifted decisively to astrophysics, influenced by coursework in stellar astrophysics. He completed his doctorate in 2021 under the supervision of Prof. Tom Prince, collaborating closely with Profs. Jim Fuller and Shri Kulkarni.

Upon completing his PhD, Kevin returned to MIT as a Pappalardo Postdoctoral Fellow from 2021 to 2024, subsequently serving as a postdoctoral associate until joining the MIT Physics faculty in July 2025.

For a list of Prof. Burdge's selected publications, please visit his faculty web page at: *physics.mit.edu/faculty/kevin-burdge/.*


Credit: MIT Physics

Brooke Russell

Assistant Professor of Physics,
Laboratory for Nuclear Science

Research Interests

Brooke Russell is an experimental nuclear and particle physicist. Her research focuses on elucidating the landscape of beyond the Standard Model (BSM) physics brought about by massive neutrinos. Neutrinos are the most abundant massive particle in the universe. Ubiquity notwithstanding, much remains unknown about their underlying properties. With the DUNE experiment, the Russell group aims to make high precision measurements of neutrino mixing to provide unique insights into fundamental neutrino properties.

The Russell group research focus also highlights the mystery of the particle nature of dark matter. The group is searching for low mass particle dark matter using quasiparticle detectors in the underground Kamioka Cryolab. Leveraging quantum sensing device readout coupled to varying detector payloads, the group is targeting model-complementary dark matter searches below the GeV-scale, a region of parameter space largely eluded by traditional weakly interacting massive particle detection limits.

Biographical Sketch

Brooke Russell earned her AB in physics from Princeton University in 2011 and her PhD in physics from Yale University in 2020. She was an Owen Chamberlain Postdoctoral Fellow at Lawrence Berkeley Lab from 2020 through 2023. In 2024, she joined MIT as the Neil and Jane Pappalardo Special Fellow in Physics. Brooke joined the MIT Physics faculty in July 2025 as an assistant professor.

For a list of Prof. Russell's selected publications, please visit her faculty web page at: *physics.mit.edu/faculty/brooke-russell/*.

Faculty & Staff Notes

Honors + Awards

Edmund Bertschinger, Professor of Physics, received the Alan J. Lazarus '53 Excellence in First Year Advising Award.

Robert Birgeneau, Professor of Physics Emeritus, was named a Fellow of the Fields Institute for Research in the Mathematical Sciences.

Cari Cesarotti, Postdoctoral Associate, received the 2024 Leona Woods Lectureship Award from Brookhaven National Laboratory.

Deepto Chakrabarty '88, Department Head of Physics, has been named the William A. M. Burden Professor of Physics.

↓ **Joseph Checkelsky**, Professor of Physics, was named a Fellow of the American Physical Society (2024).

Soonwon Choi was named the Victor F. Weisskopf Career Development Assistant Professor of Physics.

Isaac Chuang has been named the Julius A. Stratton Professor of Electrical Engineering and Physics.

↓ **Riccardo Comin**, Associate Professor of Physics, received the Wilhelm Bessel Research Award from the Humboldt Foundation.

Bruno Coppi, Professor of Physics Emeritus, was the Lectio Magistralis for the Opening of the 2024–25 Academic Year at the ISTAO Institute of Economics, Italy.

Blaise Delaney, Postdoctoral Associate, received the Seal of Research Excellence by the European Commission.

Peter Dourmashkin, Senior Lecturer, received a 2025 MIT School of Science Infinite Mile Award.

↓ **Netta Engelhardt**, Associate Professor of Physics, received the Presidential Early Career Award in Science and Engineering (PECASE).

Peter Fisher, Thomas A. Frank (1977) Professor of Physics, and **David Kaiser**, Professor of Physics and Germeshausen Professor of the History of Science, received the MIT Bose Research Award for "Cosmic Close Encounters: Novel Strategies for Detecting Primordial Black Holes."

Liang Fu, Professor of Physics, was named a 2024 Highly Cited Researcher (Clarivate).


Joseph Checkelsky

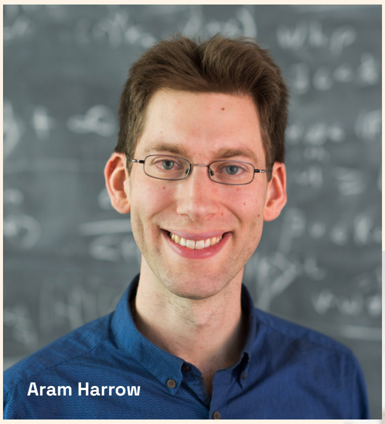

Riccardo Comin


Netta Engelhardt

Credits: Steph Stevens (Checkelsky); Cody O'Loughlin / MIT News (Comin); Adam Glanzman (Engelhardt)


Kiyoshi Masui


Sarah Millholland


Aram Harrow


Pablo Jarillo-Herrero

Credits: Justin Knight Photography (Harrow); L. Barry Hetherington (Jarillo-Herrero)

Ronald F. Garcia Ruiz was named the Thomas A. Frank Career Development Associate Professor of Physics.

↑ **Aram Harrow**, Professor of Physics, received a Fulbright Scholar Award (Spain); and a "Test of Time" Award from the FOCS conference.

↑ **Pablo Jarillo-Herrero**, Cecil and Ida Green Professor of Physics, was elected an Honorary Fellow of the European Academy of Sciences and a Member of the Royal Academy of Sciences and Arts of Barcelona, Spain; and was awarded the Lars Onsager Lecture and Medal, Norwegian University of Science and Technology.

Leah Kahn, former Physics Academic Programs Office Course Manager, received a 2025 MIT School of Science Infinite Mile Award.

Mehran Kardar, Francis Friedman Professor of Physics, received the 2025 Physical Review Boltzmann Medal.

Ho Tat Lam, Postdoctoral Associate, received a Frontier of Science Award.

Benjamin Lehmann, Pappalardo Fellow, Center for Theoretical Physics – A Leinweber Institute, received a 2025 MIT School of Science Infinite Expansion Award.

↑ **Kiyoshi Masui**, Associate Professor of Physics, was awarded the Buchalter Cosmology Prize (First Prize) of the American Astronomical Society, for the CHIME Collaboration for "Detection of Cosmological 21cm Emission with the Canadian Hydrogen Intensity Mapping Experiment"; received the Marcel Grossmann Award, International Center for Relativistic Astrophysics Network, for the CHIME/FRB Collaboration; received the North America Top Cited Paper Award in Astronomy and Astrophysics, IOP Publishing, for the CHIME/FRB Collaboration for "The First CHIME/FRB Fast Radio Burst Catalog."

↑ **Sarah Millholland**, Assistant Professor of Physics, was awarded a 2025 Sloan Research Fellowship; and received the UROP Outstanding Faculty Mentor Award.

→ **Jagadeesh S. Moodera**, Senior Research Scientist, was elected a Fellow of the American Association for the Advancement of Science (2024).

Krishna Rajagopal, William A. M. Burden Professor of Physics, received the 2025 Arthur C. Smith Award.

→ **Phiala Shanahan**, Associate Professor of Physics, was awarded a 2024 Loeb Lectureship, Harvard Department of Physics.

Shu-Heng Shao, Assistant Professor of Physics, received two Frontier of Science Awards, given by the International Congress of Basic Sciences (ICBS).

Robert Simcoe, Francis L. Friedman Professor of Physics, and Director, MIT Kavli Institute for Astrophysics and Space Research, received the Muhlman Award, Astronomical Society of the Pacific, for "Excellence in science enabled by innovative instrumentation."

Tracy Slatyer, Professor of Physics, and Director, Center for Theoretical Physics – A Leinweber Institute, received the 2024 Jon C. Graff Prize for Excellence in Science Communication; a Guggenheim Fellowship; a Radcliffe Fellowship; and named as one of "Science News 10: Scientists to Watch."

Marin Soljačić '96, was named the Cecil and Ida Green Professor of Physics; and named a Highly Cited Scientist by Web of Science (2024).

Julien Tailleur, Associate Professor of Physics, received the 2025 Tel Aviv University Prize in Biophysics.

Samuel C. C. Ting, Thomas Dudley Cabot Professor of Physics and Nobel Laureate (1976), received a Basic Science Lifetime Award, ICBS 2025.

Senthil Todadri has been named the William and Emma Rogers Professor of Physics; was elected to the National Academy of Sciences (2024); received the Distinguished Alumnus Award, Indian Institute of Technology, Kanpur (2024); was named a Highly Cited Researcher, Physics, Clarivate Web of Science (2024); and received a 2025 Frontier of Science Award.

Mark Vogelsberger, Professor of Physics, was named a 2024 Highly Cited Researcher (Clarivate Analytics).

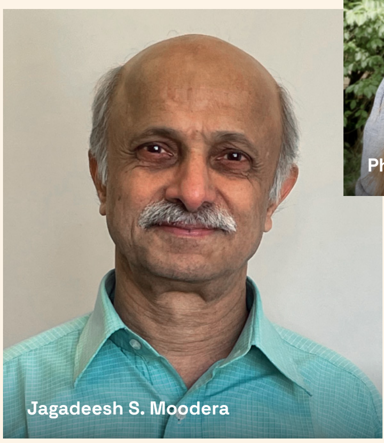
Vladan Vuletic, Lester Wolfe Professor of Physics, received the Arthur L. Schawlow Prize in Laser Science (2025); and was named Foreign Member of the Serbian Academy of Sciences and Arts (2024).

Bolek Wyslouch, Professor of Physics, and Director, Laboratory for Nuclear Science and Bates Research and Engineering Center; **Philip Harris**, Associate Professor of Physics; **Gian Michele Innocenti**, Assistant Professor of Physics; **Yen-Jie Lee**, Class of 1958 Career Development Professor of Physics; **Christoph Paus**, Professor of Physics; **Gunther Roland**, Professor of Physics and Division Head, Experimental Nuclear & Particle Physics; **Eluned Smith**, Assistant Professor of Physics; and **Michael Williams**, Professor of Physics, received the 2025 Breakthrough Prize in Fundamental Physics awarded to the LHC Collaborations (ATLAS, CMS, LHCb, and ALICE).

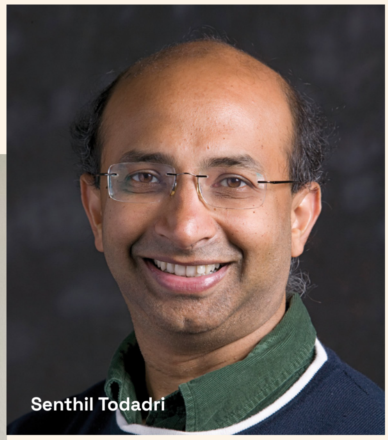
Martin Zwierlein, Thomas A. Frank (1997) Professor of Physics, was named a 2024 Winner in the Physical Sciences, Falling Walls Foundation.

Credits: Josep Ingla Aynes (Moodera); Darren Stahlman Photography (Todadri)


Phiala Shanahan


Jagadeesh S. Moodera


Julien Tailleur


Senthil Todadri

Promotions

Joseph Checkelsky to Full Professor of Physics.

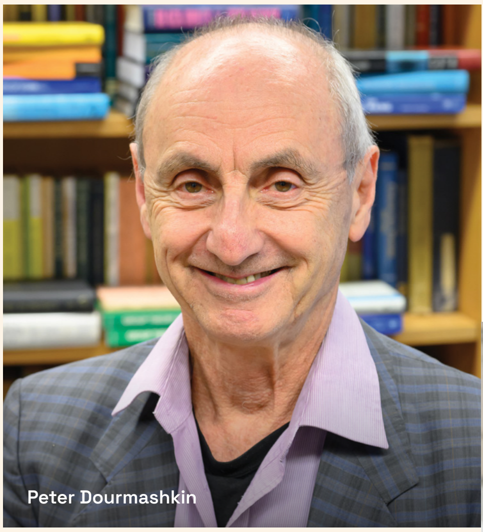
Ronald F. Garcia Ruiz to Associate Professor of Physics without tenure.

↑ **Philip Harris PhD '11** to Associate Professor of Physics with tenure.

Long Ju to Associate Professor of Physics without tenure.

↑ **Erin Kara** to Associate Professor of Physics with tenure.

↑ **Maxim Metlitski** to Associate Professor of Physics with tenure.



Peter Dourmashkin

Jacqueline Hewitt

Retirements

Peter Dourmashkin ’75, ’78, PhD ’84

Senior Lecturer; Co-Principal Investigator, Technology Enabled Active Learning (TEAL) [1984–2025]

Peter received three MIT degrees: two SBs, in physics in 1976 and in mathematics in 1978, and a PhD in physics in 1984. His teaching experience led him from MIT’s Experimental Study Group (ESG), Office of Minority Education (OME), and Integrated Studies Program (ISP), to the Physics Department and Technology Enabled Active Learning (TEAL). His awards include the Irwin Sizer Award for Most Significant Improvement to MIT Education and the Buechner Faculty Teaching Prize.

As a co-principal investigator on TEAL, Peter helped to redesign first-year physics education using interactive engagement teaching methods. Students have enthusiastically praised Peter’s ability to make first-year physics courses accessible and easier to understand, inspiring many to major in physics.

Credits: Justin Knight Photography (Dourmashkin and Hewitt)

Jacqueline Hewitt PhD ’86

Julius A. Stratton Professor of Physics Emerita [1989–2025]

Jacqueline Hewitt, PhD ’86, joined the faculty in 1989. She was a pioneer of wide-area surveys with the Very Large Array radio telescope, resulting in the discovery of the first Einstein ring gravitational lens. She continued to develop radio astronomy instrumentation to tackle new problems, most recently working on radio arrays in Australia and South Africa to study the cosmological Epoch of Reionization.

Hewitt directed MIT’s Center for Space Research, and led the establishment of the endowed Kavli Institute for Astrophysics and Space Research at MIT.

In 2012, *Time* magazine named her one of the 25 most influential people in space. Of all the honors she has received, she is particularly proud of the Edgerton Award, since it was bestowed by her fellow faculty members.

News & Events in Physics

Pappalardo Fellowships Program 25th Anniversary

Photography: Justin Knight Photography

On October 24, 2024, the Department celebrated the 25th anniversary of the Pappalardo Fellowships in Physics program. The event, co-directed by Physics Director of Administration and Finance **Matt Cubstead** and Senior Development Director **Erin McGrath Tribble**, with critical support from Events Coordinator **Reshma Ramaiah Rice** and Development Officer **Danielle Forde**, featured a symposium with talks given by five former Fellows and opening remarks by Prof. **Pablo Jarillo-Herrero**, Cecil and Ida Green Professor of Physics, a former Chair of the Pappalardo Fellowships Committee (2018-2021). Invited speakers included **Ashvin Vishwanath**, George Vasmer Leverett Professor of Physics, Harvard University (2001-2004 Fellow); **Jocelyn Monroe**, Professor of Particle Physics, University of Oxford (2006-2009 Fellow); **Nitya Kallivayalil**, Professor of Astronomy and Dean's Research Fellow, The University of Virginia (2007-2010 Fellow); **Benjamin Safdi**, Associate Professor of Physics, University of California, Berkeley (2014-2017 Fellow); and **Marin Soljačić**, Cecil and Ida Green Professor of Physics (2000-2003 Fellow).

Joining **Jane and Neil Pappalardo** and dozens of former Fellows—who arrived from Japan and California, Germany and the UK, Washington, D.C., and the other end of Mass. Ave. in Cambridge—were **Michael Pappalardo** and wife **Deirdre "Didi" O'Brien**, longstanding Physics Department supporters **Curt Marble** and **Howard and Colleen Messing**, as well as current Fellows and Department faculty.

Department Head **Deepto Chakrabarty** led a long round of applause for **Neil and Jane Pappalardo**, warmly thanking them for their generous founding gift and continued support that sustains the Pappalardo Fellowships in Physics as the Department's premier postdoctoral fellowship program. *(D. Forde)*

PAPPALARDO FELLOWSHIPS ANNIVERSARY GUESTS

1. Jane and Neil Pappalardo (*center*) surrounded by former and current Pappalardo Fellows attending the program's 25th anniversary celebration.
2. Jane (*far left*) and Neil Pappalardo (*center*) with symposium presenters (*from left*) Marin Soljačić, Ashvin Vishwanath, Benjamin Safdi, Nitya Kallivayalil, Jocelyn Monroe, and Pablo Jarillo-Herrero.
3. Curt Marble and former Assistant Dean for Development Elizabeth Chadis.
4. *From left*: Former Department Head Prof. Ed Bertschinger and Colleen and Howard Messing.
5. Deirdre "Didi" O'Brien and Michael Pappalardo.
6. *From left*: Neil Pappalardo and Professor of Physics Emeritus and Chancellor Emeritus, UC-Berkeley, Robert Birgeneau.
7. *From left*: Senior Director of Development Erin McGrath Tribble, Jane Pappalardo, and Colleen Messing.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SPEAKERS

Pablo Jarillo-Herrero, Cecil and Ida Green Professor of Physics, and former Chair, Pappalardo Fellowships Committee (2018–2021).

Invited speaker 2001–04 Pappalardo Fellow Ashvin Vishwanath, George Vasmer Leverett Professor of Physics, Harvard University.

Invited speaker 2006–09 Pappalardo Fellow Jocelyn Monroe, Professor of Particle Physics, University of Oxford.

Invited speaker 2007–10 Pappalardo Fellow Nitya Kallivayalil, Professor of Astronomy and Dean's Research Fellow, The University of Virginia.

Invited speaker 2014–17 Fellow Benjamin Safdi, Associate Professor of Physics, University of California, Berkeley.

Invited speaker 2000–03 Pappalardo Fellow Marin Soljačić, Cecil and Ida Green Professor of Physics, MIT.

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PAPPALARDO FELLOWSHIPS ANNIVERSARY GUESTS

1. Former School of Science Dean and Donner Professor of Science Emeritus Marc Kastner and Marcia Kastner.
2. 2007–10 Pappalardo Fellow Paola Rebusco, Physics Lecturer and Academic Officer, Experimental Study Group, MIT.
3. *From left*: 2000–03 Pappalardo Fellow Michael “Misha” Fogler, Professor of Physics, UC-San Diego; 2008–11 Pappalardo Fellow Yusuke Nishida, Professor of Physics, Institute of Science, Tokyo.
4. Department Head Deepto Chakrabarty ’88, William A. M. Burden Professor in Astrophysics.
5. 2008–11 Pappalardo Fellow Mustafa Amin, Associate Professor of Physics and Astronomy, Rice University.
6. *From left*: 2003–06 Pappalardo Fellow Matthew Headrick, Professor of Physics, Brandeis University; 2011–14 Pappalardo Fellow Silviu Pufu, Professor of Physics, Princeton University; 2014–17 Pappalardo Fellow Benjamin Safdi, Associate Professor of Physics, University of California, Berkeley.
7. *From left*: MIT Professor of Physics Ray Ashoori and 2012–15 Pappalardo Fellow Hugh Churchill, Professor of Physics and 21st Century Chair in Nanophysics, University of Arkansas.
8. *From left*: Harvard Postdoctoral Fellow Di Liu; 2024–27 Pappalardo Fellows Jens Hertkorn and Richard Nally.

2025–2028 Pappalardo Fellowships in Physics Competition

The Department's leading postdoctoral fellowship program, the Pappalardo Fellowships in Physics, completed its annual competition in January 2025 with the appointment of four Fellows.


Ross Dempsey

Ross Dempsey PhD '25 (**Princeton University**) works in high energy and particle theory, with a current focus on tools for making predictions about the observable data of strongly-coupled gauge theories. In particular, he is interested in simulating real-time processes, such as particle collisions. His graduate research at Princeton University was supervised by Prof. Silviu Pufu, a 2011–2014 Pappalardo Fellow.

Gillian Kopp PhD '24 (**Princeton University**) is an experimental particle physicist who develops novel detection and analysis methods to increase sensitivity to rare particle physics processes and to address outstanding questions in fundamental physics, such as the nature of dark matter. She works on the Compact Muon Solenoid (CMS) experiment at CERN, using this precision detector to probe physics beyond the known Standard Model.


Gillian Kopp


Patrick Ledwith

Patrick Ledwith '19, PhD '25 (**Harvard University**) is a theoretical condensed matter physicist who studies quantum many body systems. He is particularly interested in understanding and predicting collective properties that emerge from strongly interacting electrons. His graduate research at Harvard University was supervised by Prof. Ashvin Vishwanath, a 2001–2004 Pappalardo Fellow.


Xiaoyuan Zhang

Xiaoyuan Zhang PhD '25 (**Harvard University**) is a high energy and particle theorist whose work focuses on bridging quantum field theory with collider physics experiments using both perturbative quantum chromodynamics techniques and effective field theories.

For detailed biographies, including research descriptions and selected publications for all Pappalardo Fellows, please visit *physics.mit.edu/research/pappalardo-fellowships-in-physics/*. The MIT Pappalardo Fellowships in Physics program was initiated, and is sustained, by funds generously provided by **A. Neil** (**1964**) **and Jane Pappalardo**. *(C. Breen)*

California Trip

Physics Department Head and William A. M. Burden Professor in Astrophysics **Deepto Chakrabarty** '88 traveled to Palo Alto, CA, on March 6, 2025. At a breakfast reception at the Sheraton Palo Alto Hotel he introduced **Netta Engelhardt**, Associate Professor of Physics. She spoke on "Quantum Information as a Black Hole Escape Artist." Sixty-four alumni and friends gathered that morning to welcome the Physics Department. *(D. Forde)*

Spring 2025 Pappalardo Fellowships in Physics Annual Symposium

On April 3, 2025, the Pappalardo Fellowships in Physics program held its annual spring symposium, which features research highlights from both new and departing Fellows. This year's five featured speakers included Pappalardo Fellows Drs. **Jiaqi Cai**, **Sepehr Ebadi**, **Benjamin Lehmann**, **Richard Nally**, and **Brooke Russell**, with introductory remarks by **Or Hen**, Associate Professor of Physics, MIT, a 2015–2017 Pappalardo Fellow.

Joining Physics Department Head and William A. M. Burden Professor in Astrophysics **Deepto Chakrabarty** '88 and MIT Physics faculty, postdocs, and staff were program founder and benefactors **Neil and Jane Pappalardo**, son-in-law **Todd Lemke**, as well as longstanding Department friend and supporter alumnus **Curt Marble**.

