

Department of Physics

Like every department at MIT, and like universities across the world, the Covid-19 pandemic influenced all aspects of the Physics Department in academic year 2021. All of our instruction was done remotely. Staff members worked entirely from home. Occupancy in our research lab was limited. Graduate students and postdoctoral researchers were largely absent from campus, with some of them unable to start due to international travel bans. The stress on everyone was immense and constant. Though MIT offered to extend the tenure clocks for all of our junior faculty, they still faced an environment where travel was impossible, research difficult, teaching disjointed, and in-person collaboration unavailable. Despite it all, the department continued with its mission, which is to provide world-class research and instruction. It was not easy. The future remains uncertain. As we navigate through this new (and changing) normal, the resilience and fortitude of our faculty, students, postdocs, and staff will sustain us. There is no way to give adequate thanks to the work that so many in this department did to keep things moving forward.

Faculty Count, Promotions, and Departures

As of July 1, 2021, the Physics Department will have 71 appointed regular rank faculty members, consisting of 40 full professors, 17 associate professors, and 14 assistant professors.

Seven faculty members were promoted this year. Joseph Checkelsky and Kerstin Perez were promoted to associate professor with tenure. Jeff Gore and Jesse Thaler were promoted to full professor. Riccardo Comin, Daniel Harlow, and Or Hen were promoted to associate professor without tenure. These promotions took effect July 1, 2021.

John Belcher, Robert Jaffe, and Robert Redwine all moved to emeritus status on June 30, 2021. Each of these faculty members had immense impacts on research, teaching, and the MIT environment. Their contributions and impact were critical to the department and MIT. We thank them for their invaluable service.

The department made three offers, all of which were accepted. Andrew Vanderburg, in Astrophysics, will start on July 1, 2021. Sarah Millholland, in Astrophysics, will begin July 1, 2022. Also starting July 1, 2021 is Soonwon Cho in Theoretical Nuclear and Particle Physics and Lena Necib in Astrophysics. Both Professors Necib and Choi accepted their offer in AY2020. The total number of female faculty members in the department is 12, or 17% of our faculty. We now have seven female tenured faculty members (14% of the total tenured faculty). Both of these percentages are the highest in our department's history. In the last 11 years, we have made a total of 45 offers that resulted in 35 acceptances for a success rate of nearly 78%. This yield rate for faculty is extremely impressive and shows the attractiveness that MIT offers to the very best young scholars.

Administration

For FY2021, the Physics Council membership was:

Peter Fisher – Department Head

Deepto Chakrabarty – Associate Head

Scott Hughes – Astrophysics Division Head

Ray Ashoori – Atomic, Biophysics and Condensed Matter Division Head

Joe Formaggio – Experimental Nuclear and Particle Physics Division Head

Iain Stewart – Theoretical Nuclear and Particle Physics Division Head

Boleslaw (Bolek) Wyslouch – Director, Laboratory for Nuclear Science

Rob Simcoe – Director, Kavli Institute for Astrophysics and Space Research

Mehran Kardar – Atomic, Biophysics and Condensed Matter, Member-at-Large

Lindley Winslow – Experimental Nuclear and Particle Physics, Member-at-Large

Matt Cubstead – Administrative Officer

Nergis Mavalvala became the new dean of the School of Science in September 2020. She was replaced as the associate department head