Videos of all talks are available on the Department's YouTube page at: *youtube.com/@MITDepartmentofPhysics*. *(C. Breen)*

London Trip

On Wednesday, May 14, 2025, Department Head and William A. M. Burden Professor in Astrophysics **Deepto Chakrabarty** '88 hosted an evening talk at the IET London Savoy, featuring Professor **Robert Simcoe**, Francis L. Friedman Professor of Physics and Director of the MIT Kavli Institute for Astrophysics and Space Research. Professor Simcoe gave a talk on "Early Science in the Early Universe with the James Webb Telescope," to 58 alumni and friends of the Department. *(D. Forde)*

Patrons of Physics Fellows: 20th Anniversary

The Department celebrated the 20th Anniversary of the Patrons of Physics Fellows on April 7, 2025. Department Head and William A. M. Burden Professor in Astrophysics **Deepto Chakrabarty** '88 welcomed everyone back to this special celebration of our Patrons and the students they support. The following students gave talks: **Rosemary Zielinski, Whiteman Fellow**; **Kyle Devereaux, Lourie Fellow**; and **Maggie Kerr, Frank Fellow**. **Thomas Frank '77 (VIII), PhD '85 (VIII)** concluded the evening thanking the students for their impressive work and thanking all others present for supporting graduate fellowships in the Department. Also in attendance were **Alex Hastings**, **Dr. Neil Constable**, Donner Professor of Science Emeritus and former Dean **Marc Kastner and Marcia Kastner**, **Dr. Tomislav Kundic '91 (VIII)**, **Dr. Robert Lourie '82 (VIII), PhD '86 (VIII)**, **Dr. Chiyan Luo PhD '04 (VIII)**, **Curtis Marble '63 (VI)**, **Colleen and Howard Messing '73 (VI)**, and **Dr. Summer Zhang**. *(D. Forde)*

BELOW: Patrons of Physics 20th Anniversary celebration. Credit: Justin Knight Photography

BOTTOM: *From left*: Department Head Deepto Chakrabarty '88 (VIII), Alexandra Hastings, Tom Frank '77 (VIII), PhD '85 (VIII), and Maggie Kerr, Frank Fellow. Credit: Justin Knight Photography

Killian Faculty Achievement Award: John D. Joannopoulos

John D. Joannopoulos, the recipient of the 2024-2025 James R. Killian, Jr. Faculty Achievement Award, is the Francis Wright Davis Professor of Physics and director of the Institute for Soldier Nanotechnologies at MIT.

ABOVE: John D. Joannopoulos, Francis Wright Davis Professor of Physics; Director, MIT Institute for Soldier Nanotechnologies. Credit: Franklin E. W. Hadley

The Killian Award was established in 1971 to honor MIT's 10th president, James Killian. Each year, a member of the MIT faculty is honored with the award in recognition of their extraordinary professional accomplishments.

The 2024-2025 Killian Award citation states: "Professor Joannopoulos has been a consistent role model not just in what he does, but in how he does it....Through all these individuals he has impacted—not to mention their academic descendants—Professor Joannopoulos has had a vast influence on the development of science in recent decades."

"We recognize you as a leader, a visionary scientist, beloved mentor, and a believer in the goodness of people," said Mary Fuller, professor of literature and chair of the MIT faculty. "Your legendary impact at MIT and the broader scientific community is immeasurable."

In his lecture, which he titled "Working at the Speed of Light," Joannopoulos took the audience through the basic concepts underlying photonic crystals, and the ways in which he and others have shown that these materials can bend and twist incoming light in a controlled way.

Joannopoulos' theory, put forth in 1998, offered a new take on a type of material known as a one-dimensional photonic crystal. Photonic crystals are made from alternating layers of refractive structures whose arrangement can influence how incoming light is reflected or absorbed. The group proved in theoretical terms that, if a one-dimensional photonic crystal were made from layers of materials with certain "refractive indices," bending light to different degrees, then the crystal as a whole should be able to reflect light coming from any and all directions. Such an arrangement could act as a "perfect mirror."

The group focused the idea into a device: using the principles that they laid out, they effectively fabricated a perfect mirror and folded it into a tube to form a hollow-core fiber. When they shone light through, the inside of the fiber reflected all the light, trapping it entirely in the core as the light pinged through the fiber. In 2000, the team launched a startup to further develop the fiber into a flexible, highly precise and minimally invasive "photonics scalpel," which has since been used in hundreds of thousands of medical procedures including surgeries of the brain and spine.

Joannopoulos has helped found several startups, including Omniguide, along with Luminus Devices, Inc., WiTricity Corporation, Typhoon HIL, Inc., and Lightelligence. He is author or co-author of over 750 refereed journal articles, four textbooks, and 126 issued U.S. patents. He has earned numerous recognitions and awards, including his election to the National Academy of Sciences and the American Academy of Arts and Sciences.

Adapted from original feature by Jennifer Chu on MIT News online, with kind permission: *news.mit.edu/2025/dive-into-magical-potential-photonic-crystals-killian-lecture-0317.*

Student Honors & Awards: Undergraduate

TOP RIGHT: 2025 Alan H. Barrett Prize winner Donald (DJ) Liveoak. Credit: Justin Knight Photography

BOTTOM RIGHT: 2025 Morse/Orloff Award for Research winner Samuel (Sam) Christian. Credit: Justin Knight Photography

2025 Alan H. Barrett Prize

The prize honors the late Professor Alan H. Barrett's outstanding influence in the education of physicists and his fundamental contribution to the science and technology of astrophysics. One thousand dollars is awarded to a graduate or undergraduate student with outstanding research in astrophysics.

Donald (DJ) Liveoak SB '25

Academic Advisor: Mark Vogelsberger

The 2025 Morse/Orloff Award for Research

Given in memory of the late MIT Professor of Physics Philip Morse, one of the renowned physicists of the twentieth century, whose contributions spanned basic physics to engineering. Funds are generously provided by Dr. and Mrs. Daniel Orloff in memory of their son Joel, a Physics major, who died in an automobile accident shortly after graduation from MIT in 1978. One thousand dollars is awarded to one or more senior students of high academic standing who plan to pursue graduate studies in physics.

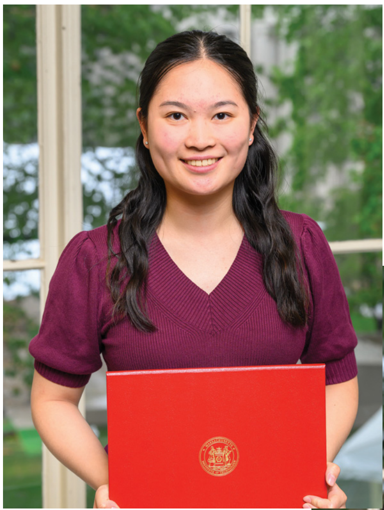
Samuel (Sam) Christian SB '25

Academic Advisor: Janet Conrad

2025 Burchard Scholars

The Burchard Scholars Program brings together distinguished members of the faculty and promising sophomores and juniors who have demonstrated excellence in some aspect of the humanities, arts, and social sciences, as well as in science and engineering. The program is sponsored by the Dean's Office, School of Humanities, Arts, and Social Sciences.

Abhay Bestrapalli '26
Yongao Hu '26
Layna Oberg '27
Jiwoo Park '26
Kartik Pingle '26
Braedon Rudolph '26



The 2025 Joel Matthew Orloff Awards

Established by Dr. and Mrs. Daniel Orloff in memory of their son Joel, a Physics major, who died in an automobile accident shortly after graduation from MIT in 1978. One thousand dollars is awarded to each winner.

SERVICE

Given to the student(s) with the most outstanding service to the Department, Institute, or community.

Karen Lei SB ’25

Academic Advisor: Joseph Checkelsky

SCHOLARSHIP

Given to the student(s) with outstanding scholastic achievement in physics.

Kayla O’Donnell SB ’25

Academic Advisor: Lindley Winslow

ABOVE LEFT: 2025 Joel Matthew Orloff Award for Service winner Karen Lei. Credit: Justin Knight Photography

ABOVE MIDDLE: 2025 Joel Matthew Orloff Award for Scholarship winner Kayla O’Donnell. Credit: Justin Knight Photography

ABOVE RIGHT: 2025 Order of the Lepton Award winner Antti Eero Asikainen. Credit: Justin Knight Photography

The 2025 Order of the Lepton Award

Awarded to a graduating senior who best exemplifies the spirit and characteristics of MIT’s Physics students. Established with gifts from alumni and friends of the Department, the Order of the Lepton embodies the community spirit and collaboration that are hallmarks of the MIT Physics Department. The fund provides a prize of $1,000.

Antti Eero Asikainen SB ’25

Academic advisor: Krishna Rajagopal

2025 Sigma Pi Sigma Inductees

Election to Sigma Pi Sigma is based upon a student's strong academic record. With over 90,000 members throughout its history, its purpose is to be of service to the broader physics community. It encourages scholarship in physics by admitting a student to the fellowship of others with similar interests and accomplishments. This year, MIT's Physics Department inducts 24 new members.

Antti Eero Asikainen
Saul Balcarcel-Salazar
Jorian Benke
Eddie Chen
Samuel (Sam) Christian
Ezekiel Daye
Garrett Heller
Dobrica Jovanovic
Alice Le
Karen Lei
Zhening Li
Donald (DJ) Liveoak
Benjamin (Ben) Lou
Jovan Markovic
Quan Nguyen
Kayla O'Donnell
Anna Orgel
Tomasz Slusarczyk
Max Tan
Cristopher Tong
Vetri Vel
Amir White
Eleanor Winkler
Leo Yao

ABOVE: 2025 Sigma Pi Sigma Inductees. Credit: Justin Knight Photography

RIGHT: 2025 Phi Beta Kappa Inductees. Credit: Justin Knight Photography

2025 Phi Beta Kappa Inductees

Phi Beta Kappa is the oldest honor society in the United States of America. Less than 10% of the graduating class is invited, and selection is based upon academic record, dedication to the liberal arts, and language skills. This year, MIT's Chapter (Xi) of Phi Beta Kappa voted to invite 19 physics majors to membership in the Society.

Antti Eero Asikainen
Eddie Chen
Samuel (Sam) Christian
David Dai
Ezekiel Daye
Dobrica Jovanovic
Alice Le
Karen Lei
Donald (DJ) Liveoak
Benjamin (Ben) Lou
Jovan Markovic
Kayla O'Donnell
Anna Orgel
Lawrence Shi
Tomasz Slusarczyk
Max Tan
Christopher Tong
Vetri Vel
Leo Yao

2024–2025 Buechner Undergraduate Advising Award

Ronald F. Garcia Ruiz

Thomas A. Frank Career Development Associate Professor of Physics

Other Undergraduate Awards & Honors

Ezekiel Daye (SB ’25, *Physics & Electrical Engineering*. Academic advisors: Liang Fu, Luqiao Liu) was inducted into the electrical and computer engineering honor society, Eta Kappa Nu, in recognition of academic excellence and leadership potential within the EECS department; received the Everett Longstreth Jazz Award for “distinguished service and musical contributions to the MIT Festival Jazz Ensemble”; and received the Laya and Jerome B. Wiesner Student Art Award for “outstanding contributions to the arts at MIT, recognizing leadership and long-term impact within the artistic community, particularly through music and performance.”

Taisiia Karasova (SB ’26. Academic advisor: Julien Tailleur) received a Rai Weiss Undergraduate Travel Award for her project: “Statistical Modeling of Gravitational Wave Sources Using Cosmological simulations: Cross-Correlations with Galaxy Catalogs for Cosmological Inference.” The award provides up to $2,000 for 2025 summer travel.

Alice Trang Le (SB ’25. Academic advisor: Soonwon Choi) was awarded First Prize in the Karmel Writing Prize Competition, Robert A. Boit Essay category; and Second Prize in the Karmel Writing Prize Competition, Rebecca Blevins Faery Autobiographical Essay category.

Benjamin Lou (SB ’25. Academic/Research advisors: Janet Conrad, Nergis Mavalvala) received the 2025 Hertz Fellowship for support of “bold, high-impact scientific research”; and was awarded a 2025 NSF Graduate Research Fellowship, which will provide three years of financial support, including an annual stipend of $37,000.

Isabella Vesely (SB ’27. Academic advisor: Yen-Jie Lee) received the 2025 Jeffrey L. Pressman Award, for research or internship in U.S. government, politics, or law.

Felicia Xiao (SB ’26. Academic advisor: Tracy Slatyer) received a Rai Weiss Undergraduate Travel Award for her project: “Investigating zero bias cosmic voids as standard cosmological rulers.” The award provides up to $2,000 for 2025 summer travel.

Student Honors & Awards: Graduate

The Department's graduate awards winners for the 2023-2024 academic year (listed below) were publicly announced at an on-campus event in September 2024. A listing of all prizes and winners for 2024-2025 will appear in the Fall 2026 issue of *physics@mit*.

2023-2024 Martin Deutsch Student Award for Excellence in Experimental Physics

Created in 1987 in honor of Professor Martin Deutsch's outstanding career as an experimentalist and for his influence as an educator. One thousand dollars is awarded annually to one or more graduate students mid-way through thesis research in any field, with preference for an experimentalist.

Hudson Loughlin
Atomic Physics
Thesis supervisors: Matthew Evans; Nergis Mavalvala

2023-2024 Andrew M. Lockett III Memorial Fund Award

Awarded to a graduate student in theoretical physics, with preference given to students from Los Alamos, NM, and New Orleans, LA. The award currently carries a prize of $1,000. The award was established by Mrs. Lucille Lockett Stone in memory of her husband, Dr. Andrew M. Lockett, who received his PhD in physics from MIT in 1954.

Yugo Onishi
Condensed Matter Theory
Thesis supervisor: Liang Fu

Other Graduate Honors & Awards

Zhaoyi Li (Center for Ultracold Atoms. Thesis supervisor: Isaac Chuang) received the Best Student Paper Prize at the 2025 Theory of Quantum Computation, Communication, and Cryptography conference for her work on quantum purity amplification.

Hudson Loughlin (Atomic Physics. Thesis supervisors: Nergis Mavalvala, Matthew Evans) received an Enrico Fermi Fellowship from the John Templeton Foundation and the Center for SpaceTime and the Quantum; and was awarded a Draper Scholars Fellowship.

Hyo Sun Park (Atomic Physics. Thesis supervisor: Wolfgang Ketterle) received the 2025 Ragnar & Margaret Naess Award from the MIT Music and Theater Arts Section in recognition of "exceptional talent and commitment to performance at MIT."

Sahaj Patel (Condensed Matter Experiment. Thesis supervisor: Riccardo Comin) received an NSF Graduate Research Fellowship, which will provide three years of financial support, including an annual stipend of $37,000.

Stella Schindler (Center for Theoretical Physics. Thesis supervisor: Iain Stewart) received the 2025 J. J. and Noriko Sakurai Dissertation Award in Theoretical Particle Physics from the American Physical Society.

Graduate Degree Recipients 2024–25

SEPTEMBER 2024

Alexander Yu Chuang PhD
Margarita Davydova PhD
Batyr Ilyas PhD
Wenxuan Jia PhD
Robert Jones PhD
Honggeun Kim PhD
Ouail Kitouni PhD
Evgenii Kniazev PhD
Jeffrey Krupa PhD
Daniel Mayer PhD
Tri Nguyen PhD
Patrick Oare PhD
Connor Occhialini PhD
Olumakinde Ogunnakie PhD
Kaliroe Mabelle Pappas PhD
Changnan Peng PhD
Bruna Sebastian Scheihing Hitschfeld PhD
Stella Tallulah Schindler PhD
Yifan Su PhD
Silviu-Marian Udrescu PhD
Tianyu Justin Yang PhD
Ming Zheng PhD

FEBRUARY 2025

Mikail Khona PhD
Jackson Pybus PhD
Tim Johnson PhD
Blox Bloxham PhD
Jacob Pearcy PhD
David Rower PhD

MAY/JUNE 2025

Molly Park PhD
Enrique Toloza PhD
Ben Stein-Lubrano PhD
Andrea Perry SM
Andrew Denniston PhD
Rahul Jayaramen PhD
Eunice Lee PhD
John Martyn PhD
Oriol Rubies Bigorda PhD
Paul Neves PhD
Rikab Gambhir PhD
Daniel Swartz PhD
Jinggang Xiang PhD
Samuel Alipour-fard PhD
Pin-Chun Chou SM
Nicholas Demos PhD
Ali Ghorashi PhD
Beili Hu PhD
Gianni LeVecchia PhD
Yukun Lu PhD
Geoffrey Mo PhD
Xiaowei Ou PhD
Zhengyan Shi PhD
Kaitlyn Shin PhD
Joshua Wakefield PhD
Jacob Willis SM
Zhiren Zheng PhD

Student Profile: Karen Lei ’25

by Sandi Miller

Fu Group, Condensed Matter Theory

Senior Karen Lei is working with Prof. Liang Fu to wrap up her research on the ground state spin textures of the ferromagnetic kondo lattice model, which could lead to applications in advanced quantum technologies such as spintronics and topological quantum computing. She previously conducted research in trapped-ion quantum computing in the Quanta Lab under Prof. Isaac Chuang.

Karen is also active in extracurriculars at MIT, including serving as co-president of Undergraduate Women in Physics, and she previously served as co-social chair of the Society of Physics Students, was an Educational Studies Program Science Outreach Teacher, and an active member of the MIT Rock Climbing Club. She begins the doctoral program in physics at Stanford University this Fall 2025.

What inspired your interest in condensed matter physics?

For most of my childhood, my main focus was competitive gymnastics. Until I was 14, I was training over 20 hours a week on the Junior Olympic track. This taught me a lot about discipline, pain tolerance, and grit. There’s no such thing as a perfect day in gymnastics—you’re always tired, something hurts, or things just don’t go your way—but you suck it up and keep going. I’m not afraid of doing challenging things, and that mindset comes from gymnastics.

In middle school, I found a new kind of challenge when I joined the math club. Though I’d always enjoyed puzzles growing up, there I learned how to spend hours thinking and chipping away at a single question. Later, I took my first physics class as a high school freshman and it changed how I saw the world—I was fascinated by how math could explain nature. But I didn’t consider pursuing physics as a career seriously until my junior year when I was running the astronomy club and read an article on a hobbyist radio forum that inspired me to build a DIY radio telescope. After convincing some friends to join the project, we learned basic skills like drilling, spent hours in Home Depot, and weeks hunting down obscure parts like double-sided conductive tape.

It took about six months to build the telescope. Then, by myself, I set out to see if it could actually detect something—and chose the 21-centimeter hydrogen line. This was more difficult than I expected. I had to learn about Fast Fourier transforms, reading datasheets for amplifiers, and debugging noise sources. That experience gave me my first real taste of doing science. Coincidentally, this project is actually a Junior Lab project—though they use a pre-built radio telescope instead of making one from scratch.

Also in high school, I read *Crystal Fire: The Invention of the Transistor and the Birth of the Information Age*, by Michael Riordan and Lillian Hoddeson, which introduced me to physicists like Shockley, Bardeen, and Brattain. Their work fascinated me, particularly as I had grown up in Silicon Valley, where the transistor's impact is everywhere. This sparked my interest in condensed matter physics and the intersection of physics and technology: to explore fundamental questions while driving new applications.

What do you find especially intriguing about your current research?

When I came to MIT, I wanted to join a lab, get my hands dirty, and learn as much as possible. I joined Prof. Isaac Chuang's AMO group to explore my interest in trapped-ion quantum computing. A major challenge in quantum computing is decoherence, which limits quantum gate fidelity. Motivated by this, I built a frequency-locking optical system from scratch to achieve long coherence times in barium ions. I aligned a 1762 nm infrared laser to an optical cavity, performed mode matching calculations, and implemented the Pound-Drever-Hall technique. I successfully achieved a very narrow linewidth (<1 kHz)—crucial for future experiments.

I then designed and conducted a clock protocol experiment to investigate the motional frequency stability of trapped ions, a key factor in two-qubit gate fidelity. I performed experiments such as spectroscopy, Rabi flopping, and Ramsey interferometry. This experiment became a valuable diagnostic in the lab and helped pave the way toward high-fidelity quantum gates. I presented my research at conferences such as the 2024 APS March Meeting.

In my junior fall, a fascinating condensed matter physics class—combined with my growing interest in theoretical physics—led me to work with Prof. Liang Fu in condensed matter theory. I'm now finishing up a project investigating the ground state spin texture phase diagram for the ferromagnetic Kondo lattice model (FKLM) on a 2D triangular lattice. The FKLM is a foundational model that captures the interplay between localized and itinerant electrons that drives magnetic ordering. Basically, a material's magnetic properties arise from how each electron's spin "arrow" interacts with other spins. By studying models like the FKLM, we can better understand and predict interesting magnetic orderings, which could be useful for applications such as spintronics or topological quantum computing.

Previous literature either assumed a specific spin ansatz or only considered a limited number of spin configurations, so I independently developed a numerical program to perform a comprehensive and unbiased search for the ground state. I presented this research at the CT.QMAT conference in Germany, and gave a talk at the 2025 APS March Meeting.

What is next for you?

I'll be pursuing my PhD in physics at Stanford University. I am primarily interested in experimental condensed matter physics—specifically, studying strongly correlated electron systems where interactions between electrons are significant. These systems exhibit fascinating phenomena like high-temperature superconductivity, magnetism, and topological phases.

Long-term, I'm particularly motivated by the urgent challenges of heat dissipation and energy consumption in modern electronics—challenges that are only intensifying with the growing demands of AI and data centers. I believe advances in fundamental physics will be essential to driving the transformative new solutions we need, and I aspire to contribute to those solutions.

Cosmic Interference Patterns

Resolve the Heart of a Radio Burst

BY KIYOSHI MASUI

Fast radio bursts (FRBs) are one of the most captivating enigmas in modern astrophysics: intense, millisecond-long flashes of radio light arriving from galaxies billions of light-years away. Despite over a decade of observations, these phenomena remain poorly understood. What exactly produces them? And how is such powerful radio emission generated?

These two questions—the *what* and the *how*—have driven much of the theoretical and observational effort in FRB research. The *what* concerns the nature of the progenitor: what kind of astrophysical object launches these bursts? The *how* seeks to uncover the physical process responsible for generating the radio waves.

In our recent work [1], my collaborators and I have made a significant advance on the *how*. By observing an interference pattern—known as SCINTILLATION—in the signal from an FRB, alongside a telltale swing in its polarization angle (a hallmark of a rotating source), we've gained a clearer window into the emission process. The evidence points to radio waves being produced directly within the ultra-strong magnetic fields of the progenitor, likely during sudden and violent magnetic reconfiguration events.

Before we tackle the question of how FRBs are produced, it's worth revisiting what we know about their progenitors—and how we found out.

Which neutron stars emit FRBs?

From early on, the brevity of fast radio bursts pointed toward compact objects as their likely sources. FRBs last only a few milliseconds—implying that whatever produces them must be extremely small. To see why, consider the speed of light: in a millisecond, light travels just about 300 kilometers. If an FRB source were significantly larger than this, the travel time of light emitted from different parts of the object would smear out the burst, erasing the sharp temporal signature we observe.

This constraint rules out most astrophysical bodies. The only known objects compact and energetic enough to fit the bill are neutron stars—the collapsed cores of massive stars that have exhausted their nuclear fuel. With no radiation pressure left to counteract gravity, these remnants compress under their own weight to densities comparable to that of atomic nuclei. A neutron star can pack twice the mass of the Sun into a sphere just 20 kilometers across. To put that in perspective: a single thimbleful of neutron star matter would weigh about a billion tons.

Neutron stars can be classified by the energy source that powers their emission. Many are effectively silent: they no longer emit detectable light because they have no active energy reservoir. These neutron stars can still reveal themselves occasionally—most spectacularly when they merge with another compact object. Such mergers are now routinely observed through gravitational waves by detectors like LIGO, and can be accompanied by gamma-ray bursts, linking neutron stars to some of the most energetic events in the universe.

Among the luminous neutron stars, some shine by tapping into their rotational energy. These are the pulsars—rapidly spinning neutron stars that lose energy through magnetic braking. As they rotate, their strong magnetic fields accelerate charged particles and emit beams of radiation. When one of these beams sweeps past Earth, we observe a precisely timed pulse, earning pulsars a reputation as nature's most reliable clocks.

FIGURE 1:
Artist's impression of scintillation in an FRB. A radio flash is generated close to the neutron star, within its magnetic field. The radio waves are lensed by interstellar gas creating a speckle interference pattern. Credit: Daniel Liévano / MIT

FIGURE 2:
The CHIME telescope in British Columbia, Canada. With no moving parts, CHIME points via digital signal processing of the signals coming from its thousand antennas in a method called beamforming. This capability allows it to continually monitor a large swath of the sky and detect FRBs at a rate much greater than other telescopes. Credit: Richard Shaw

Others are powered by their magnetic fields. These are the magnetars, whose fields are the strongest known in the universe. Vast amounts of energy are stored in these fields, which can suddenly reconfigure in violent magnetic reconnection events. These abrupt releases of energy can produce powerful outbursts, making magnetars particularly compelling candidates for the kind of rapid, intense flashes seen in FRBs.

A digital telescope implicates magnetars

Much of the recent progress in understanding FRBs has come from a telescope I helped design and build: the Canadian Hydrogen Intensity Mapping Experiment (CHIME). CHIME is unlike most other radio telescopes—it has no moving parts. Instead of swiveling dishes, it uses a thousand fixed antennas spread across four large cylindrical reflectors. The telescope “points” digitally, using a technique called beamforming to combine signals from its array in real time. This digital steering allows CHIME to observe many directions in the sky simultaneously—an ideal design for detecting rare and unpredictable radio flashes like FRBs.

Since turning on, CHIME has observed over five thousand FRBs. By comparison, all other radio telescopes worldwide have collectively detected fewer than two hundred. This dramatic increase in detection rate has transformed the field and opened the door to new discoveries about the nature of FRBs.

One of the most pivotal came in April 2020: CHIME detected an FRB that was hundreds of thousands of times brighter than usual. The reason? Its source was remarkably nearby—just 30,000 light-years away, within our own Milky Way galaxy. This proximity allowed us to directly associate the burst with an active magnetar, which was simultaneously emitting X-rays.

This detection provided the first direct evidence that magnetars can indeed produce FRBs. It was a decisive “existence proof”: even if not all FRBs come from magnetars—something we still can’t determine, since typical FRB sources lie far beyond the observational reach of X-ray or gamma-ray instruments—some certainly do. That alone marked a major leap forward in understanding the origins of these mysterious cosmic flashes.

Making the radio waves: competing models

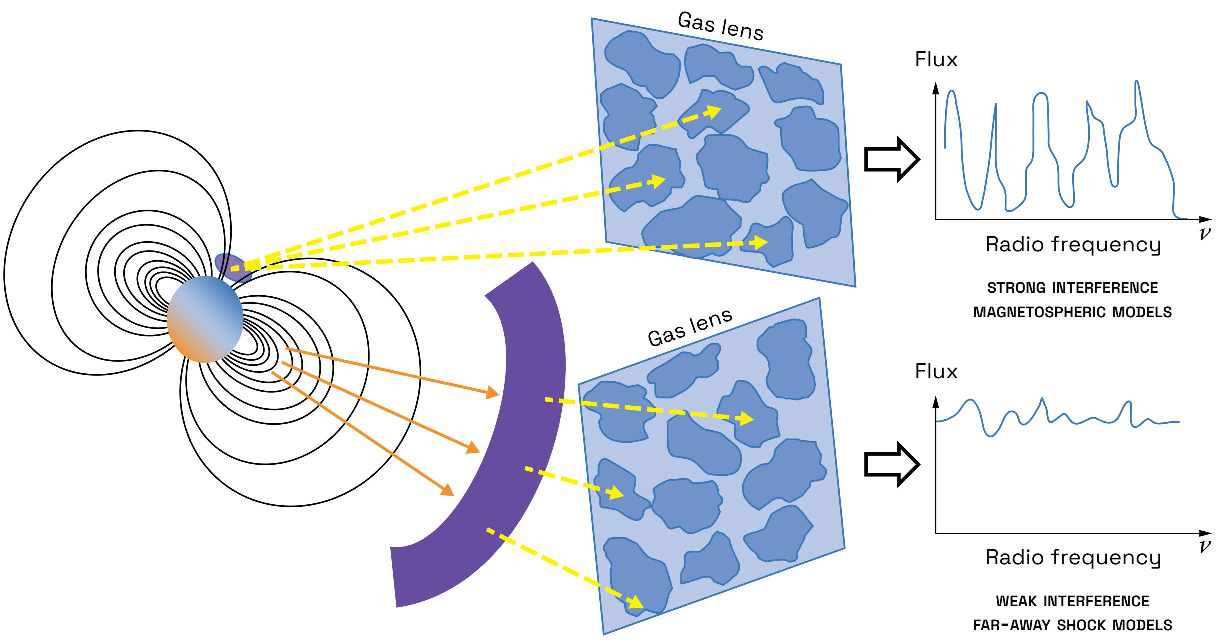
Even as progress has been made in identifying the *progenitors* of fast radio bursts, another profound mystery remains: the emission mechanism. How does nature produce a burst of radio waves so intense, so brief, and so coherent that it can outshine an entire galaxy—for just a millisecond? While there are many detailed theories, most fall into two broad classes.

The first class involves magnetospheric emission, where the radio waves are generated directly within the intense magnetic environment of the neutron star. In these models, a violent magnetic reconfiguration—such as a magnetic reconnection event triggered by a crustal quake—drives nonlinear electromagnetic processes that directly produce coherent radio emission. Because the emission is generated close to the star, where the magnetic field is strongest, these models are tightly linked to the magnetospheric structure and dynamics.

The second class of models envisions a different geometry. Here, an explosive release of energy from the neutron star launches a relativistic shock wave that travels outward through the surrounding medium. As this shock front propagates, it generates radio waves via a synchrotron maser process. Unlike the magnetospheric models, where emission originates near the star's surface, these shock models produce FRBs much farther out—hundreds of thousands of kilometers from the progenitor.

Distinguishing between these emission models would be straightforward—if we could directly image the source. Magnetospheric models predict compact emission near the neutron star, while shock models require a much more extended region. But resolving structures just hundreds of kilometers across at cosmological distances is far beyond current technology. Even the Event Horizon Telescope (EHT), which imaged the shadow of a black hole in M87 by forming an Earth-sized interferometer, could only resolve features spanning billions of kilometers. And M87 is closer than most FRBs; zooming in on an FRB would require a telescope billions of times larger than the EHT.

FIGURE 3:
Schematic of how the presence of interference patterns observed in an FRB spectrum constrains the size of the emission region and thus distinguishes between magnetospheric emission and far-away emission generated by a shock wave. (Adapted from "Constraining the FRB mechanism from scintillation in the host galaxy," Kumar, Pawan; Beniamini, Paz; Gupta, Om; and Cordes, James M.; *Monthly Notices of the Royal Astronomical Society* **527**, 457–470, 2023.)



> "To produce a clear interference pattern, the light passing through each slit must be coherent—its wave phases perfectly correlated from one path to the other."
>
> KIYOSHI MASUI

Cosmic interference patterns

Fortunately, nature offers another way—scintillation allows us to use clumpy interstellar gas as a giant telescope.

Those trained in physics are likely familiar with the classic double-slit experiment, in which light travels along two distinct paths and produces an interference pattern of alternating bright and dark fringes. But this effect doesn't occur for just any light source. To produce a clear interference pattern, the light passing through each slit must be coherent—its wave phases perfectly correlated from one path to the other.

There are two ways to satisfy this condition. One is to use a coherent light source, like a laser. The other is to use a source that is small and distant enough that it appears unresolved by the slits, effectively behaving as a point source. In that case, the path-length difference between the slits and the detector remains well-defined, allowing coherent interference to occur. This means that the mere presence of an interference pattern tells us something important: it implies the source is sufficiently compact in angular size.

We apply this same principle to determine the size of the FRB emission region using scintillation. The diffuse gas that fills galaxies is inhomogeneous and has a refractive index for radio waves. As FRBs travel through this clumpy gas, it acts like a vast, irregular lens, bending the radio waves so that the signal reaches Earth along thousands of distinct paths—paths that can be separated by billions of kilometers. If the FRB emission is sufficiently small and distant, these many paths remain coherent with one another and interfere just as in the two-slit experiment. In this way, the interstellar gas acts as an interferometer with a scale of billions of kilometers.

With so many disorganized paths, the interference pattern produced by scintillation resembles a random speckle pattern, like those seen when a laser illuminates a rough surface. If we could project this pattern onto a screen, it would span an enormous area—far too large to observe directly. Instead, we detect the interference through radio spectroscopy, where the speckle pattern manifests as a random variation in brightness across different frequencies—a distinctive signature of constructive and destructive interference.

This pattern has a characteristic frequency scale—the typical width of features in the spectrum—which encodes information about the geometry of the lensing gas. And crucially, the mere presence of such a pattern tells us that the source must be compact enough to maintain coherence across these paths.

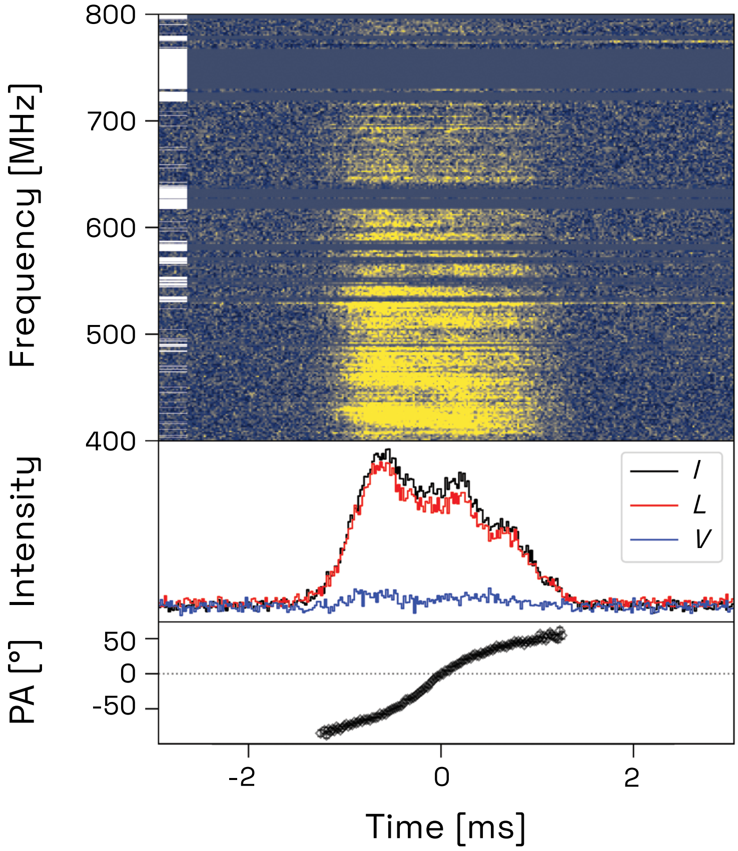


FIGURE 4:
FRB 20221022A. The top panel show the dynamic spectrum of the FRB: its intensity as a function of time and frequency. The middle panel shows its frequency-averaged pulse profile in intensity (I), and linear (L) and circular (V) polarizations. The bottom panel shows the angle of the linear polarization. The characteristic S-shaped swing of the polarization angle is a hallmark of emission from a rotating magnetic field. (Adapted from Mckinven, R., Bhardwaj, M., Eftekhari, T. *et al.* "A pulsar-like polarization angle swing from a nearby fast radio burst." *Nature* **637**, 43–47, 2025).

Zooming in on the emission

In the early days of FRB research—when the total number of known bursts could be counted on your fingers and a few toes—I observed, for the first time, scintillation in an FRB caused by gas in the Milky Way. This allowed me to effectively "zoom in" on the environment of the source, showing it lived in a dense environment typical of magnetars. That observation offered circumstantial support for the magnetar progenitor hypothesis—some of the strongest such evidence available at the time. But even that accomplishment was a long way from answering the deeper question of how FRBs are produced. It gave hints about the surroundings of the source, but not the nature of the emission mechanism itself.

Our latest discovery takes the scintillation method a significant step further. We set out to search CHIME's archive for FRBs that had experienced scintillation twice—that is, FRBs showing two distinct frequency scales in their interference pattern. We reasoned that this could only happen if the burst had been lensed by gas both in the Milky Way and in its own host galaxy. And crucially, the lens in the host galaxy—being much closer to the FRB source—would provide much finer resolving power, allowing us to zoom in much more tightly on the emission region.

Eventually, we found what we were looking for in FRB 20221022A—named, like all FRBs, for the date it was detected. This burst was ideal in several respects: its host galaxy is relatively nearby, at just 200 million light-years, and the FRB itself was bright, providing ample signal-to-noise for detailed spectral analysis. When we examined the burst's spectrum, we found two distinct scintillation frequency scales, at 120 kHz and 6 kHz. By analyzing this double-lensed interference pattern, using both the geometric information contained in these frequency scales and the coherence of the interference in each lens, we inferred that the size of the emission region was no more than 30,000 kilometers.

It's the magnetosphere–this time

Our measurement—that the FRB emission region is no larger than 30,000 kilometers—places a strong constraint on the viable emission mechanisms. This size limit is inconsistent with shock-based models, which predict that the radio waves are generated far from the neutron star, more than hundreds of thousands of kilometers away. By contrast, the observation is entirely compatible with magnetospheric models, where the emission originates much closer to the neutron star, within the region dominated by its magnetic field.

This FRB also carried a second clue pointing in the same direction. Over the few-millisecond duration of the burst, the polarization angle of the radio waves exhibited a smooth and characteristic swing. Such polarization swings are well known from pulsars, where they arise from the rotation of the neutron star. As the star spins, the orientation of its magnetic field vector changes with respect to our line of sight, producing a systematic sweep in the polarization angle. Seeing a similar signature here adds further support to the idea that the emission is tied to the rotating magnetosphere of a neutron star.

While these observations may seem to close the book on shock models for FRB emission, the picture is not so simple. This is, after all, just one FRB—a single event among the thousands that CHIME has observed. And so far, we haven't been especially systematic about looking for similar signatures in the rest of the population.

Our ability to make these measurements depended on several fortunate alignments: gas lenses needed to be present both in the Milky Way and in the host galaxy, positioned just right to produce distinct scintillation patterns. The FRB also had to be bright enough to allow for detailed spectral and polarization analysis. It's unclear how often this precise combination occurs, which introduces a degree of selection bias if we try to generalize these results too broadly.

Still, as with the discovery linking at least one FRB to a magnetar progenitor, this finding gives us an important existence proof: some fraction of FRBs originates from magnetospheric emission. That alone marks significant progress—and provides a concrete foundation on which to build a more complete understanding of these mysterious cosmic flashes. Each clue adds to a growing picture: fast radio bursts are no longer just mysterious flashes in the dark. They're becoming a story we can tell.

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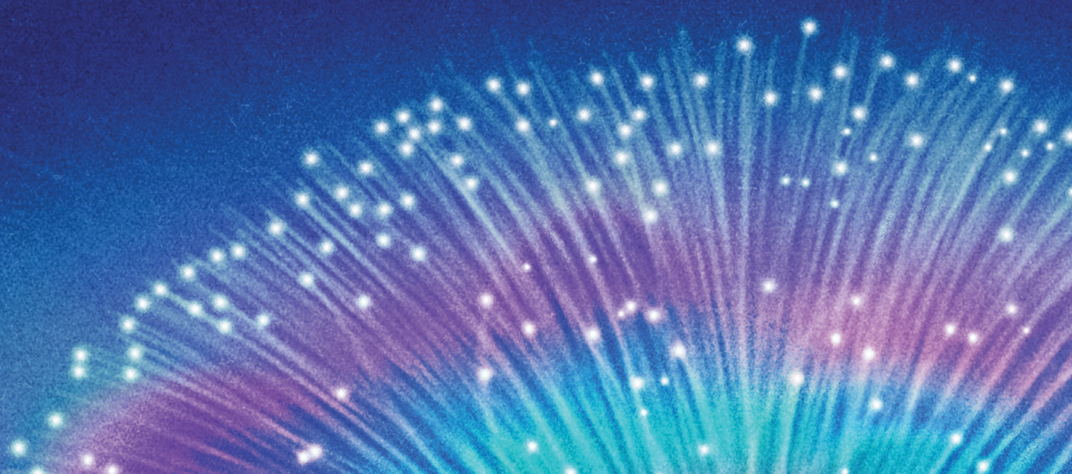
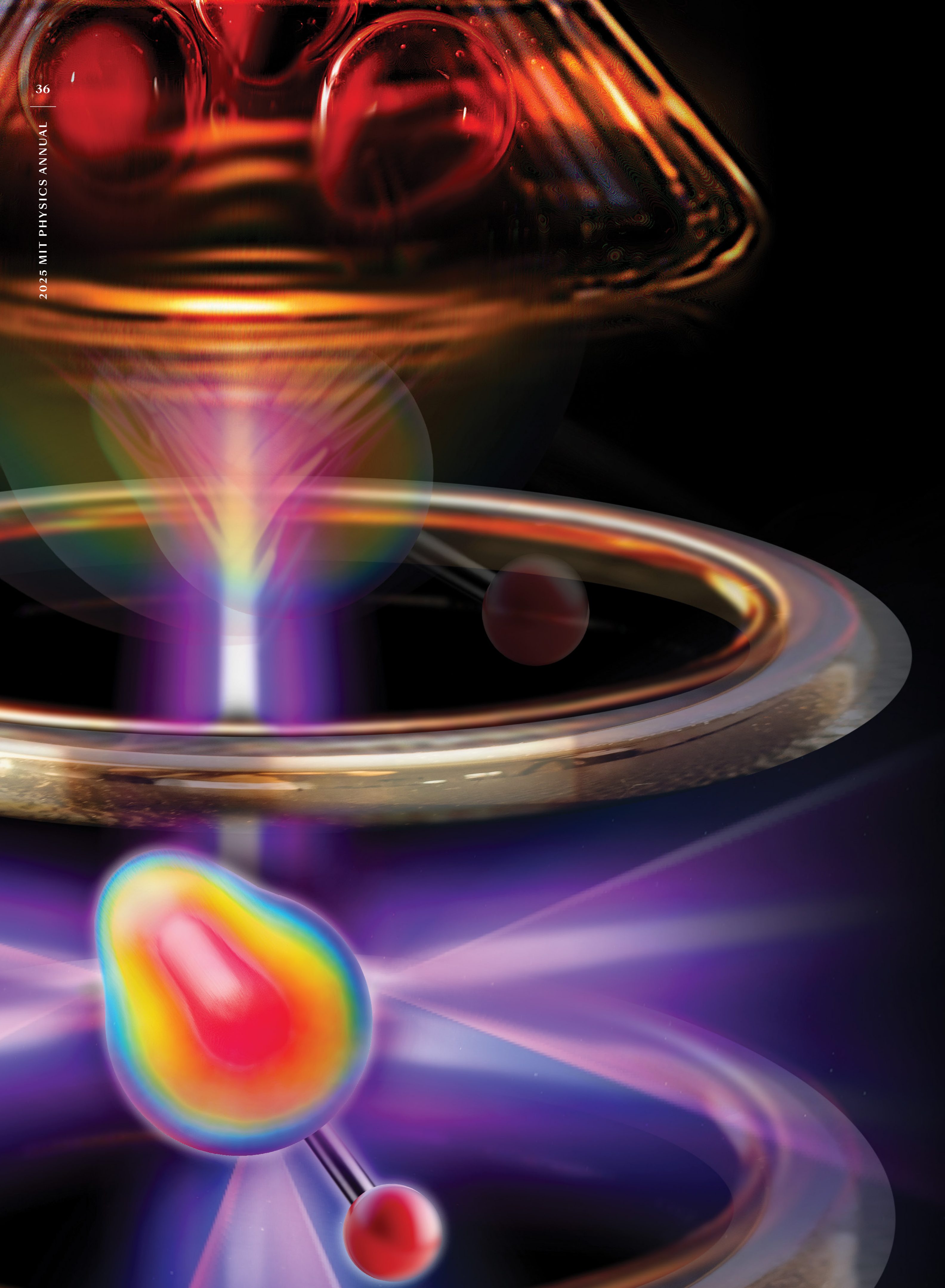
PROFESSOR KIYOSHI MASUI's Synoptic Radio Lab works with wide-field, radio-wavelength sky surveys to establish new ways to observe the Universe. These include developing the technique of hydrogen intensity mapping for rapidly surveying large volumes of space, and exploiting the recently-discovered phenomena of fast radio bursts (FRBs) as probes of the Universe's contents. This work includes creating digital instrumentation for radio telescopes, developing algorithms for analyzing observational data, and making theoretical predictions for the signals we should be looking for.

Kiyoshi Masui studied engineering physics at Queen's University in Canada and did his undergraduate thesis in experimental astroparticle physics. He received his PhD in physics in 2013 in the Canadian Institute for Theoretical Astrophysics (CITA) at the University of Toronto. For his graduate work he led one of the first radio surveys to use hydrogen to map large-scale structure beyond the local universe. He then moved to the University of British Columbia as a Canadian Institute for Advanced Research Global Scholar and subsequently a CITA National Fellow. Masui joined the MIT Department of Physics as an assistant professor in 2018.





Searching for Time-Reversal Violation with Unstable Molecules

BY RONALD F. GARCIA RUIZ

The matter–antimatter imbalance in the universe

The visible universe is composed almost entirely of matter, while antimatter accounts for less than one part in a billion. Yet according to the known laws of physics, the Big Bang should have produced matter and antimatter in equal amounts. The large imbalance we observe today, with matter vastly prevailing, remains one of the most profound and unresolved questions in modern physics. Explaining this asymmetry likely requires discovering new sources of symmetry violation beyond those already known within the current framework of fundamental physics. These subtle effects may have shifted the balance toward matter in the earliest stages of the universe.

Symmetry principles are fundamental to our understanding of the physical universe, and play an essential role in guiding our understanding of elementary particles and their interactions. In physics, a symmetry means that a system remains unchanged under certain transformations. The fundamental symmetries, illustrated in Figure 1, include parity (P), charge conjugation (C), and time reversal (T). *Parity* involves inverting spatial coordinates, producing a mirror image of a physical process. *Charge conjugation* switches particles with their corresponding antiparticles, reversing the sign of charge. *Time reversal* refers to the invariance of physical laws when the flow of time is reversed. Of the four fundamental forces of nature—electromagnetic, gravitational, strong nuclear, and weak—the weak force is the only one that has been experimentally observed to violate C, P, T, and combined CP symmetries. Although CP violation is theoretically allowed within the framework of the strong interaction, such effects have not been observed. This striking absence is known as the strong CP problem, and it remains one of the outstanding puzzles in modern physics.

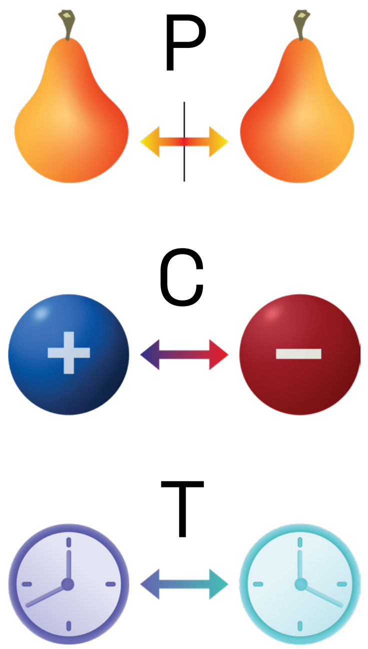


FIGURE 1:
Fundamental symmetries—parity (P), charge conjugation (C), and time reversal (T)—are central to particle physics. P creates a mirror image of a process by flipping spatial coordinates, C transforms particles into their antiparticles, and T reverses the direction of time. Credit: Sampson Wilcox

In 1967, physicist Andrei Sakharov proposed a set of conditions that must be satisfied to explain the origin of the matter–antimatter asymmetry in the universe, requiring three necessary ingredients: violation of baryon number conservation, departure from thermal equilibrium, and violation of the combined charge conjugation and parity (CP) symmetry. CP symmetry was once thought to be universally conserved, until this view was overturned in 1964 with the discovery of CP violation in the decay of neutral kaons. This landmark result later earned the Nobel Prize in Physics in 1980 [James Watson Cronin and Val Logsdon Fitch], and more recently, CP violation has also been observed in baryon decays at CERN. However, the level of CP violation observed to date is too small to account for the vast predominance of matter in the visible universe. This points to the possible existence of new sources of CP violation beyond those described by the Standard Model of particle physics. Searching for such sources is one of the central goals of modern physics. One possibility is the existence of unknown, heavy particles at energy scales well beyond the reach of current particle accelerators like the Large Hadron Collider (LHC) at CERN. Although these particles may be too massive to be produced directly, they could leave detectable signatures by subtly altering the properties of known particles such as neutrons, protons, and atomic nuclei. To probe these effects, researchers are developing increasingly precise experiments that can measure tiny symmetry-violating properties using "table-top" experiments. In particular, molecules containing heavy, reflection-asymmetric nuclei have emerged as powerful systems for testing these ideas, due to their exceptional sensitivity to CP-violating effects [1].

Unstable molecules as amplifiers of time-reversal violation

Some atomic nuclei exhibit reflection-asymmetric shapes that deviate from spherical symmetry, resembling the shape of a pear, as illustrated in Figure 2. These nuclei also possess pairs of quantum states with the same total angular momentum (spin) but opposite parity, with nearly degenerate energies. If the fundamental laws of physics include even a slight violation of time-reversal symmetry (T), meaning they do not behave identically when time is reversed, these near-degenerate states can mix, and would mix more strongly than they would in symmetric nuclei. Smaller energy separation results the larger the mixing, and this enhanced mixing leads to a dipole-like asymmetry in the nuclear charge distribution. As the combined CPT

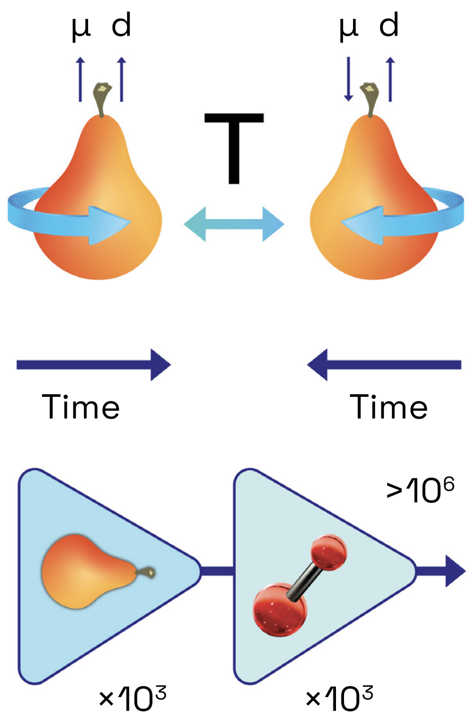


FIGURE 2:
Top row: a pear-shaped nucleus with both a magnetic dipole moment (μ) and a permanent electric dipole moment (d) has enhanced sensitivity to time-reversal (T) violation due to its large asymmetry of the charge distribution. Under time reversal, the spin and magnetic dipole moment reverse direction, while d remains unchanged, indicating a violation of time-reversal symmetry. *Bottom row*: by combining the molecular enhancement from the intense internal electromagnetic fields of polar molecules with the nuclear amplification offered by heavy, pear-shaped (octupole-deformed) nuclei, we can achieve over six orders of magnitude greater sensitivity to potential time-reversal symmetry violation compared to atoms composed of non-octupole-deformed nuclei. Credit: Sampson Wilcox

symmetry is a fundamental principle in the framework of quantum field theory, any violation of time-reversal symmetry is interpreted as a violation of CP symmetry to preserve overall CPT invariance. Consequently, the observation of a permanent electric dipole moment (EDM)—denoted as d—in a fundamental particle or a composite system like an atomic nucleus, implies the existence of CP violation. But how can one measure an electric dipole moment, d? One approach is to apply an external electric field, E, and measure the interaction energy between the field and the dipole, given by the product $d \cdot E$. To maximize the observable effect, it is desirable to apply the strongest possible electric field. In a vacuum, electrostatic fields are typically limited to about 100 kV/cm. However, certain diatomic molecules can be fully polarized, generating internal effective electric fields on the order of 10–100 GV/cm, up to six orders of magnitude larger than what can be applied in the laboratory [5, 8]. These large internal fields effectively amplify the interaction, making molecules powerful tools for probing fundamental properties of the particles they contain. The use of such molecular systems has enabled the most stringent experimental limits on the EDM of the electron [5, 8]. Similarly, atomic nuclei can also possess an EDM, arising from CP-violating properties of the protons, neutrons, and their constituent quarks. Moreover, certain unstable nuclei, such as radium-225, which has a large imbalance between protons ($Z = 88$) and neutrons ($N = 137$), can exhibit reflection-asymmetric shapes. These pear-shaped nuclei can lead to an enhancement of CP-violating effects by more than three orders of magnitude compared to spherical, symmetric nuclei. When such nuclei are embedded in polar molecules, the moments of the nuclear charge distribution interact with the large internal effective electric fields of the molecule, producing tiny shifts in molecular energy levels. Therefore, the energy shifts caused by CP-violating nuclear properties are effectively amplified at the molecular quantum levels. The resulting enhancement can exceed six orders of magnitude compared to atoms composed of symmetric nuclei, dramatically increasing the sensitivity for CP-violation searches.

From a beaker to precise quantum control

Nuclei exhibiting pear-shaped deformation are extremely rare in nature, and their large proton-to-neutron asymmetries make them unstable, typically possessing lifetimes of only a few days or less. Consequently, they must be artificially produced and are available only in trace quantities, often less than a microgram. This extreme scarcity poses significant experimental challenges, as their study requires highly sensitive and precise techniques. Moreover, even when such nuclei can be produced, the unambiguous identification of the molecules that they form remains difficult due to the lack of well-characterized spectroscopic signatures. Prior to our work, direct experimental studies of these exotic species were not feasible. Only recently did our group and collaborators develop the experimental methods that have, for the first time, enabled laser spectroscopy studies of molecules composed of unstable, short-lived nuclei [3, 6, 7].

An additional complication arises from the fact that these rare nuclei are produced alongside contaminants that can be more than eight orders of magnitude more abundant within a given sample. Consequently, a major challenge is to begin with a compound—illustrated schematically in Figure 3 as a beaker—containing only a few atoms of the nucleus of interest, and from that starting point, efficiently form the desired molecule, separate it from the overwhelming background of contaminants, prepare it in a specific quantum state, trap it, and ultimately perform precision measurements. Over the past few years, our group has been steadily overcoming these challenges [2, 3, 6, 7, 9].

One of the most powerful techniques for studying individual atoms is laser cooling. In atomic systems, this method is well established and routinely applied to many elements that can be approximated as isolated two-level quantum systems. In contrast, laser cooling of molecules is a relatively recent and rapidly developing field. The presence of complex vibrational and rotational degrees of freedom in molecules makes it exceedingly rare to find species that can be effectively approximated as closed two-level systems. When a molecule is excited to an electronic state by a laser, it can decay into a wide range of vibrational and rotational levels, thereby complicating the implementation of efficient optical cycling and quantum control.

In a few rare cases, such as molecules formed by alkaline earth atoms bonded with fluorine, the molecular structure exhibits properties that are favorable for laser cooling. Motivated by this, our group and collaborators have performed precise spectroscopic measurements of radium monofluoride (RaF), enabling an experimental determination of its laser cooling scheme [7]. These exciting results open the door to achieving precise quantum control and interrogation of molecules, comparable to what has long been possible with atoms.

In collaboration with colleagues from Harvard, Caltech, and the new world-class Facility for Rare Isotope Beams (FRIB) at Michigan State University, we are developing an experimental platform to extract radium-containing molecules from liquid sources (such as the beaker illustrated in Figure 3) and to establish, step by step, the full sequence of techniques required to laser cool and trap molecules made of unstable, pear-shaped nuclei. We are optimistic that the unprecedented amplification of CP-violating effects offered by these molecules will enable the discovery of new sources of CP violation, potentially pointing to the existence of previously unseen heavy particles and shedding light on the matter–antimatter asymmetry of our visible universe.

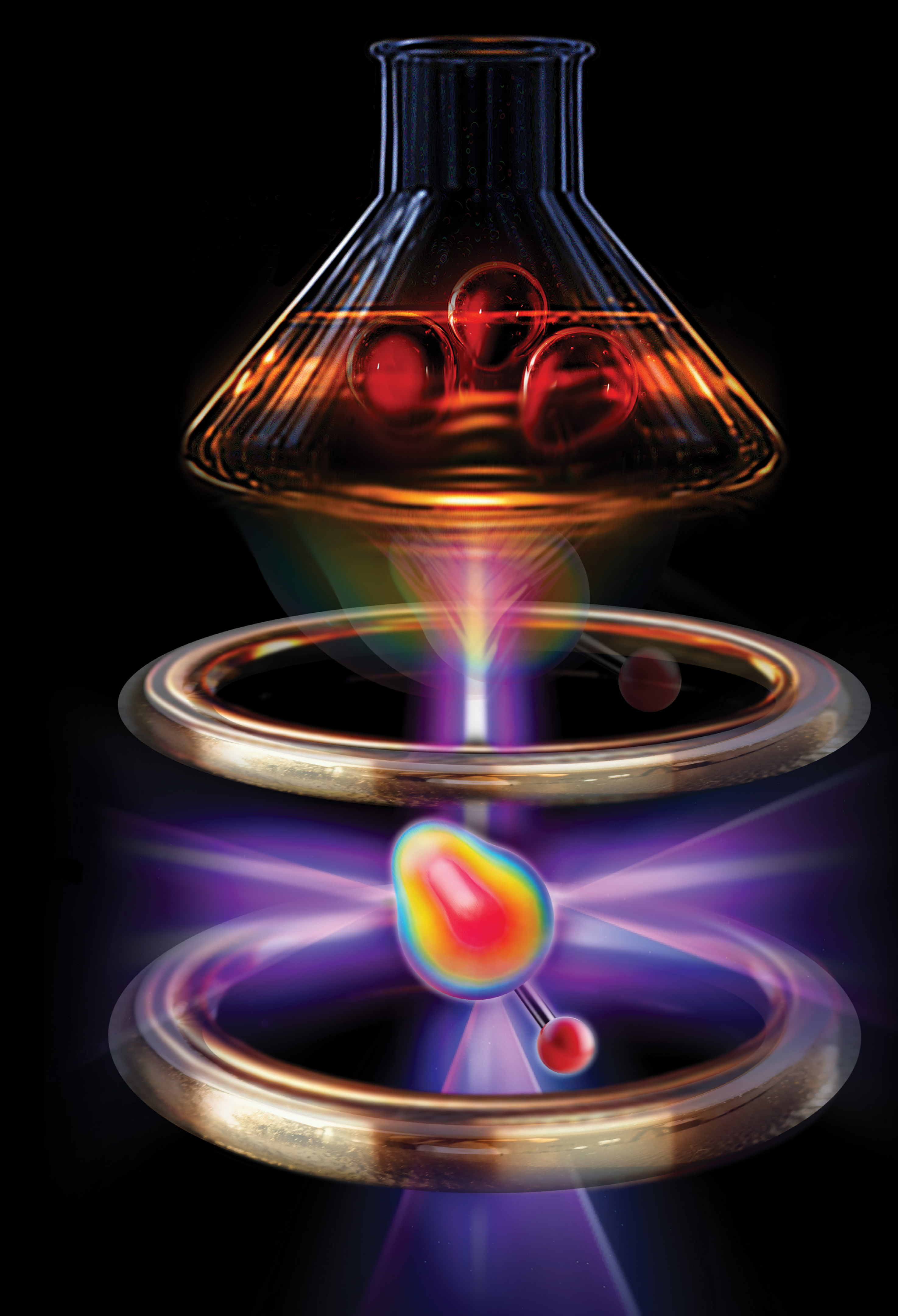
The existence of a heavy particle can induce a measurable electric dipole moment. Conversely, the absence of such a signal can be interpreted as excluding the presence of new heavy particles up to energy scales set by the precision of the experiment. The more precise the measurement, the higher the energy scale that can be probed. Owing to the large amplification provided by a heavy, pear-shaped nuclei, even a single trapped molecule could place constraints on new physics at mass scales exceeding 100 TeV, well beyond the reach of current high-energy colliders.

Molecules as an angstrom-scale laboratory for nuclear and particle physics

In addition to their extreme sensitivity to the dipole-like deformation of the nucleus, molecules can also be highly sensitive to a range of nuclear properties and fundamental interactions. A non-negligible overlap between the electron cloud and the nucleus, combined with the asymmetry of the molecular electron orbitals, enhances the sensitivity of the molecular quantum levels to short-range electron-nucleon and nucleon–nucleon interactions. This is especially relevant for probing yet unexplored electroweak nuclear properties, which remain extremely challenging to access in accelerator-based experiments.

Figure 4 illustrates a diatomic molecule such as RaF and highlights its hierarchical structure, from the molecular scale down to the subatomic level. In such a system, each atom consists of a nucleus surrounded by a cloud of electrons. These electrons interact with the protons and neutrons in the nucleus primarily via the electromagnetic force. In certain cases, particularly involving heavy nuclei, the weak interaction can also contribute significantly, especially in mediating rare processes or symmetry-violating effects. These fundamental forces influence the structure and energy levels of the molecule, which can be precisely probed using advanced laser spectroscopy techniques.

FIGURE 3:
From beaker to trapped molecule. A compound, represented by the beaker, contains only a few atoms of the rare nucleus of interest. These must be efficiently converted into the desired molecule. Multiple lasers are then used to prepare the molecule in a specific quantum state, trap it, and perform precision measurements. Credit: Sampson Wilcox



At higher levels of precision, molecular energy levels become sensitive to the internal structure of the atomic nuclei, where protons and neutrons themselves are composed of quarks bound by gluons via the strong nuclear force. Consequently, precision spectroscopy of molecular quantum states enables the investigation of diverse nuclear and particle physics phenomena. These include the possible existence of dark matter candidates and CP-violating effects in the strong nuclear forces, both of which are unresolved questions in modern physics.

Motivated by the exceptional sensitivity of molecules to subtle nuclear and particle physics properties, our group at MIT is actively developing a series of tabletop precision experiments using different molecular systems [4]. These experiments aim to establish powerful new platforms for probing electroweak nuclear properties, testing the violation of fundamental symmetries, and exploring the existence of new physics beyond the Standard Model.

A new era of precision physics

In recent years, the development of highly precise experimental techniques, combined with advanced theoretical tools for describing fundamental particles, nuclei, atoms, and molecules, has opened up exciting

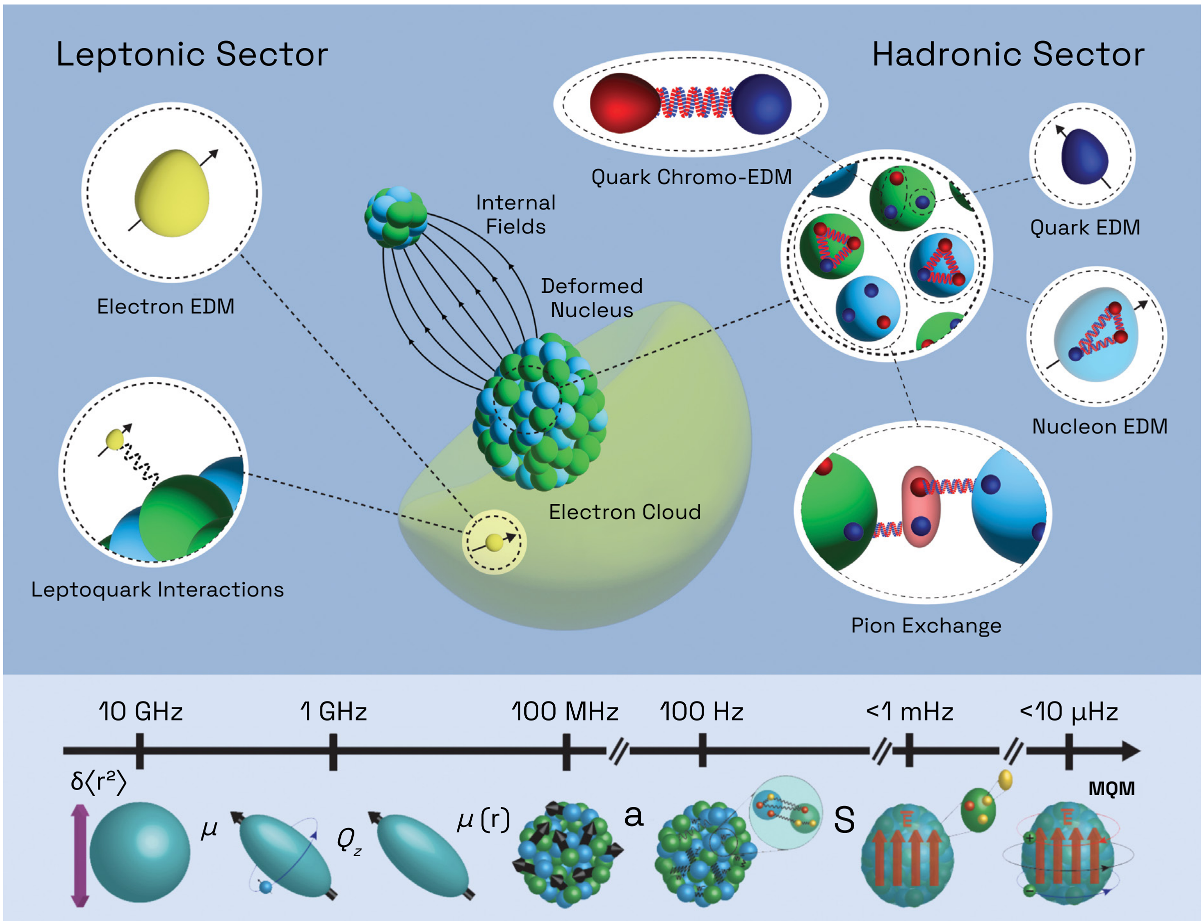


FIGURE 4:
Top: Schematic representation of a diatomic molecule and interactions among its fundamental constituents. Electrons interact with the protons and neutrons within each atomic nucleus primarily via the electromagnetic and weak forces. Inside the nuclei, additional complex interactions occur among protons and neutrons, as well as their fundamental building blocks—quarks and gluons—through a combination of the electromagnetic, weak, and strong forces. Within certain molecules the effective electromagnetic fields experienced by their constituents can be millions of times stronger than those achievable in the laboratory, leading to enhanced sensitivity to their intrinsic properties. *Bottom*: Illustration of how various nuclear features can affect the energy levels of molecules. *From left*: energy effects caused by changes in nuclear size, magnetic dipole moment, electric quadrupole moment, internal magnetization structure, effects of the weak nuclear forces, and the time-reversal violating dipole and magnetic quadrupole moments. The greater the precision of the measurements, the finer the resolution with which we can probe the microscopic structure of the nucleus and its fundamental constituents. Credit: Sampson Wilcox

new opportunities to explore previously inaccessible physical phenomena. In parallel, several major facilities in North America and Europe have been established to produce and deliver rare radioactive isotopes for research and industrial applications. As a result, experiments with these exotic systems are now becoming feasible in university laboratories such as ours at MIT.

Technological advances in cryogenics, buffer gas cooling, laser cooling, and ion trapping are making it possible to manipulate and study molecules made of unstable nuclei with unprecedented precision. At the same time, theoretical efforts are advancing *ab initio* calculations of molecular and nuclear structure, guiding experimental developments and enabling the interpretation of potential discoveries within the framework of particle physics.

While significant challenges remain, from the availability of unstable nuclei to the complexity of achieving precise quantum control and interrogation of these molecules, the field is advancing rapidly. As these techniques continue to mature, radioactive molecules are poised to enable a new experimental platform to push the boundaries of our understanding of the universe.

We anticipate that over the next decades, experiments with molecular systems conducted in university laboratories will uncover previously unknown properties of fundamental particles and interactions. These efforts have the potential to discover new fundamental particles and forces. In doing so, these unstable molecules serve as a unique bridge, connecting the properties of the smallest building blocks of matter with open questions about our macroscopic, asymmetric universe.

RONALD FERNANDO GARCIA RUIZ is the Thomas A. Frank Career Development associate professor in the Department of Physics at MIT. His research is focused on the development of laser spectroscopy techniques to investigate the properties of subatomic particles using atoms and molecules made up of short-lived radioactive nuclei. His experimental work provides unique information about the fundamental forces of nature, the properties of nuclear matter at the limits of existence, and the search for new physics beyond the Standard Model of particle physics.

Garcia Ruiz grew up in a small town in the Colombian mountains. As a teenager he moved to Bogota, where he obtained a bachelor's degree in physics in 2009 at Universidad Nacional de Colombia. After earning a Master's degree in Physics in 2011 at Universidad Nacional Autónoma de México, he moved to Belgium to start his PhD degree at KU Leuven. Garcia Ruiz was based at CERN during most of his PhD, working on laser spectroscopy techniques for the study of short-lived atomic nuclei. After his PhD, he became a research associate at the University of Manchester, UK (2016–2017). In 2018, he was awarded a CERN Research Fellowship to lead the local CRIS team. At CERN, he led several experimental programs motivated by modern developments in nuclear science, atomic physics and quantum chemistry. In January 2020, Garcia Ruiz joined the MIT Physics Department as an assistant professor and promoted to associate professor in July 2025.

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From Nuclei to Nebulae: The Scientific Journey of Vera Kistiakowsky

by Lindley Winslow

Professor of Physics Vera Kistiakowsky. Credit: MIT Museum

Professor Vera Kistiakowsky was a climber—of summits and of scientific frontiers. An experimental nuclear and particle physicist, she became the first woman appointed to the MIT physics faculty, forging a path at a time when women in science were few and far between. Her career was defined not only by the barriers she broke, but by a deep and enduring commitment to experimental inquiry—a passion that carried her from the chemistry lab to the bubble chamber, and ultimately, to the stars.

From chemistry kits to the Manhattan Project

Kistiakowsky's introduction to science began not in a classroom, but at home, with a childhood chemistry set. Her father, well-known Harvard chemist George Kistiakowsky, showed her a few entertaining chemical reactions, including one memorable favorite: synthesizing low boiling point fluids that, as she gleefully recalled, "you could set your clothes on fire and scare other peoples' mothers into fits." In high school, balancing her academic strengths with more conventional aspirations, she initially set her sights on medicine, believing it to be a practical and respectable application of her interests in science.

She began college at Mount Holyoke just before her sixteenth birthday. Her father believed that Mount Holyoke, with its strong and independent faculty of women scientists, would offer a more substantive education, especially during wartime. Chief among them was Emma Carr, a pioneering spectroscopist whose warmth, energy, and passion for research made a lasting impression on Kistiakowsky. Inspired by Carr and eager for hands-on experience, Kistiakowsky quickly shifted from pre-med to a chemistry major. Yet even as she embraced laboratory work, she began to sense the limits of her enthusiasm: the meticulous routines of analytical chemistry left her cold—"bubbles in burettes and ashes in crucibles and all kinds of misfortunes like that," she later quipped. Still, Mount Holyoke provided a rare environment where women's intellectual ambitions were expected and supported.

During this time, Kistiakowsky also had an extraordinary window into wartime science. When George Kistiakowsky was recruited to lead the explosives division of the Manhattan Project, his daughter received a rare dispensation to spend summers at the top-secret Los Alamos laboratory. While most teenagers spent their summers working or attending camp, Kistiakowsky rode horses across the New Mexico mesas and absorbed the atmosphere of a scientific enterprise unlike anything she had encountered—intense, collaborative, and cloaked in secrecy. She knew the work was important, and that it involved physics and chemistry, but not exactly what was being built until much later. "My father would point out that this gentleman was Niels Bohr and that gentleman was Enrico Fermi," she recalled, "and I should pay attention because they were very famous physicists. But I think I paid more attention to my horse." Even so, the experience left a mark. It broadened her understanding of what science could be—its urgency, its scale, its human dimensions.

PhD in nuclear chemistry

In 1948 Kistiakowsky arrived at the University of California, Berkeley to begin graduate work in nuclear chemistry—joining one of the most intense and competitive research environments in the country. Coming from the supportive, all-women setting of Mount Holyoke, she found the transition daunting. Berkeley was filled with returning servicemen and wartime scientists, many with extensive practical experience. "Academically, I was not terribly

> "My father would point out that this gentleman was Niels Bohr and that gentleman was Enrico Fermi, and I should pay attention because they were very famous physicists. But I think I paid more attention to my horse." VERA KISTIAKOWSKY

well-prepared...and it was a very painful first year there," she later recalled. She was young and struggled with the pace of coursework and the rigor of the qualifying exams, but encouragement from fellow students and her own stubbornness kept her going. She joined Glenn Seaborg's lab—a soon-to-be Nobel Prize winner and a powerhouse in actinide and transuranic research. Like many of Seaborg's students, she saw him only occasionally; direct supervision was limited, and much of the day-to-day work required self-direction, persistence, and technical ingenuity.

As a graduate student in that setting, Kistiakowsky undertook the challenging task of identifying and characterizing the radioactive decay of several promethium (Pm) isotopes—an element with no stable isotopes and only trace amounts found in nature. Her 1952 paper, based on her PhD thesis, reported the half-lives and radiation energies of Pm-141, Pm-142, Pm-143, Pm-144, Pm-146, Pm-149, and Pm-150. These were produced through proton and helium-ion bombardments of isotopically enriched neodymium and praseodymium oxides. The work involved intricate chemical separations and beta- and gamma-ray spectroscopy to tease apart complex decay chains, occasionally correcting earlier misidentifications in the literature. These isotopes were of particular interest for testing and refining the nuclear shell model, especially in the region just beyond the N = 82 closed neutron shell, where promethium's anomalous absence in nature suggested structural instabilities. Kistiakowsky's careful measurements helped fill in critical gaps in the chart of nuclides and contributed to a more nuanced understanding of nuclear stability. Reflecting on the experience later, "So, the physics part was very interesting....The chemistry parts and I didn't work out too well together."

Transition to experimental nuclear physics

Following her PhD, Kistiakowsky took a position at the United States Naval Radiological Defense Laboratory (NRDL) in San Francisco—a defense-oriented lab focused on the effects of radiation, but one that afforded limited opportunities for original research. Undeterred, she used her own time to return to Berkeley, where she produced samples of Pm-150 using the cyclotron and studied their decay using equipment she had access to in the Radiation Laboratory. "So that was sort of the first piece of postdoctoral research I did, to really run that into the ground," she later recalled. What made this possible was the emergence of a powerful new research tool: sodium iodide (NaI) scintillation detectors, which enabled a new level of precision in gamma-ray spectroscopy. With these, she built and deployed a custom pulse-height analyzer—pioneering techniques that bridged her earlier radiochemistry training with the more electronics-driven experimental physics she would embrace going forward. This transitional period, marked by both institutional constraint and technical innovation, shaped her identity as an experimental physicist and demonstrated the initiative she would carry throughout her career.

A postdoctoral fellowship gave Kistiakowsky the opportunity to work with the Alvarez group at the UC-Berkeley Radiation Laboratory—one of the most prestigious and innovative experimental physics groups of the time, led by future Nobel laureate Luis Alvarez. Immersed in this dynamic environment, she studied short-lived isotopes with atomic numbers between 60 and 82—a region rich in closed nuclear shells and metastable states. "These were really very short-lived," she recalled, "so I had a slide mechanism that held a target of rare earths....At the end of a short period of time, I released the slide, and the whole thing would drop down in front of my detectors." This custom-designed timing system allowed her to measure the decay of isotopes with half-lives ranging from a few seconds to a couple of minutes—too fleeting for conventional techniques. Bombarding rare-earth oxide targets with 31.5 MeV protons from the lab's linear accelerator, she used sodium iodide scintillation detectors to capture gamma spectra and construct decay curves. The work, published in 1955, identified several new metastable states—Re-180m, Ir-191m, Au-193m, Pb-201m and Pb-203m—and contributed valuable data to the growing understanding of nuclear structure near closed shells. It also marked her transition into physics-centered experimentation, blending her radiochemical foundation with the electronic and timing techniques that were reshaping the study of fundamental particles.

Climbing in energy

At Columbia University (1954–1959), Kistiakowsky completed her transformation from nuclear chemist to full-fledged experimental physicist. She was initially hired to do nuclear chemistry, "I was hired as a chemist, and I discovered I didn't like chemistry any better than I had before." With the quiet support of Chien-Shiung Wu—a titan of nuclear physics and a pioneer in the discovery of parity violation—she shifted her focus toward experimental physics. "She was very good in supporting me in my efforts to become independent.... I think it was just that she was a very honorable person." In Wu's demanding yet supportive group, Kistiakowsky began designing her own experiments and acquiring the technical fluency that would define her career.

That fluency translated into increasingly ambitious work, as she moved to higher energies and more sophisticated instrumentation. She played a central role in developing tools such as ΔE–E telescopes for charged-particle identification, solenoid-based beta spectrometers, and pulse-height analyzers integrated with early magnetic-core memory systems. This was used to measure the angular distribution of products of reactions in light nuclei using 10–50 MeV beams at Brookhaven National Lab. Reflecting on this period, she described her trajectory as "a climb in energy," a steady ascent toward finer experimental resolution and deeper insight: "It was giving you a somewhat finer resolution device to study the nuclear force with. That was what I was doing while I was at Columbia."

> "Doing a bubble chamber run is fun, and getting the physics out of the data is fun."
>
> VERA KISTIAKOWSKY

Return to Massachusetts

In 1959, Vera Kistiakowsky moved back to Massachusetts to take a faculty position at Brandeis University—a move that enabled both her and her husband to secure academic appointments and came as they were starting their family. Though the department was newly established and broadly focused, she began "looking around" for work that aligned with her deepening interest in particle physics. This led her to a collaborative bubble chamber experiment with groups from Harvard, Brown, and MIT. "So that sort of was my first independent piece of high-energy physics research," she later recalled. The experiment used a large bubble chamber filled with a high-density liquid to study the neutral decays of the Λ^0 hyperon and the $K_1{}^0$ meson. Bubble chambers captured the tracks of particles as trails of bubbles in superheated liquid, allowing researchers to visually reconstruct decay events. Kistiakowsky spent long hours at scanning tables, examining film and tracing particle paths by hand. Her work helped determine the branching ratios of these particles, offering new insight into the nature of these particles and solidifying her place in the world of high-energy experimental physics.

MIT Laboratory for Nuclear Science

By 1963, Kistiakowsky found herself at a crossroads. Seeking greater flexibility to balance the needs of a young family and an environment where she could focus fully on experimental physics, she spoke with her collaborator at MIT, Professor of Physics Irwin Pless, about the possibility of joining MIT's Laboratory for Nuclear Science. His response was quick and enthusiastic: "Yes, immediately, if not sooner."

Kistiakowsky's move to MIT in 1963 coincided with a transformative era in high-energy physics—a time when new accelerators and detector technologies were uncovering a flood of new hadrons, and physicists worked to make sense of them all, laying the groundwork for the Standard Model. As a staff researcher in the Laboratory for Nuclear Science, she had, in her words, "complete freedom to do research," unburdened by teaching or departmental politics. The work was intensely hands-on and collaborative, with physicists, postdocs, and students gathering around scanning tables to analyze thousands of bubble chamber photographs in search of rare events. She later recalled simply, "Doing a bubble chamber run is fun, and getting the physics out of the data is fun." During this period, she built a prolific career in hadronic physics. Her technical acumen and leadership led to her promotion to senior research scientist in 1969, and in 1973, Irwin Pless—recognizing her stature—put her forward for a faculty position, with strong support from colleagues like Bob Hulsizer. She was appointed that year, becoming the first woman on the MIT physics faculty and ultimately co-authoring more than 70 publications in this area over her career at MIT.

Advocacy and institutional change

In the 1970s, Kistiakowsky emerged as a national advocate for women in science, helping to found the American Physical Society's Committee on the Status of Women in Physics (CSWP) in 1971 and served as its first chair. The committee became a force for change within the physics community, publishing several high-profile reports and articles that documented the underrepresentation and systemic obstacles faced by women in physics. These efforts helped establish a framework for action. Years later, in 1988, she was a founder of the *MIT Faculty Newsletter* in response to the abrupt, controversial closure of the Department of Applied Biological Sciences—an act that exemplified her commitment to transparency, shared governance, and the principle that faculty should have a voice in institutional decisions.

B physics, Cornell, and planetary nebulae

During a sabbatical year at Cornell in 1981–82, Kistiakowsky joined the CLEO collaboration just as the Cornell Electron Storage Ring (CESR) was coming online. CESR was the first of a new generation of precision electron-positron colliders—machines that would evolve into the B factories and now inspire visions of future Higgs factories. Its high luminosity and clean environment made it ideal for exploring heavy quark dynamics with unprecedented detail. It was a particularly productive year for Kistiakowsky, leading to results on a range of topics from charm-quark fragmentation to transitions in the upsilon system. Most notably, she contributed to an early accelerator search for axions—hypothetical particles proposed by theorists including Frank Wilczek to explain the absence of CP violation in strong interactions. The work helped set early limits on axion models, which have since become a major focus of research as the axion remains one of the most well-motivated dark matter candidates.

Disillusioned with the direction of high-energy physics—particularly the increasing scale of experiments and the difficulty of securing NSF funding for B-physics within the DOE-centric Laboratory for Nuclear Science—Kistiakowsky made a decisive shift to observational astronomy. She focused on planetary nebulae as markers of stellar evolution and Galactic structure, turning to a style of research that was smaller in scale and more personal. Working with David Helfand, she conducted her own hands-on observations at the Michigan-Dartmouth-MIT Observatory on Kitt Peak, using narrowband near-infrared imaging centered on [S III] emission lines. Their surveys revealed dozens of previously unidentified planetary nebulae obscured by interstellar dust near the Galactic plane. This work not only demonstrated the power of [S III] as a tracer of distant, reddened nebulae, but also marked a return to the direct, hands-on, small-team research that had defined the most satisfying chapters of her scientific life.

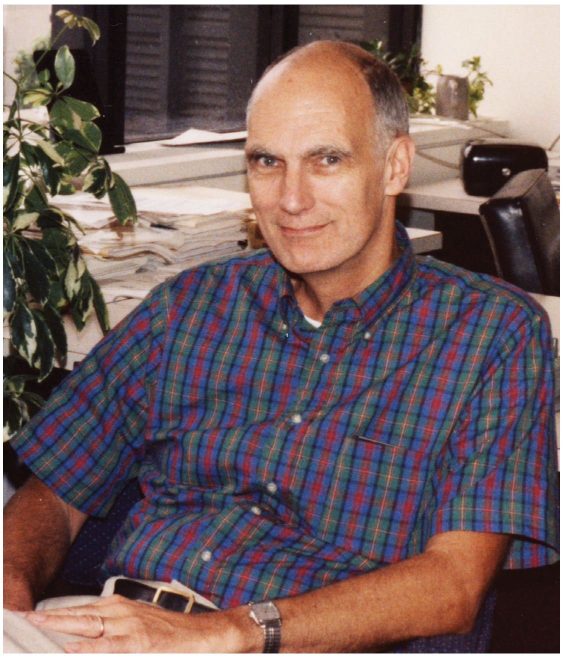
Among giants

Vera Kistiakowsky transitioned to emeritus status in 1994 but remained active and adventurous, continuing to trek in Nepal well into her later years. Over a five-decade career that stretched from the early days of nuclear chemistry to the precision era of high-energy physics and into observational astronomy, she helped shape multiple fields while mentoring generations of scientists. She worked in an era of giants—towering figures who reshaped our understanding of the physical world—and she climbed among them, both literally and figuratively. Her legacy lives on in the experiments she built, the institutions she helped transform, and the physicists she trained. Asked once whether building a complex scattering chamber had been difficult, she answered with characteristic clarity and delight: "No. It's fun."

PROFESSOR LINDLEY WINSLOW is Associate Department Head, MIT Department of Physics, an experimental nuclear and particle physicist, and as a teenager, she would probably have preferred her horse to famous physicists, too. The author thanks Profs. Edmund Bertschinger, Ruth Perry, Jean Jackson, and Paul Schechter for their help on this piece. A special thank you to Prof. Karen Fischer of Brown University for their memories of their mother and additional materials from which this piece was drawn. Quotes by Prof. Kistiakowsky are from Shirlee Sherkow's interview of Kistiakowsky for the MIT Oral History Project in 1976.

In Remembrance

Professor Emeritus Hale Van Dorn Bradt, an X-ray astronomy pioneer, dies at 93



Credit: MIT Physics Department

Longtime MIT faculty member used X-ray astronomy to study neutron stars and black holes and led the All-Sky Monitor instrument on NASA's Rossi X-ray Timing Explorer.

by Sandi Miller

MIT Professor Emeritus Hale Van Dorn Bradt PhD '61, formerly of Salem and Belmont, MA, passed away on November 14, 2024; he was 93. He is survived by his wife, Dorothy Haughey Bradt; two daughters and their husbands: Elizabeth Bradt and J. Bartlett Hoskins and Dorothy and Bart McCrum; two grandchildren; as well as siblings, nieces, and nephews.

PUBLISHER'S NOTE: The following faculty obituaries are adapted from the original, full-length features posted to MIT News online at *news.mit.edu*.

Bradt, a longtime member of the Department of Physics, worked primarily in X-ray astronomy with NASA rockets and satellites, studying neutron stars and black holes in X-ray binary systems using rocket-based and satellite-based instrumentation. He was the original principal investigator for the All-Sky Monitor instrument on NASA's Rossi X-ray Timing Explorer (RXTE), which operated from 1996 to 2012.

Much of his research was directed toward determining the precise locations of celestial X-ray sources, most of which were neutron stars or black holes. This made possible investigations of their intrinsic natures at optical, radio, and X-ray wavelengths. "Hale was the last of the cosmic ray group that converted to X-ray astronomy," says Bruno Rossi Professor of Physics Claude Canizares. "He was devoted to undergraduate teaching and, as a postdoc, I benefited personally from his mentoring and guidance." He shared the Bruno Rossi Prize in High-Energy Astrophysics from the American Astronomical Society in 1999.

Bradt earned his PhD at MIT in 1961, working with advisor George Clark in cosmic ray physics, and taught undergraduate courses in physics from 1963 to 2001. In the 1970s, he created the department's undergraduate astrophysics electives 8.282 and 8.284, which are still offered today. He wrote two textbooks based on that material, "Astronomy Methods" (2004) and "Astrophysics Processes" (2008), the latter which earned him the 2010 Chambliss Astronomical Writing Prize of the American Astronomical Society (AAS).

Son of a musician and academic

Hale Bradt was born in 1930 to Wilber and Norma Bradt in Washington state, where his mother was a musician and writer, and his father was a chemistry professor who served in the Army during World War II. Six weeks after Bradt's father returned home from the war, he took his own life. Bradt was 15. In 1980, Bradt discovered a stack of his father's personal letters written during the war, which led to a decades-long research project that took him to the Pacific islands where his father served. This culminated with the book trilogy, "Wilber's War," which earned him two silver awards from the IBPA's Benjamin Franklin and Foreword Reviews' IndieFAB; he was also an award finalist from National Indie Excellence.

Bradt discovered his love of music early; he sang in the Grace Church School choir in fifth and sixth grades, and studied the violin from the age of 8 until he was 21. He studied musicology and composition at Princeton University, where he played in the Princeton Orchestra. He also took weekly lessons in New York City with one of his childhood teachers, Irma Zacharias, who was the mother of MIT professor Jerrold Zacharias. "I did not work at the music courses very hard and thus did poorly," he recalled. In the 1960s, at MIT he played with a string quartet that included MIT mathematicians Michael Artin, Lou Howard, and Arthur Mattuck. Bradt and his wife, Dottie, also sang with the MIT Chorale Society from about 1961 to 1971, including a 1962 trip to Europe. Well into his 80s, Bradt retained an interest in classical music, both as a violinist and as a singer, performing with diverse amateur choruses, orchestras, and chamber groups. At one point he played with the Belmont Community Orchestra, and sang with the Paul Madore Chorale in Salem. In retirement, he and his wife enjoyed chamber music, opera, and the Boston Symphony Orchestra.

In the Navy

In the summer before his senior year at Princeton University he began Naval training, which is where he discovered a talent for "mathematical-technical stuff," he said. "I discovered that on quantitative topics, like navigation, I was much more facile than my fellow students. I could picture vector diagrams and gun mechanisms easily." He said he came back to Princeton "determined to get a major in physics," but because that would involve adding a fifth year to his studies, "the dean wisely convinced me to get my degree in music, get my Navy commission, and serve my two years." He graduated in 1952, trained for the Navy with the Reserve Officer Candidate program, and served in the U.S. Navy as a deck officer and navigator on the USS Diphda cargo ship during the Korean War.

MIT years

Bradt returned to Princeton to work in the Cosmic Ray lab, then joined MIT as a graduate student in 1955, working in Bruno Rossi's Cosmic Ray Group as a research assistant. Recalled Bradt, "The group was small, with only a half-dozen faculty and a similar number of students. Sputnik was launched, and the group was soon involved in space experiments with rockets, balloons, and satellites."

The beginnings of celestial X-ray and gamma-ray astronomy took root in Cambridge, MA, as did the exploration of interplanetary space. Bradt also worked under Bill Kraushaar, George Clark, and Herbert Bridge, and was soon joined by radio astronomers Alan Barrett and Bernard Burke, and theorist Phil Morrison.

As a professor, he studied extensive air showers with gamma-ray primaries (as low-mu showers) on Mt. Chacaltaya in Bolivia, and in 1966, he participated in a rocket experiment that led to a precise celestial location and optical identification of the first stellar X-ray source, Scorpius X-1. "X-ray astronomy was sort of a surprise," said Bradt. "Nobody really predicted that there should be sources of X-rays out there." His group studied X-rays originating from the Milky Way Galaxy by using data collected with rockets, balloons, and satellites. In 1967, he collaborated with NASA to design and launch sounding rockets from White Sands Missile Range, which would use specialized instruments to detect X-rays above Earth's atmosphere. Bradt was a senior participant or a principal investigator for instruments on the NASA X-ray astronomy satellite missions SAS-3 that launched in 1975, HEAO-1 in 1977, and RXTE in 1995.

All Sky Monitor and RXTE

In 1980, Bradt and his colleagues at MIT, Goddard Space Flight Center, and the University of California at San Diego began designing a satellite that would measure X-ray bursts and other phenomena on time scales from milliseconds to years. By 1995, the team launched RXTE.

Until 2001, Bradt was the principal investigator of RXTE's All Sky Monitor, which scanned vast swaths of the sky during each orbit. When it was decommissioned in 2012, the RXTE provided a 16-year record of X-ray emissions from various celestial objects, including black holes and neutron stars. The 1969 sounding rocket experiment by Bradt's group discovered X-ray pulsations from the Crab pulsar, which demonstrated that the X-ray and optical pulses from this distant neutron star arrived almost simultaneously, despite traveling through interstellar space for thousands of years. He received NASA's Exceptional Scientific Achievement Medal in 1978 for his contributions to the HEAO-1 mission and shared the 1999 Bruno Rossi Prize of the American Astronomical Society's High Energy Astrophysics Division for his role with RXTE.

"Hale's work on precision timing of compact stars, and his role as an instrument PI on NASA's Rossi X-ray Timing Explorer played an important part in cultivating the entrepreneurial spirit in MIT's Center for Space Research, now the MIT Kavli Institute," says Rob Simcoe, the Francis L. Friedman Professor of Physics and director of the MIT Kavli Institute for Astrophysics and Space Research. Without Bradt's persistence, the HEAO 1 and RXTE missions may not have launched, recalls Alan Levine PhD '76, a principal research scientist at Kavli who was the project scientist for RXTE. "Hale had to skillfully negotiate to have his MIT team join together with a (non-MIT) team that had been competing for the opportunities to provide both experimental hardware and scientific mission guidance," he says. "The A-3 experiment was eventually carried out as a joint project between MIT under Hale and Harvard/Smithsonian under Herbert (Herb) Gursky."

"Hale had a strong personality," recalls Levine. "When he wanted something to be done, he came on strong and it was difficult to refuse. Often it was quicker to do what he wanted rather than to say no, only to be asked several more times and have to make up excuses." "He was persistent," agrees former student, Professor Emeritus Saul Rappaport PhD '68. "If he had a suggestion, he never let up."

Rappaport also recalls Bradt's exacting nature. For example, for one sounding rocket flight at White Sands Missile Range, "Hale took it upon himself to be involved in every aspect of the rocket payload, including parts of it that were built by Goddard Space Flight Center—I think this annoyed the folks at GSFC," recalls Rappaport. "He would be checking

> "I'm so grateful to have had the chance to work with Hale as an undergraduate. He taught me so much about high-energy astrophysics, the research world, and how to be a good mentor."
>
> — ANDREA GHEZ '87, UNIVERSITY OF CALIFORNIA AT LOS ANGELES PROFESSOR AND NOBEL LAUREATE

everything three times. There was a famous scene where he stuck his ear in the (compressed-air) jet to make sure that it went off, and there was a huge blast of air that he wasn't quite expecting. It scared the hell out of everybody, and the Goddard people were, you know, a bit amused. The point is that he didn't trust anything unless he could verify it himself."

Supportive advisor

Many former students recalled Hale's supportive teaching style, and was a strong advocate for his students' professional development. "He was a wonderful mentor: kind, generous, and encouraging," recalls physics department head Professor Deepto Chakrabarty '88, who had Bradt as his postdoctoral advisor when he returned to MIT in 1996.

"I'm so grateful to have had the chance to work with Hale as an undergraduate," recalls University of California at Los Angeles professor and Nobel laureate Andrea Ghez '87. "He taught me so much about high-energy astrophysics, the research world, and how to be a good mentor. Over the years, he continuously gave me new opportunities– starting with working on onboard data acquisition and data analysis modes for the future Rossi X-Ray Timing Explorer with Ed Morgan and Al Levine. Later, he introduced me to a project to do optical identification of X-ray sources, which began with observing with the MIT-Michigan-Dartmouth Telescope (MDM) with then-postdoc Meg Urry and him."

Bradt was a relatively new professor when he became Saul Rappaport's advisor in 1963. At the time, MIT researchers were switching from the study of cosmic rays to the new field of X-ray astronomy. "Hale turned the whole rocket program over to me as a relatively newly minted PhD, which was great for my career, and he went on to some satellite business, the SAS 3 satellite in particular. He was very good in terms of looking out for the careers of junior scientists with whom he was associated."

Bradt looked back on his legacy at MIT physics with pride. "Today, the astrophysics division of the department is a thriving community of faculty, postdocs, and graduate students," Bradt said recently. "I cast my lot with X-ray astronomy in 1966 and had a wonderfully exciting time observing the X-ray sky from space until my retirement in 2001."

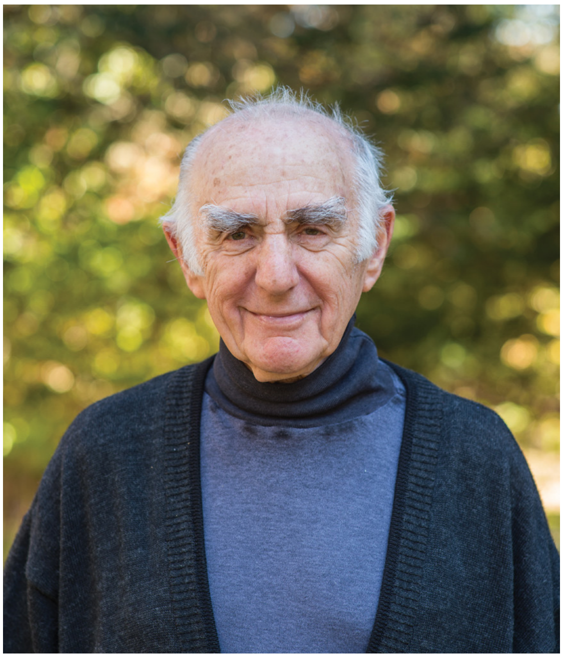
After retirement, Bradt served for 16 years as academic advisor for MIT's McCormick Hall first-year students. He received MIT's Buechner Teaching Prize in Physics in 1990, Outstanding Freshman Advisor of the Year Award in 2004, and the Alan J. Lazarus (1953) Excellence in Advising Award in 2017.

Recalls Ghez, "He was a remarkable and generous mentor and helped me understand the importance of helping undergraduates make the transition from the classroom to the wonderfully enriching world of research."

Bradt's additional recognitions include earning a 2015 Darius and Susan Anderson Distinguished Service Award of the Institute of Governmental Studies, a 1978 NASA Exceptional Scientific Achievement Medal, and being named a 1972 American Physical Society Fellow and 2020 AAS Legacy Fellow. Bradt served as secretary-treasurer (1973-75) and chair (1981) of the AAS High Energy Astrophysics Division, and on the National Academy of Science's Committee for Space Astronomy and Astrophysics from 1979 to 1982. He recruited many of his colleagues and students to help him host the 1989 meeting of the American Astronomical Society in Boston, a major astronomy conference.

He established the Thomas Fellowship in memory of Barbara E. Thomas, who was the Department of Physics undergraduate administrator from 1931 to 1965, as well as to honor the support staff who have contributed to the department's teaching and research programs. "MIT has provided a wonderful environment for me to teach and to carry out research," said Bradt. "I am exceptionally grateful for that and happy to be in a position to give back." He added, "Besides, I am told you cannot take it with you."

Professor Emeritus Lee Grodzins, pioneer in nuclear physics, dies at 98



An MIT faculty member for 40 years, Grodzins performed groundbreaking studies of the weak interaction, led in detection technology, and co-founded the Union of Concerned Scientists.

by Sandi Miller

Nuclear physicist and MIT Professor Emeritus Lee Grodzins died on March 6, 2025, at his home in Weston, MA; he was 98. The husband of the late Lulu Anderson Grodzins, he is survived by sons Hal (Cathy Salmons) and Dean (Nora Nykiel Grodzins), and granddaughter, Lily.

Grodzins was a pioneer in nuclear physics research. He was perhaps best known for the highly influential experiment determining the helicity of the neutrino, which led to a key understanding of what's known as the weak interaction. He was also the founder of Niton Corp. and the nonprofit Cornerstones of Science, and was a co-founder of the Union of Concerned Scientists.

He retired in 1999 after serving as an MIT physics faculty member for 40 years. As a member of the Laboratory for Nuclear Science (LNS), he initiated the relativistic heavy-ion physics program. He published over 170 scientific papers and held 64 U.S. patents. "Lee was a very good experimental physicist, especially with his hands making gadgets," says Heavy Ion Group and Francis L. Friedman Professor Emeritus Wit Busza PhD '64. "His enthusiasm for physics spilled into his enthusiasm for how physics was taught in our department."

Industrious son of immigrants

Grodzins was born in 1926, in Lowell, MA, the son of Eastern European Jewish immigrants, and grew up in Manchester, NH. His father, David, who ran a gas station and a used-tire business, died when Lee was 15. To help support his family, Lee sold newspapers, a business he grew into the second-largest newspaper distributor in Manchester.

At 17, Grodzins attended the University of New Hampshire, graduating in less than three years with a degree in mechanical engineering. However, he decided to be a physicist after disagreeing with a textbook that used the word "never." "I was pretty good in math and was undecided about my future," Grodzins said in a 1958 *New York Daily News* article. "It wasn't until my senior year that I unexpectedly realized I wanted to be a physicist. I was reading a physics text one day when suddenly this sentence hit me: 'We will never be able to see the atom.' I said to myself that that was as stupid a statement as I'd ever read. What did he mean 'never!' I got so annoyed that I started devouring other writers to see what they had to say and all at once I found myself in the midst of modern physics." He wrote his senior thesis on "Atomic Theory."

After graduating in 1946, he approached potential employers by saying, "I have a degree in mechanical engineering, but I don't want to be one. I'd like to be a physicist, and I'll take anything in that line at whatever you will pay me." He accepted an offer from General Electric's Research Laboratory in Schenectady, New York, where he worked in fundamental nuclear research building cosmic ray detectors, while also pursuing his master's degree at Union College. "I had a ball," he recalled. "I stayed in the lab 12 hours a day. They had to kick me out at night."

Brookhaven

After earning his PhD from Purdue University in 1954, he spent a year as a lecturer there, before becoming a researcher at Brookhaven National Laboratory (BNL) with Maurice Goldhaber's nuclear physics group, probing the properties of the nuclei of atoms. In 1957, he, with Goldhaber and Andy Sunyar, used a simple table-top experiment to measure the helicity of the neutrino. Helicity characterizes the alignment of a particle's intrinsic spin vector with that particle's direction of motion.

> "I had a ball. I stayed in the lab 12 hours a day. They had to kick me out at night."
>
> — LEE GRODZINS, NUCLEAR PHYSICIST AND MIT PROFESSOR EMERITUS

The research provided new support for the idea that the principle of conservation of parity—which had been accepted for 30 years as a basic law of nature before being disproven the year before, leading to the 1957 Nobel Prize in Physics—was not as inviolable as the scientists thought it was, and did not apply to the behavior of some subatomic particles.

The experiment took about 10 days to complete, followed by a month of checks and rechecks. They submitted a letter on "Helicity of Neutrinos" to *Physical Review* on Dec. 11, 1957, and a week later, Goldhaber told a Stanford University audience that the neutrino is left-handed, meaning that the weak interaction was probably one force. This work proved crucial to our understanding of the weak interaction, the force that governs nuclear beta decay. "It was a real upheaval in our understanding of physics," says Grodzins' longtime colleague Stephen Steadman. The breakthrough was commemorated in 2008, with a conference at BNL on "Neutrino Helicity at 50."

Steadman also recalls Grodzins' story about one night at Brookhaven, where he was working on an experiment that involved a radioactive source inside a chamber. Lee noticed that a vacuum pump wasn't working, so he tinkered with it a while before heading home. Later that night, he gets a call from the lab. "They said, 'Don't go anywhere!'" recalls Steadman. It turns out the radiation source in the lab had exploded, and the pump filled the lab with radiation. "They were actually able to trace his radioactive footprints from the lab to his home," says Steadman. "He kind of shrugged it off."

The MIT years

Grodzins joined the faculty of MIT in 1959, where he taught physics for four decades. He inherited Robley Evans' Radiation Laboratory, which used radioactive sources to study properties of nuclei, and led the Relativistic Heavy Ion Group, which was affiliated with the LNS.

In 1972, he launched a program at BNL using the then-new Tandem Van de Graaff accelerator to study interactions of heavy ions with nuclei. "As the BNL tandem was getting commissioned, we started a program, together with Doug Cline at the University of Rochester, tandem to investigate Coulomb-nuclear interference," says Steadman, a senior research scientist at LNS. "The experimental results were decisive but somewhat controversial at the time. We clearly detected the interference effect." The experimental work was published in *Physical Review Letters*.

Grodzins' team looked for super-heavy elements using the Lawrence Berkeley National Laboratory Super-Hilac, investigated heavy-ion fission and other heavy-ion reactions, and explored heavy-ion transfer reactions. The latter research showed with precise detail the underlying statistical behavior of the transfer of nucleons between the heavy-ion projectile and target, using a theoretical statistical model of Surprisal Analysis developed by Rafi Levine and his graduate student. Recalls Steadman, "these results were both outstanding in their precision and initially controversial in interpretation."

In 1985, he carried out the first computer axial tomographic experiment using synchrotron radiation, and in 1987, his group was involved in the first run of Experiment 802, a collaborative experiment with about 50 scientists from around the world that studied relativistic heavy ion collisions at Brookhaven. The MIT responsibility was to build the drift chambers and design the bending magnet for the experiment. "He made significant contributions to the initial design and construction phases, where his broad expertise and knowledge of small area companies with unique capabilities was invaluable," says George Stephans, physics senior lecturer and senior research scientist at MIT.

Professor emeritus of physics and Nobel laureate (2017) Rainer Weiss '55, PhD '62 recalls working on a Mossbauer experiment to establish if photons changed frequency as they traveled through bright regions. "It was an idea held by some to explain the 'apparent' red shift with distance in our universe," says Weiss. "We became great friends in the process, and of course, amateur cosmologists." "Lee was great for developing good ideas," Steadman says. "He would get started on one idea, but then get distracted with another great idea. So, it was essential that the team would carry these experiments to their conclusion: they would get the papers published."

MIT mentor

Before retiring in 1999, Lee supervised 21 doctoral dissertations and was an early proponent of women graduate students in physics. For many years, he helped teach the Junior Lab required of all undergraduate physics majors. He got his favorite student evaluation, however, for a different course, billed as offering a "superficial overview" of nuclear physics. The comment read: "This physics course was not superficial enough for me." "He really liked to work with students," says Steadman. "They could always go into his office anytime. He was a very supportive mentor."

"He really liked to work with students. They could always go into his office anytime. He was a very supportive mentor."

— STEPHEN STEADMAN, SENIOR RESEARCH SCIENTIST AT LNS AND LONGTIME COLLEAGUE

"He was a wonderful mentor, avuncular and supportive of all of us," agrees Karl van Bibber '72, PhD '76, now at the University of California at Berkeley. He recalls handing his first paper to Grodzins for comments. "I was sitting at my desk expecting a pat on the head. Quite to the contrary, he scowled, threw the manuscript on my desk and scolded, 'Don't even pick up a pencil again until you've read a Hemingway novel!'... The next version of the paper had an average sentence length of about six words; we submitted it, and it was immediately accepted by *Physical Review Letters*."

Early in George Stephans' MIT career as a research scientist, he worked with Grodzins' newly formed Relativistic Heavy Ion Group. "Despite his wide range of interests, he paid close attention to what was going on and was always very supportive of us, especially the students. He was a very encouraging and helpful mentor to me, as well as being always pleasant and engaging to work with. He actively pushed to get me promoted to principal research scientist relatively early, in recognition of my contributions." "He always seemed to know a lot about everything, but never acted condescending," says Stephans. "He seemed happiest when he was deeply engaged digging into the nitty-gritty details of whatever unique and unusual work one of these companies was doing for us."

Al Lazzarini '74, PhD '78 recalls Grodzins' investigations using proton-induced X-ray emission (PIXE) as a sensitive tool to measure trace elemental amounts. "Lee was a superb physicist," says Lazzarini. "He gave an enthralling seminar on an investigation he had carried out on a lock of Napoleon's hair, looking for evidence of arsenic poisoning." Robert Ledoux '78, PhD '81, a former professor of physics at MIT who is now program director of the U.S. Advanced Research Projects Agency with the Department of Energy, worked with Grodzins as both a student and colleague. "He was a 'nuclear physicist's physicist'— a superb experimentalist who truly loved building and performing experiments in many areas of nuclear physics. His passion for discovery was matched only by his generosity in sharing knowledge."

The research funding crisis starting in 1969 led Grodzins to become concerned that his graduate students would not find careers in the field. He helped form the Economic Concerns Committee of the American Physical Society, for which he produced a major report on the "Manpower Crisis in Physics" (1971), and presented his results before the American Association for the Advancement of Science, and at the Karlsruhe National Lab in Germany.

Grodzins played a significant role in bringing the first Chinese graduate students to MIT in the 1970s and 1980s. One of the students he welcomed was Huan Huang PhD '90. "I am forever grateful to him for changing my trajectory," says Huang, now at the University of California at Los Angeles. "His unwavering support and 'go do it' attitude inspired us to explore physics at the beginning of a new research field of high energy heavy ion collisions in the 1980s. I have been trying to be a 'nice professor' like Lee all my academic career."

Niton Corp. and post-MIT work

Grodzins liked what he called "tabletop experiments," like the one used in his 1957 neutrino experiment, which involved a few people building a device that could fit on a tabletop. "He didn't enjoy working in large collaborations, which nuclear physics embraced." says Steadman. "I think that's why he ultimately left MIT."

In the 1980s, he launched what amounted to a new career in detection technology. In 1987, after developing a scanning proton-induced X-ray microspectrometer for use measuring elemental concentrations in air, he founded the Niton Corp., which developed, manufactured, and marketed test kits and instruments to measure radon gas in buildings, lead-based paint detection, and other nondestructive testing applications. ("Niton" is an obsolete term for radon.) "At the time, there was a big scare about radon in New England, and he thought he could develop a radon detector that was inexpensive and easy to use," says Steadman. "His radon detector became a big business."

He later developed devices to detect explosives, drugs, and other contraband in luggage and cargo containers. Handheld devices used X-ray fluorescence to determine the composition of metal alloys and to detect other materials. The handheld XL Spectrum Analyzer could detect buried and surface lead on painted surfaces, to protect children living in older homes. Three Niton X-ray fluorescence analyzers earned R&D 100 awards. "Lee was very technically gifted," says Steadman.

In 1999, Grodzins retired from MIT and devoted his energies to industry, including directing the R&D group at Niton. In the 1990s, he was vice president of American Science and Engineering, and between the ages of 70 and 90, he was awarded three patents a year. "Curiosity and creativity don't stop after a certain age," Grodzins said to *UNH Today*. "You decide you know certain things, and you don't want to change that thinking. But thinking outside the box really means thinking outside your box."

A better world

In the 1950s, Grodzins and other Brookhaven scientists joined the American delegation at the Second United Nations International Conference on the Peaceful Uses of Atomic Energy in Geneva. Early on, he joined several Manhattan Project alums at MIT in their concern about the consequences of nuclear bombs. In Vietnam-era 1969, Grodzins co-founded the Union of Concerned Scientists, which calls for scientific research to be directed away from military technologies and toward solving pressing environmental and social problems. He served as its chair in 1970 and 1972. He also chaired committees for the American Physical Society and the National Research Council.

As vice president for advanced products at American Science and Engineering, which made homeland security equipment, he became a consultant on airport security, especially following the 9/11 attacks. As an expert witness, he testified at the celebrated trial to determine whether Pan Am was negligent for the bombing of Flight 103 over Lockerbie, Scotland, and he took part in a weapons inspection trip on the Black Sea. He also was frequently called as an expert witness on patent cases.

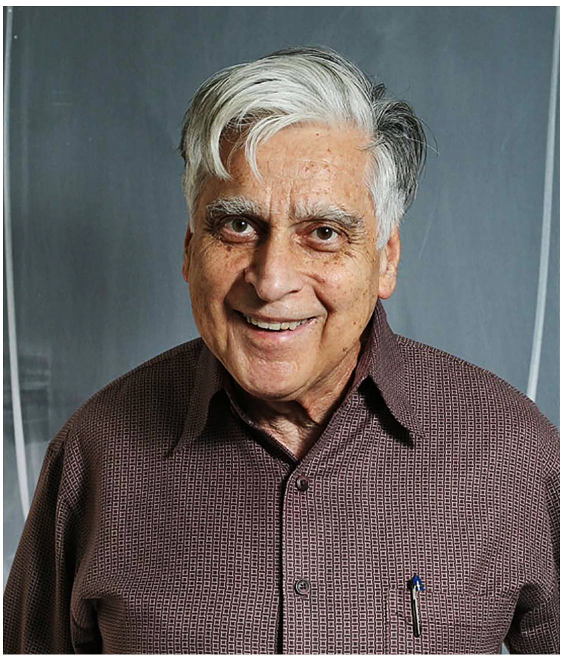
In 1999, Grodzins founded the nonprofit Cornerstones in Science, a public library initiative to improve public engagement with science. Based originally at the Curtis Memorial Library in Brunswick, Maine, Cornerstones now partners with libraries in several U.S. states. Among their initiatives was one that has helped supply telescopes to libraries and astronomy clubs around the country.

Awards

Grodzins authored more than 170 technical papers and holds more than 60 U.S. patents. His numerous accolades included being named a Guggenheim Fellow in 1964 and 1971, and a senior von Humboldt fellow in 1980. He was a fellow of the American Physical Society and the American Academy of Arts and Sciences, and received an honorary doctor of science degree from Purdue University in 1998. In 2021, the Denver X-Ray Conference gave Grodzins the Birks Award in X-Florescence Spectrometry, for having introduced "a handheld XRF unit which expanded analysis to in-field applications such as environmental studies, archeological exploration, mining, and more."

Lee Grodzins, says Steadman, "had a strong sense of wanting to do good for mankind."

Professor Emeritus Earle Lomon, nuclear theorist, dies at 94



On the physics faculty for nearly 40 years and a member of the Center for Theoretical Physics, he focused on the interactions of hadrons and developed an R-matrix formulation of scattering theory.

by Sandi Miller

Earle Leonard Lomon PhD '54, MIT professor emeritus of physics, died on March 7, 2025, in Newton, MA; he was 94. Husband of the late Ruth Lomon, he is survived by his daughters Glynis Lomon and Deirdre Lomon; his son, Dylan Lomon; three grandchildren and six great-grandchildren.

A longtime member of the Center for Theoretical Physics, Lomon was interested primarily in the forces between protons and neutrons at low energies, where the effects of quarks and gluons are hidden by their confinement. His research focused on the interactions of hadrons—protons, neutrons, mesons, and nuclei—before it was understood that they were composed of quarks and gluons.

"Earle developed an R-matrix formulation of scattering theory that allowed him to separate known effects at long distance from then-unknown forces at short distances," says longtime colleague Robert Jaffe, the Jane and Otto Morningstar Professor of Science, Post-Tenure. "When QCD (quantum chromodynamics) emerged as the correct field theory of hadrons, Earle moved quickly to incorporate the effects of quarks and gluons at short distance and high energies," says Jaffe. "Earle's work can be interpreted as a precursor to modern chiral effective field theory, where the pertinent degrees of freedom at low energy, which are hadrons, are matched smoothly onto the quark and gluon degrees of freedom that dominate at higher energy."

"He was a truly cosmopolitan scientist, given his open mind and deep kindness," says Bruno Coppi, MIT professor of physics, emeritus.

Early years

Born in 1930 in Montreal, Quebec, Earle was the only son of Harry Lomon and Etta Rappaport. At Montreal High School, he met his future wife, Ruth Jones. Their shared love for classical music drew them both to the school's Classical Music Club, where Lomon served as president and Ruth was an accomplished musician.

While studying at McGill University, he was a research physicist for the Canada Defense Research Board from 1950 to 1951. After graduating in 1951, he married Jones, and they moved to Cambridge, where he pursued his doctorate at MIT in theoretical physics, mentored by Professor Hermann Feshbach. Lomon spent 1954 to 1955 at the Institute for Theoretical Physics (now the Niels Bohr Institute) in Copenhagen. "With the presence of Niels Bohr, Aage Bohr, Ben Mottelson, and Willem V.R. Malkus, there were many physicists from Europe and elsewhere, including MIT's Dave Frisch, making the Institute for Physics an exciting place to be," recalled Lomon. In 1956–57, he was a research associate at the Laboratory for Nuclear Studies at Cornell University. He received his PhD from MIT in 1954, and did postdoctoral work at the Institute of Theoretical Physics in Denmark, the Weizmann Institute of Science in Israel, and Cornell. He was an associate professor at McGill from 1957 until 1960, when he joined the MIT faculty.

In 1965, Lomon was awarded a Guggenheim Memorial Foundation Fellowship and was a visiting scientist at CERN. In 1968, he joined the newly formed MIT Center for Theoretical Physics. He became a full professor in 1970 and retired in 1999.

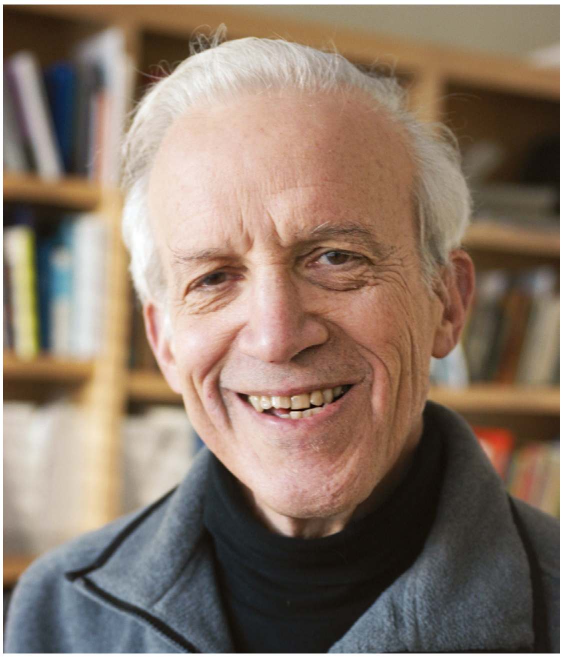
Los Alamos and math theory

From 1968 to 2015, Lomon was an affiliate researcher at the Los Alamos National Laboratory. During this time, he collaborated with Fred Begay, a Navajo nuclear physicist and medicine man. New Mexico became the Lomon family's second home, and Lomon enjoyed the area hiking trails and climbing Baldy Mountain.

Lomon also developed educational materials for mathematical theory. He developed textbooks, educational tools, research, and a creative problem-solving curriculum for the Unified Science and Mathematics for Elementary Schools. His children recall when Earle would review the educational tools with them at the dinner table. From 2001 to 2013, he was program director for mathematical theory for the U.S. National Science Foundation's Theoretical Physics research hub.

Lomon was an American Physical Society Fellow and a member of the Canadian Association of Physicists.

Professor Emeritus Daniel Kleppner, highly influential atomic physicist, dies at 92



Credit: Donna Coveney / MIT

The "godfather of Bose-Einstein condensation" and MIT faculty member of 37 years led research into atomic, molecular, and optical physics that led to GPS and quantum computing.

by Sandi Miller

Daniel Kleppner, the Lester Wolfe Professor Emeritus of Physics at MIT whose work in experimental atomic physics made an immense mark on the field, died on June 16, 2025, at the age of 92. He leaves behind his wife Beatrice; three children, Sofia, Andrew, and Paul; and a global community of colleagues, friends, and former students.

Kleppner's varied research examined the interactions of atoms with static electric and magnetic fields and radiation. His work included creating precision measurements with hydrogen masers, including the co-invention of the hydrogen maser atomic clock; his research into the physics of Rydberg atoms and cavity quantum electrodynamics; and his pioneering work in Bose-Einstein condensation (BEC).

Kleppner, who retired in 2003 after 37 years at MIT, was a highly literate and articulate scientist whose exacting research and communication skills helped set the direction of modern atomic, molecular, and optical (AMO) physics. From 1987 to 2000, he was associate director of the MIT Research Laboratory of Electronics (RLE), and served as interim director in 2001. He also co-founded the MIT-Harvard Center for Ultracold Atoms (CUA) in 2000, where he was co-director until 2006.

While he was never awarded a Nobel Prize, Kleppner's impact on the field of atomic physics and quantum optics, and his generous mentorship, enabled the Nobel achievements of many others. His patient and exacting pursuit of discovery led to basic research insights that led to major achievements. His extensive research into the tiny atom provided the fundamental knowledge necessary for the huge: the eventual development of groundbreaking technologies such as the global positioning system (GPS), magnetic resonance imaging (MRI), and quantum computing.

"He was a leader in the department, and a leader in the American Physical Society," says Wolfgang Ketterle, the John D. MacArthur Professor of Physics at MIT and a 2001 Nobel laureate. "He was a statesman of science. He was this eloquent person, this master of words who could express things in memorable ways, and at the same time he has this sense of humility."

"Dan Kleppner was a giant in the area of AMO physics, and in science more broadly," says John Doyle PhD '91, Harvard Quantum Initiative co-director and Kleppner advisee who helped Kleppner create the Bose-Einstein condensate from atomic hydrogen. "Perhaps his most impactful legacy is leading a culture of respect and supportive community actions that all scientists in the area of AMO physics enjoy today. Not only did his science lay the path for current research directions, his kindness, erudition, and commitment to community—and community service—are now ever-expanding waves that guide AMO physics. He was a mentor and friend to me."

Kleppner's daughter Sofie notes: "People who worked on early lasers never imagined we would be scanning groceries at the checkout counter. When they developed the hydrogen maser, they were a bunch of nerdy people who really wanted to understand Einstein's theory of relativity. This was the basis for GPS, this is how our flights run on time. Our dad was convinced that basic research today could lead to all sorts of valuable things down the road."

Early life and career

Born in Manhattan in 1932, Kleppner was the son of Vienna native and advertising agency founder Otto Kleppner. "As a teenager, I just liked building things," Kleppner once said. "And that turned out to be very useful when I went on to become an experimental physicist. I had a crystal radio, so I could listen to the radio over earphones. And the thought that the signals were just coming out of the atmosphere, I remember thinking: totally remarkable. And actually, I still do. In fact, the idea of the electromagnetic field, although it's very well understood in physics, always seems like a miracle to me."

In high school, he was inspired by his physics teacher, who allowed Kleppner to work all hours in the labs. "There was one time when the whole school was having a pep rally, and I wasn't that interested in cheering football, so I stayed up and worked in the lab, and the high school principal noticed that I was in there and called me in and gave me a dressing down for lack of school spirit." He didn't care. His teacher also talked with Kleppner about quantum mechanics, and "that sort of put a bee in my bonnet on that," and taught him a little calculus. "In those years, physics was extremely fashionable. These were the post-war years, and physicists were considered heroes for having brought the war to conclusion with the atom bomb, and ... the development of radar." He knew by then that he was "destined to spend a life in physics," he said in a video interview for InfiniteMIT. "It was an easy era to become delighted by physics, and I was."

Studying physics at Williams College, he was drawn to Albert Einstein's theory of general relativity. He built a programmable machine that he called a forerunner of cybernetics. Williams also instilled in him a lifelong love of literature, and he almost became an English major. However, he didn't appreciate what he called the school fraternities' "playboy" and "anti-intellectual" atmosphere, and worked to graduate quickly within three years, in 1953.

He deferred his acceptance to Harvard University with a Fulbright Fellowship to Cambridge University, where he met the young physicist Kenneth Smith, whose research was with atomic beam resonance. Smith introduced him to the book "Nuclear Moments," by Harvard professor Norman Ramsey, and presented a proposal by Ramsey's advisor I.I. Rabi, who invented a technique that could make an atomic clock so precise "that you could see the effect of gravity on time that Einstein predicted," said Kleppner. "I found that utterly astonishing," Kleppner noted. "The thought that gravity affects time: I had a hard time just visualizing that."

A new atomic clock

When Kleppner wandered Harvard's halls in 1955, he was excited to see a door with Ramsey's name on it. He was interested in Ramsey's research on molecular beam magnetic resonance, atomic clocks, and precision measurements. "Fortunately, I came along at a time when he had an opening in his research group," Kleppner recalled.

As Kleppner's advisor, Ramsey encouraged him to create a new type of atomic clock, believing that cesium and ammonia masers, a technology of amplified microwaves, were not precise enough to measure the effect of gravity on time. Kleppner's thesis was on using the concepts behind an ammonia maser to advance toward a hydrogen maser, which uses the natural microwave frequency of hydrogen atoms and amplifies it through stimulated emission of radiation. Kleppner discovered that coherent cesium atoms can bounce from properly prepared surfaces without losing their coherence.

After his 1959 PhD, Kleppner stayed on at Harvard, becoming an assistant professor in 1962.

Kleppner's research on hydrogen led to a method to keep hydrogen atoms locked in a glass container for study over a longer period of time. The result, featuring hydrogen atoms bouncing within a microwave cavity, is used to stabilize the frequency of a clock to a precision better than one microsecond in a year. In 1960, he and Ramsey successfully created a new atomic clock whose significant stability could confirm the minute effects of gravity on time, as predicted by Einstein's theory of general relativity. The current generation of optical clocks "are good enough to see the gravitational red shift for a few centimeters in height, so that's quite extraordinary, and it's had an extraordinary result," said Kleppner. "We got to rethink just what we mean by time."

While the hydrogen maser did verify Einstein's conjecture about time and gravity, it took more than a decade before being widely used, at first by radio astronomers. Today, atomic clocks such as the hydrogen maser are used in applications requiring high short-term stability, such as the synchronization of ground-based timing systems that track global positioning satellites, for timekeeping and communication by naval observatories to maintain a precise and stable time reference known as UTC (USNO); very long-baseline microwave interferometry (VLBI) that enables astronomers to achieve very high resolution and study distant radio sources, including black holes; and, indirectly, in magnetic resonance imaging.

"When we first set out to make these atomic clocks, our goals were about the least practical you can think of," Kleppner said in an interview with the MIT Physics Department. "From being a rather abstract idea that you'd like to somehow witness, it becomes a very urgent thing for the conduct of human affairs." Ramsey went on to win the Nobel Prize in Physics in 1989 for his work on the separated oscillatory fields method and its application in the hydrogen maser and atomic clocks.

MIT, ultracold gases, and BEC advancements

Kleppner figured he wouldn't get tenure at Harvard, "because no matter how generous and good-spirited Norman was, he casts a long shadow, and it was good for me to be at just the right distance. When I came to MIT, I had a pallet of experiments that I wanted to pursue, and some ideas about teaching that I wanted to pursue, and the transition was very simple." Kleppner joined the Institute in 1966, and his Harvard PhD student (and current MIT professor post-tenure) David Pritchard followed him, to work on scattering experiments: Kleppner worked with pulsed lasers, and Pritchard with continuous-wave (CW) lasers.

"He was young, he was verbal, and he seemed to have new ideas about what to do," says Pritchard. "We foresaw how important lasers would become. For a long time, it was just Dan and myself. That was actually the era in which lasers took over. Dan and I started off, we both got into lasers, and he did Rydberg atoms, and I did collisions and spectroscopy of weakly bound molecules and two-photon spectroscopy."

Kleppner led the tiny MIT Atomic Physics Group to eventually become the *US News and World Report*'s No. 1 nationally ranked atomic physics group in 2012. "Dan was the leader on this," recalled Pritchard. "To start from non-tenure and build it into the number-one ranked department in your subfield, that's a lifetime achievement." The group became what Pritchard called "the supergroup" of laser developers that included Charles Townes, who won the Nobel for his work; Ali Javan, who established a major laser research center at MIT; and Dolly Shibles. Pritchard joined the faculty in 1970, and Ketterle joined in 1990 as his postdoc. "We were pioneers, and the result was of course that our total group had a bigger impact." "He's not just the father figure of the field, he is my scientific father," says Pritchard. "When I'm writing something and it's not going very well, I would sort of think to myself, 'What would Dan say? What would he advise you?'"

With MIT low-temperature physicist Tom Greytak '63, PhD '67, Kleppner developed two revolutionary techniques—magnetic trapping and evaporative cooling. When the scientific community combined these techniques with laser cooling, atomic physics went into a major new direction. In 1995, a group of researchers, led by Kleppner's former students Eric Cornell PhD '90 and Carl Weiman '73, made a BEC using rubidium atoms, and Ketterle succeeded with sodium atoms. For this achievement, they received the 2001 Nobel Prize in Physics. Kleppner called BEC "the most exciting advance in atomic physics for decades."

At a conference on BEC in 1996, Ketterle recalls Kleppner describing his own contributions: "'I feel like Moses, who showed his people the Holy Land, but he never reached it himself.' This was exactly what Dan did. He showed us the Holy Land of Bose-Einstein condensation. He showed us what is possible....He was the godfather of Bose-Einstein condensation." But he did reach the Holy Land. In 1998, when only a few groups had been able to create BECs, Kleppner and Greytak realized a hydrogen BEC. When he presented their work at the summer school in Varenna soon afterward, he received a long-lasting standing ovation—after 20 years of hard work, he had reached his goal. "It is an irony that when Dan started this work, hydrogen was the only choice to reach the low temperatures for BEC," says Ketterle. But in the end, it turned out that hydrogen has special properties that made it much harder to reach BEC than with other atoms.

Rydberg atoms

In 1976, Kleppner pioneered the field of Rydberg atoms, a highly excited atom that shares the simple properties that characterize hydrogen. Kleppner showed that these states could be excited by a tunable laser and easily detected with field ionization. He then mapped out their response in high electric and magnetic fields, which he used to provide new physical insights into the connections between quantum mechanics and classical chaos.

In 1989, his research into atomic energy levels, under conditions where the corresponding classical motion is chaotic, mapped out the positions of thousands of quantum levels as a function of laser frequency and applied field using high-resolution laser spectroscopy. His observations gave new physical insight into the implications of classical chaos on quantum systems. "I see Dan as being the inventor of Rydberg atoms," says Dan's former student William Phillips PhD '76, physicist at the Institute of Standards and Technology (NIST). "Of course, Rydberg atoms is something that nature gives you, but Dan was the one who really understood this was something that you could use to do really new and wonderful things."

Such atoms have proved to be useful for studying the transition between quantum mechanics and classical chaos. Kleppner's 1976 paper on Rydberg atoms' strong interactions, long lifetimes, and sensitivity to external fields has led to current scientific research and multimillion-dollar startups interested in developing the promising Rydberg quantum computer; highly accurate measurements of electric and magnetic fields; and in quantum optics experiments. "Largely due to Dan's seminal roadmap, Rydberg atoms have become atomic physics' *E. coli* for investigating the interaction of radiation with matter," wrote Ketterle in his nomination for Kleppner's 2017 APS Medal for Exceptional Achievement in Research. "They are being used by others in quests for experimental systems to realize Schrödinger's cat, as well as for making a quantum computer."

In 1981, Kleppner suggested in a theoretical paper the possibility of suppressing spontaneous emission with a cavity: excited atoms cannot decay when the cavity lacks the oscillatory modes to receive their emissions. This was followed by his demonstration of this effect, and launched the field of cavity quantum electrodynamics (cQED), the study of how light confined within a reflective cavity interacts with atoms or other particles. This field has led to the creation of new lasers and photonic devices. "This work fundamentally changed the way physicists regard the process of spontaneous emission by showing that it is not a fixed property of a quantum state, but can be modified and controlled," said Ketterle. "Current applications of these principles, which Dan terms 'wrecking the vacuum,' include thresholdless lasers and the construction of photonic bandgap materials in which light propagation is forbidden at certain frequencies."

MIT-Harvard Center for Ultracold Atoms

In 2000, Kleppner secured National Science Foundation funding to co-found the Center for Ultracold Atoms (CUA), an MIT-Harvard collaboration that linked RLE with the Harvard Department of Physics to explore the physics of ultracold atoms and quantum gases. Kleppner served as its first director until 2006, and was a member of a group that included MIT professors Ketterle, Pritchard, Vladan Vuletic, Martin W. Zwierlein, Paola Cappellaro PhD '06, Isaac Chuang '90, and later joined by former Pappalardo Fellow Richard Fletcher.

"Many centers disappear after 10 to 20 years; sometimes their mission is fulfilled," says Ketterle, the CUA director from 2006 to 2023. "But given the excitement and the rapid evolution in atomic physics, the CUA is a super-active center brimming with excitement, and we just recently got renewed. That's partially due to the efforts of Dan. He created the tradition of atomic physics at MIT. We are one of the best atomic physics groups in the world. And we are really a family."

Boost-phase intercept report

Kleppner co-authored a highly influential 2003 report that examined the technical feasibility of boost-phase intercept, a concept central to President George H.W. Bush's proposed controversial Strategic Defense Initiative (SDI), nicknamed "Star Wars," which purportedly would render nuclear weapons obsolete. The focus of the APS Study on Boost-Phase Intercept for National Missile Defense, published as a special supplement to *Reviews of Modern Physics*, was on the physics and engineering challenges of intercepting a missile during its boost phase.

"This was a subject on which I had no technical background at all," Kleppner recalled, so he expressed gratitude for the skills of co-chair Fred Lamb of the University of Illinois. "But the APS [American Physical Society] felt that it was important to have information for the public… and no one knew anything about it. It was the point in my life where I could do that. And I feel that you have an obligation when the need arises and you can do it, to do that." The result? "Technically, it really would not succeed, except in very limited circumstances," Kleppner said. Added Pritchard, "It vastly changed the path of the nation."

"He was the perfect person to chair the committee," says Ketterle. "He excelled in being neutral and unbiased, and to create a no-nonsense report. I think the APS was very proud of this report. It shows how physicists analyze something which was at that moment of immense political and societal importance. This report helped to understand what laser weapons cannot do and what they can do. The fact that (SDI) eventually, slowly, disappeared, the report may have contributed to that."

Dedicated educator

Kleppner trained generations of physicists, including as advisor to 23 PhD students who have gone on to attain positions in major universities and achieve major scientific awards. He was awarded the Oersted Medal of the American Association of Physics Teachers in 1997, and earned the Institute's prestigious 1995-1996 James R. Killian, Jr. Faculty Achievement Award for his service to MIT and society on behalf of atomic physics. "He has given generously of his time and effort to the formation of national science policy, and he has served the Institute with distinction as teacher, administrator and counselor," the Killian committee wrote.

Kleppner and Ramsey wrote the widely used text "Quick Calculus" in 1972—the third edition of the book was updated in 2022 with MIT Department of Physics Senior Lecturer Peter Dourmashkin '75, '78, PhD '84. With Robert J. Kolenkow, Kleppner also wrote "An Introduction to Mechanics" in 1973, and its second edition in 2013. Physics department head Deepto Chakrabarty '88 called it "a masterpiece." "It has formed the foundation of our freshman 8.012 course for potential physics majors for over 50 years and has provided a deep, elegant, and mathematically sophisticated introduction to classical mechanics of physics majors across the U.S. It was my own introduction to serious physics as an MIT freshman in 1984."

Kleppner called his method of teaching "an engagement with the students and with the subject." He said that his role model for teaching was his wife, who taught high school psychology. "Fortunately, at MIT, the students are so great. There's nothing tough about teaching here, except trying to stay ahead of the students."

He leaves a legacy of grateful physicists impacted by his generous teaching style. "I've always felt that I've just been incredibly lucky to be part of Dan's group," says Phillips, who was at Princeton when his research into magnetic resonance caught Kleppner's attention, and invited him to MIT. "Dan extended this idea to putting this hydrogen maser in a much higher magnetic field. Not that many people are trained by somebody like Dan Kleppner in the art of precision measurement." Kleppner also gifted Phillips an apparatus he built for his thesis, which shaved years off the laser cooling experiments that led to Phillips' Nobel.

Ketterle credited Kleppner's mentorship for his career at MIT. "He was an older, experienced person who believed in me. He had more trust in me than I had initially myself. I felt whenever I was at a crossroads, I could go to Dan and ask him for advice. When I gave him a paper to edit… there was red ink all over it, but he was absolutely right on almost everything."

In 2003, Kleppner was dismayed at the statistic that over 60 percent of middle and high school teachers teaching physics have no background in the subject. He started the CUA's Teaching Opportunities in Physical Science (TOPS) summer program with his then-postdoc Ted Ducas to train physics majors to prepare and teach physics material to middle and high school students. In its 14-year run, they worked with 112 students. According to Ducas, one survey "indicates over 60 percent of our undergraduates have gone into, or plan to go into, pre-college teaching– a higher percentage than expected, because physics majors have so many other career opportunities often paying significantly more. The potential positive impact of that number of highly qualified and motivated teachers is dramatic."

Kleppner also partnered with Japanese mathematician Heisuke Hironaka on the mentoring program Japanese Association for Mathematical Sciences (JAMS), which connected American college science students with their Japanese counterparts. "His interest in ensuring that future generations also see the value of international communities was reflected in JAMS," says Sofie Kleppner.

Recognitions and public service

Kleppner was promoted to professor in 1974 and headed the physics department's Division of Atomic, Plasma and Condensed Matter Physics from 1976 to 1979. He was named the Lester Wolfe Professor of Physics in 1985.

Active in the interface between physics and public policy, he served on more than 30 committees. For the APS, he was on the Panel on Public Affairs (POPA), chaired the Physics Planning Committee and the Division of Atomic, Molecular and Optical Physics, and contributed to a study on the growth and mentorship of young physics professors. He chaired a report for the National Academy of Sciences on atomic physics that he presented on various congressional committees, served on the National Research Council's Physics Survey Committee, and was chair of the International Union of Pure and Applied Physics' Commission on Atomic and Molecular Physics. At MIT, he was also an ombuds of the Physics Department.

Kleppner was a fellow of the American Academy of Arts and Sciences, American Association for the Advancement of Science, OSA (now Optica), French Academy of Sciences, and the American Philosophical Society; a member of the National Academy of Sciences; and a Phi Beta Kappa lecturer.

His interest in literature at Williams bloomed into a secondary career as a writer, including decades of writing witty and insightful, yet accessible, pieces for *Physics Today*, including his "Reference Frame" columns on physics history and policy. "What he had really done was invent the blog long before the internet," says Pritchard.

Kleppner was a recipient of many awards, including the 2005 Wolf Prize in Physics "for groundbreaking work in atomic physics of hydrogenic systems, including research on the hydrogen maser, Rydberg atoms, and Bose-Einstein condensation." Other accolades include the 2014 Benjamin Franklin Medal in Physics "for many pioneering contributions to discoveries of novel quantum phenomena involving the interaction of atoms with electromagnetic fields and the behavior of atoms at ultra-low temperatures," and the 2006 National Medal of Science for his research on cold atoms and BECs that "was instrumental in opening up a new field of physics." He also received the 2007 Frederic Ives Medal, 1991 William F. Meggers Award, 1991 Lilienfeld Prize, and 1986 Davisson-Germer prize.

Kleppner said that he was inspired by his mentor, Ramsey, to get involved in the scientific community. "It's a privilege to be a scientist in this country," said Kleppner. "And I think that one has some obligation to pay for the privilege, when you can."

He wrote, "Any scenario for a decent future of our nation and the world must include a reasonable component of science that is devoted to the search for new knowledge. We cannot afford to abandon this vision under a barrage of criticism, no matter how eloquent or powerful the critics."

Alumni Notes

’51

Josef Eisinger (PhD. Thesis supervisor: Jerrold Zacharias) is now 101 years old and lives in Greenwich Village, NYC. His loving family includes wife Styra Avinswith, cellist and renowned Brahms scholar; son Simon, an MIT architecture alumnus; and daughter Alison, who leads a housing and homelessness advocacy organization in Seattle. After retiring from a career in physics, molecular biology, and history, Josef wrote four books (all available on *amazon.com*): two on Albert Einstein and two autobiographies about his “checkered early life.” That said, he does not recommend living so long, but since it’s not under his control, he will take this opportunity to promote MIT physics research and wish all of its alumni very well!

’57

Paul H. Carr (SB; SM ’61; PhD ’66 Brandeis University. Thesis supervisors: David Frisch, M.W.P. Strandberg) independently published his book, *Containing Climate Change: To Save Us*, in early 2025 (available on *amazon.com*). This past May 2025 he celebrated his 90th birthday.

Edward Friedman (SB; PhD ’63 Columbia University; Honorary Doctorate ’00 Sofia University, Bulgaria. Thesis advisor: Martin Deutsch). Just short of his 90th year, Edward recently completed a book on nuclear energy, its history, and its potential impact on global warming: *Nuclear Energy: Boom, Bust, and Emerging Renaissance* (Oxford University Press, Summer 2025). He also writes a Substack newsletter, “Nuclear Tomorrow.” These topics have been of great concern to him for many years.

’61

Stephen N. Salomon (SB. Thesis advisor: Wayne B. Nottingham) visited Biosphere 2, near Tucson, AZ, early this year to learn more about climate change. He has followed it since 1973 when he joined the U.S. Atomic Energy Commission and became the lead economist on the study, *Nuclear Energy Site Survey-1975, NUREG-0001*. Stephen thinks that had the U.S. become nearly all nuclear-powered, it may have avoided climate change altogether.

’62

Larry Zamick (PhD. Thesis supervisor: Herman Feshbach) reached age 90 on March 15, 2025; was named an Outstanding Referee for the American Physical Society (2025); and still publishes. His most recent paper appeared in the *International Journal of Modern Physics E* (January 2025), with another forthcoming for the same publication.

’63

Wallace Manheimer (SB; PhD ’67. Thesis supervisors: Uno Ingard, Thomas Dupree) was inspired by Lawrence Livermore National Lab’s result of a fusion burn with a Q>1, as well as supporting results from the University of Rochester and the Naval Research Lab, to argue that the emphasis of the American fusion effort should shift from magnetic to inertial confinement fusion. A paper, “For a New Department of Energy lab to examine laser fusion for energy,” was published in *Open Journal of Applied Science* (April 2025), and is available online.

Philip Pearle (PhD. Thesis supervisor: Kerson Huang) published *Introduction to Dynamical Wave Function Collapse* (Oxford University Press, 2024). It describes his theory—a resolution of the so-called “measurement problem” of standard quantum theory—which adds a randomly fluctuating term to Schrodinger’s equation, so that the wave function description of a measurement results in one or another outcome of the measurement (as opposed to standard quantum theory where the description results in the sum of outcomes). In other words, the theory generates a wave function that describes what actually happens. Discovered 35 years ago, and the subject of much theoretical and experimental work, the theory has as yet neither been verified nor refuted.

’68

Owen Franken (SB) is a photographer who began his career covering the campaign of Eugene McCarthy in the late ’60s. Originally, he planned to do graduate work in either nuclear physics or astrophysics, but decided to focus (literally) on visible light. Owen is currently working with a recipe writer to produce a cookbook connecting his worldwide travels to local recipes, which will be illustrated with his photographs. His work can be seen at *owenfranken.com*.

’70

Mark Pawlak (SB. Thesis advisor: George Bekefi) performed readings from his 10th poetry collection, *Away Away* (Arrowsmith Press, 2024) this past year at libraries throughout New England and New York. He published 18 new poems in journals including *New American Writing*, *Mobius*, *Beltwa*, and *The Red Letters*. Mark continues to edit Hanging Loose Press, America’s oldest independent literary press (*hangingloosepress.com*).

’71

Sekazi K. Mtingwa (SB, *Physics; Mathematics*. Thesis advisor: Victor Weisskopf) was named a 2025 Fellow of the African Academy of Sciences, and received the 2025 APS John Wheatley Award “for exceptional contributions to capacity building in Africa, the Middle East, and other developing regions, including leadership in training researchers in beamline techniques at synchrotron light sources and establishing the groundwork for future facilities in the Global South.” He also co-led a NASEM survey and report of U.S. visa application experiences of international colleagues and students.

’75

Francine Wright Bellson (SM. Thesis supervisor: Daniel Kleppner) In March 2025, Francine was awarded the Women in American History Medal from the Los Altos, CA, chapter of Daughters of the American Revolution. She was recognized for “her careers in technology and music, her service to youth interested in technical careers, and her work to preserve and protect the history and heritage of Louie Bellson and his music.”

’77

Abhay K. Ram (PhD. Thesis supervisor: James E. Young) Along with colleagues, Abhay is developing algorithms for quantum computers that simulate propagation of electromagnetic waves in fusion plasmas. The research was featured on the cover of *Physics of Plasmas*, and selected as Editor’s Choice Paper for *Future Generation Computer Systems*. One chapter, “Mathematical Foundation for Quantum Computing of Electromagnetic Wave Propagation in Dielectric Media,” will be included in a forthcoming textbook.

’78

Edward Sittler (PhD. Thesis supervisor: Stanislaw Olbert) published a paper (Sittler *et al.*, *JGR Space Physics*) on the discovery of plasma protons between the F&G rings of Saturn; launched two ion velocity mass spectrometers, which use both electric and magnetic deflection on two auroral sounding rockets; published a technical memorandum on the response of microchannel plates to energetic electrons (0.1 to 1.4 MeV and 9.5 to 26 MeV electrons); and is now developing Tandem IMS (TIMS), which has been submitted by Goddard’s patent office. TIMS can be used for M2M lunar and Mars missions and a flagship mission to Uranus.

’79

Mahmoud (Moe) Shahram (SM. Thesis supervisor: Roshan Aggarwal) is an Engineering Physics Professor at West Valley College, CA, where he is developing MyOpenMath (MOM) assets and procedures for Open Educational Resources (OER). This initiative empowers physics professors to download and utilize online OER assets from the MOM website, ensuring that their teaching aligns with the content of OpenStax University Physics Textbooks. Moe is also promoting the Science, Technology, Engineering, and Mathematics (STEM) program to the West Valley students.

’80

Ron Lenk (SB) recently published *Design of Power Supplies in a Supply-Chain Challenged World* (Wiley, 2025). His next book, *Foundations of the Science of Economics*, uses the scientific method on the fundamental objects of macroeconomics. Actual data is used, best-fit models are determined using information criteria, falsifiable hypotheses are formed and verified, and novel laws of economics are proposed from the hypotheses, then verified.

’81

Robert Close (SB. Thesis advisor: George Bekefi) published “Plane Wave Solutions to a Proposed Equation of Everything,” in *Foundations of Physics*. Using an elastic solid model of the vacuum, the paper provides classical physics interpretations of spin angular momentum, the Dirac equation, and the dynamical operators of relativistic quantum mechanics. Robert is also with *All Oregon Votes* to give all voters equal rights, regardless of party affiliation. He advocates for Top-3 inclusive primaries followed by three-way round-robin instant runoffs in general elections.

Jim Pekar (SB; PhD *Biophysics*, University of Pennsylvania. Thesis advisor: William Bertozzi) recently celebrated a “silver” work-anniversary. In October 2024, he spoke on “Hairballs, Obliteration, and Dark Matter,” at a symposium marking the 25th-year anniversary of the F.M. Kirby Research Center for Functional Brain Imaging. Jim has served as manager of the center since its founding, and is also a professor of radiology at Johns Hopkins University.

’82

José Antonio Garcia-Barreto (PhD. Thesis supervisor: Bernard Burke) After 42 years of academic work (1982–2024), including research, lecturing, and outreach, at the Instituto de Astronomia, Universidad Nacional Autónoma de México (UNAM), José decided to retire. He looks forward to travel and enjoying his family.

Lawrence M. Krauss (PhD) recently edited an anthology with 39 well-known scholars, *The War on Science* (Post Hill Press, July 2025), about attacks on free speech and open inquiry in science.

’83

Tom Armstrong (PhD. Thesis supervisor: Alan Barrett) co-authored a paper for the *Journal of Astronomical Instrumentation* before finishing his astronomy career after 31 years in NRL’s optical interferometry project, and retiring at the end of 2019 with occasional contract work. Tom is now focused on playing bass, mostly jazz and klezmer, and volunteering for local organizations.

Hitomi Ohkawa (SM) is semi-retired, but has worked as an independent consultant on biomedical research data management for new drug discovery. Hitomi has also explored ways to optimize AI programs for lower energy consumption and more sustainable execution, as well as mentoring graduate students on scientific communication.

’85

Bob Tench (PhD. Thesis supervisor: Shaoul Ezekiel) is the Principal Fiber Laser Scientist at Fibertek in Herndon, VA. His roles there include principal investigator and lead researcher for fiber lasers and amplifiers for space and airborne applications. Bob is also President and Chief Scientist of the independent photonics consulting company RET and Associates LLC.

’86

Brad Waller (SB) transitioned from aerospace engineering into entrepreneurship, co-founding EPage, Inc., a tech firm specializing in websites and mobile apps. Recently, he embarked on a new journey and was elected to the City Council in Redondo Beach, CA. Brad is enthusiastic about bringing a technical and science-based perspective to local governance, addressing technological advancement, infrastructure improvements, and sustainable growth.

’87

Jennifer Wiseman (SB; PhD ’95 *Astronomy*, Harvard University. Thesis advisor: Jim Elliot) serves as NASA’s Senior Project Scientist for the Hubble Space Telescope Mission. Her role is to ensure the observatory is as scientifically productive as possible, working with the Hubble project team at the Goddard Space Flight Center and with scientists around the world to best manage the observatory and disseminate its findings. This year marked the 35th anniversary of Hubble's launch and Jennifer enjoyed speaking at the several commemorative events.

'89

Mark Andersen (SB, *Physics, Political Science*) works at Vendr, a startup helping companies get a fair price for SaaS. He leads a data science team combining LLMs with traditional data techniques to analyze and systematize contract data and generate pricing insights. Mark has spent 30 years in tech, including 17 at Vistaprint, and is still having fun.

'91

Maha Achour (PhD. Thesis supervisor: Barton Zwiebach) is leading a disruptive AI startup, Kodamai, out of the UK, as cofounder and CEO. The company is at the forefront of revolutionizing the digital economy through its innovative and scientifically-proven communities of AI-driven collaborating agents. The core team comprises leading academic and industry experts in the field with backgrounds in AI, machine learning, computer science, theoretical particle physics, and engineering. Maha is also a member of the board and investment committee of TASARU, a mobility fund out of the KSA.

'98

Paul Konigsberg (SB) After successfully founding and managing a 13-year run with a fixed-income investment fund (Bluebird Funds), Paul has created a new equity investment fund based in equities and equity options: the Market Income Fund. Fitting in golf here and there while raising three young kids also fills the time.

'99

Sean P. Robinson (SB; PhD '05. Thesis advisor, supervisor: Edward Farhi, Frank Wilczek) After a long year of planning and hard work, Sean represented MIT as the host institution for the 2024 Summer Meeting of the American Association of Physics Teachers, which returned to Boston for the first time in decades. He found it exciting to see how rich the physics education community is with MIT alums, and thought that there were so many alums attending that they could have held a mini-reunion! Sean is especially proud of his colleagues in the MIT Physics Education Group, who all really shined as the home team for this great physics event.

'00

Michael Bradley (PhD. Thesis supervisor: David Pritchard) is a professor in the Department of Physics and Engineering Physics, University of Saskatchewan, Canada, a member of Canada's U15 group of top research-intensive universities and home to STOR-M, the country's only tokamak. After serving as Head of the Department of Physics and Engineering Physics, Michael was selected as Dean of Engineering in 2024. He looks forward to working with MIT colleagues old and new, especially in the context of the growing interest in nuclear power in Saskatchewan, which is home to the world's highest-grade uranium ores.

'01

Aaron Santos (SB) recently signed a publishing contract with Harvard University Press for his upcoming book on the history, science, and future of nanotechnology.

'03

Alex Wissner-Gross (SB, *Physics, Electrical Science and Engineering, Mathematics*. Thesis advisor: Bolek Wyslouch) co-authored a paper on *in-vivo* optical clearing of the mammalian brain, and spoke at the Abundance Summit. To learn more, visit *alexwg.org*.

'05

Jeremy Schnittman (PhD. Thesis supervisor: Edmund Bertschinger) is an astrophysicist at NASA's Goddard Space Flight Center, for nearly 15 years, focusing on theoretical models of black hole accretion and gravitational waves. A recent highlight was LISA (Laser Interferometer Space Antenna) moving forward with confirmation, one major step to a 40+ year dream becoming reality. Also exciting are results from the small X-ray polarization mission IXPE, which appear to confirm some of our theories of light bending around black holes.

'09

Maria Chan (PhD. Thesis supervisors: Gerbrand Ceder, John Joannopoulos) is a scientist at Argonne National Laboratory (2012–present). In fall 2024, she was named a Fellow of the American Physical Society for her "contributions to methodological innovations, developments and demonstrations toward the integration of computational modeling and experimental characterization to improve the understanding and design of renewable energy materials." Maria is also a member of the leadership team of the DOE Energy Storage Hub ESRA (Energy Storage Research Alliance), and serves on the Condensed Matter and Materials Research Committee at the National Academies.

Will Fox (PhD. Thesis supervisors: Miklos Porkolab, Jan Egedal) was appointed an Assistant Professor of Physics, University of Maryland. His research is in high-energy plasma physics, including laser-plasma interactions and plasma astrophysics. Will was awarded the APS Thomas H. Stix Award for Outstanding Early Career Contributions to Plasma Physics Research (2019), and the APS John Dawson Award for Excellence in Plasma Physics Research (2020).

'10

Javier Duarte (SB, *Physics*, *Mathematics*. Thesis advisor: Janet Conrad) and his partner Kristen recently welcomed a new addition to the family, Sequoyah Fox Duarte. They reside in San Diego and would love to catch up with old friends. Javier also recently received tenure at UC-San Diego, where he leads a research group working on experimental particle physics and machine learning.

'11

Colin McSwiggen (SB) relocated to Taipei, Taiwan, in fall 2024 to begin a tenure-track faculty position at the Institute of Mathematics of Academia Sinica, the national academy of Taiwan. His research focuses on probability and mathematical physics. Colin is also a Venture Partner at TA Ventures.

'12

Shankari Rajagopal (SB; PhD '19 *Physics*, University of California, Santa Barbara) wrapped up postdoctoral work at Stanford University with Prof. Monika Schleier-Smith in 2024, and began a tenure-track physics faculty position at the University of Michigan, Ann Arbor, in 2025. Her group will work on quantum sensing and quantum simulation using hybrid cold atom experiments, focusing on new ways measurement can be used to steer and feed back on quantum state evolution. She would love to say hello to any members of the MIT community, especially PhysPOP/ Discover Physics folks, in the Ann Arbor area.

'14

William Uspal (PhD. Thesis supervisor: Patrick Doyle) was awarded tenure and promotion to Associate Professor at the University of Hawai'i, Manoa, in the Department of Mechanical Engineering. His research group studies how fluid mechanics and transport phenomena are implicated in active matter and self-organization. Details on Will's current research direction, hydrodynamics of active colloids, can be found at *youtube.com/ watch?v=_-Z23ZwtUWY*.

'17

Alexander Ji (PhD. Thesis supervisor: Anna Frebel) is an Assistant Professor of Astronomy and Astrophysics at the University of Chicago. He was recently awarded an Alfred P. Sloan Research Fellowship and an RCSA Scialog Award.

'19

Elenna Capote (SB. Academic advisor: Deepto Chakrabarty) successfully defended her PhD in physics at Syracuse University in June 2024 ("Overcoming Controls and Noise Challenges for High Power Interferometric Gravitational-Wave Detectors"). In August 2024, she began a postdoctoral associate position at Caltech in the LIGO Laboratory, followed in April 2025 with a position as Gravitational Wave Experimental Physicist at the LIGO Hanford Observatory. Elenna is lead author on the paper, "Advanced LIGO detector performance in the fourth observing run," *Physical Review D*, March 2025.

'20

Jason Necaise (SB, *Physics*, *Mathematics*) co-founded quantum computing startup qBraid, after graduation, which is building a platform to easily learn and develop quantum algorithms. He has since returned to research, studying the sources of quantum and classical complexity in fermionic systems under James Whitfield in Dartmouth College's PhD program. In summer 2025, Jason did a research internship with Hewlett Packard Labs' quantum computing research team.

'21

Yunjie Yang (PhD. Thesis supervisor: Michael Williams) After earning his PhD in experimental particle physics, Yunjie transitioned to medical physics. He did a postdoctoral fellowship at the New York Proton Center, followed by a residency in radiotherapy physics at the Memorial Sloan Kettering Cancer Center, where he joined the faculty as a clinical medical physicist in March 2025. He applies physics knowledge to directly benefit patient care, conducts research to find better ways in the fight against cancer, and educates the next generation of scientists and clinicians.

'22

Kylie Yui Dan (SB) published a paper in December 2024 outlining new JWST observations of a very fast warm molecular outflow in a local ultraluminous infrared galaxy (*arxiv.org/abs/2412.05859*).

Larry Leinweber

$20 million gift supports theoretical physics research and education at MIT

Gift from the Leinweber Foundation, in addition to a $5 million commitment from the School of Science, will drive discovery, collaboration, and the next generation of physics leaders.

by Julia C. Keller, School of Science

LEINWEBER FOUNDATION

A $20 million gift from the Leinweber Foundation, in addition to a $5 million commitment from the MIT School of Science, will support theoretical physics research and education at MIT.

Leinweber Foundation gifts to seven institutions, exceeding $100 million, will establish the newly renamed MIT Center for Theoretical Physics – A Leinweber Institute within the Department of Physics, affiliated with the Laboratory for Nuclear Science at the School of Science, as well as Leinweber Institutes for Theoretical Physics at four other top research universities: Stanford University, the University of Michigan, the University of California at Berkeley, and the University of Chicago, as well as a Leinweber Forum for Theoretical Physics at the California Institute of Technology and a Leinweber Forum for Theoretical and Quantum Physics at the Institute for Advanced Study.

“MIT has one of the strongest and broadest theory groups in the world,” says Professor Washington Taylor, the director of the newly funded center and a leading researcher in string theory and its connection to observable particle physics and cosmology.

"This landmark endowment from the Leinweber Foundation will enable us to support the best graduate students and postdoctoral researchers to develop their own independent research programs and to connect with other researchers in the Leinweber Institute network. By pledging to support this network and fundamental curiosity-driven science, Larry Leinweber and his family foundation have made a huge contribution to maintaining a thriving scientific enterprise in the United States in perpetuity."

The Leinweber Foundation's investment across seven institutions—constituting the largest philanthropic commitment ever for theoretical physics research, according to the Science Philanthropy Alliance, a nonprofit organization that supports philanthropic support for science—will strengthen existing programs at each institution and foster collaboration across the universities. Recipient institutions will work both independently and collaboratively to explore foundational questions in theoretical physics. Each institute will continue to shape its own research focus and programs, while also committing to big-picture cross-institutional convenings around topics of shared interest. Moreover, each institute will have significantly more funding for graduate students and postdocs, including fellowship support for three to eight fully endowed Leinweber Physics Fellows at each institution.

"This gift is a commitment to America's scientific future," says Larry Leinweber, founder and president of the Leinweber Foundation. "Theoretical physics may seem abstract to many, but it is the tip of the spear for innovation. It fuels our understanding of how the world works and opens the door to new technologies that can shape society for generations. As someone who has had a lifelong fascination with theoretical physics, I hope this investment not only strengthens

"Theoretical physics may seem abstract to many, but it is the tip of the spear for innovation. It fuels our understanding of how the world works and opens the door to new technologies that can shape society for generations. As someone who has had a lifelong fascination with theoretical physics, I hope this investment not only strengthens U.S. leadership in basic science, but also inspires curiosity, creativity, and groundbreaking discoveries for generations to come." Larry Leinweber, *founder and president of the Leinweber Foundation*

U.S. leadership in basic science, but also inspires curiosity, creativity, and groundbreaking discoveries for generations to come."

The gift to MIT will create a postdoc program that, once fully funded, will initially provide support for up to six postdocs, with two selected per year for a three-year program. In addition, the gift will provide student financial support, including fellowship support, for up to six graduate students per year studying theoretical physics. The goal is to attract the top talent to the MIT Center for Theoretical Physics – A Leinweber Institute and support the ongoing research programs in a more robust way.

A portion of the funding will also provide support for visitors, seminars, and other scholarly activities of current postdocs, faculty, and students in theoretical physics, as well as helping with administrative support.

"Graduate students are the heart of our country's scientific research programs. Support for their education to become the future leaders of the field is essential for the advancement of the discipline," says Nergis Mavalvala, dean of the MIT School of Science and the Curtis (1963) and Kathleen Marble Professor of Astrophysics.

The Leinweber Foundation gift is the second significant gift for the center. "We are always grateful to Virgil Elings, whose generous gift helped make possible the space that houses the center," says Deepto Chakrabarty, head of the Department of Physics. Elings PhD '66, co-founder of Digital Instruments, which designed and sold scanning probe microscopes, made his gift more than 20 years ago to support a space for theoretical physicists to collaborate.

"Gifts like those from Larry Leinweber and Virgil Elings are critical, especially now in this time of uncertain funding from the federal government for support of fundamental scientific research carried out by our nation's leading postdocs, research scientists, faculty, and students," adds Mavalvala.

Professor Tracy Slatyer, whose work is motivated by questions of fundamental particle physics, particularly the nature and interactions of dark matter, will be the subsequent director of the MIT Center for Theoretical Physics – A Leinweber Institute beginning in fall 2025. Slatyer will join Mavalvala, Taylor, Chakrabarty, and the entirety of the theoretical physics community for a dedication ceremony planned for the near future.

The Leinweber Foundation was founded in 2015 by software entrepreneur Larry Leinweber, and has worked with the Science Philanthropy Alliance since 2021 to shape its philanthropic strategy. "It's been a true pleasure to work with Larry and the Leinweber family over the past four years and to see their vision take shape," says France Córdova, president of the Science Philanthropy Alliance. "Throughout his life, Larry has exemplified curiosity, intellectual openness, and a deep commitment to learning. This gift reflects those values, ensuring that generations of scientists will have the freedom to explore, to question, and to pursue ideas that could change how we understand the universe."

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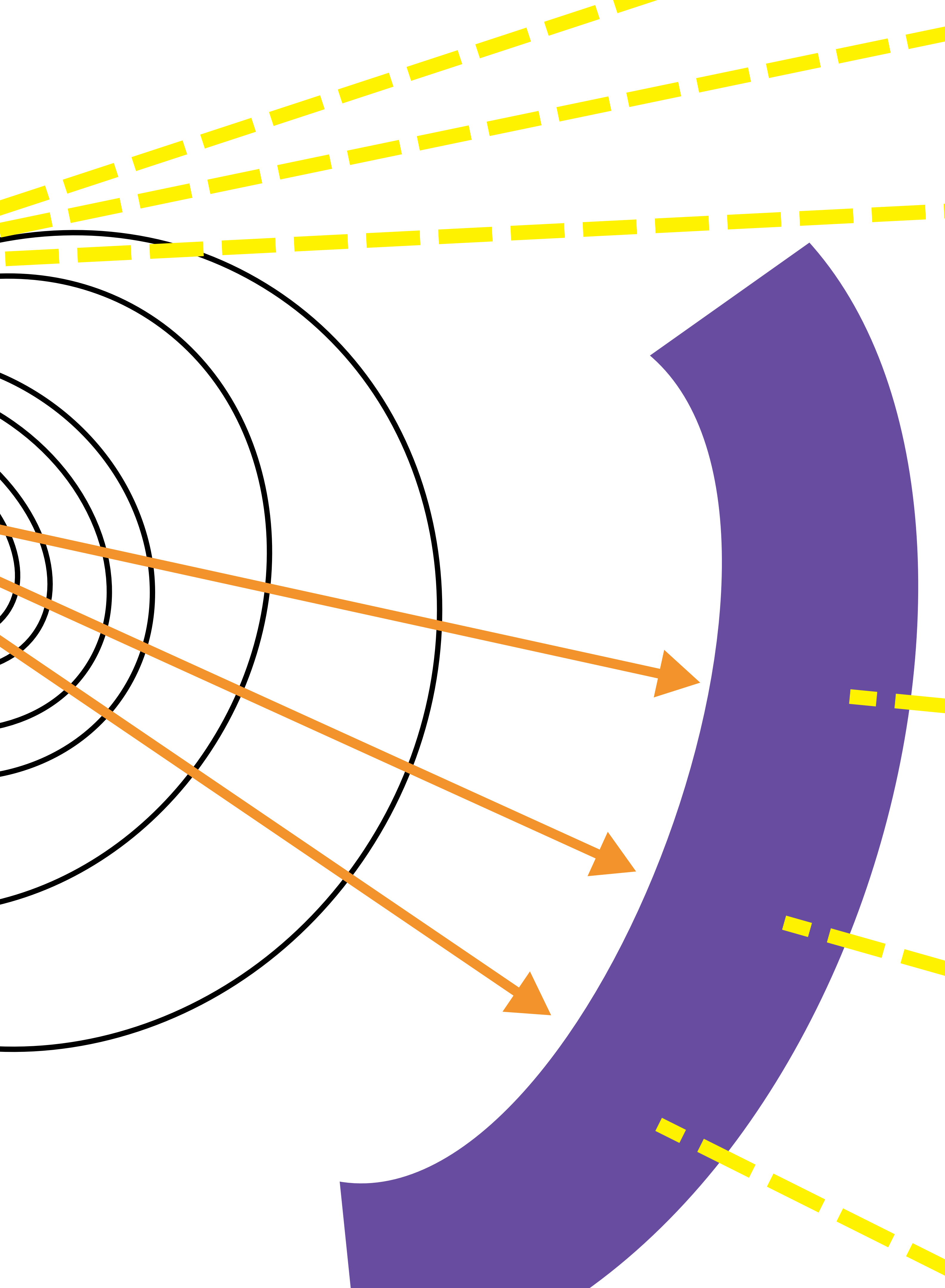

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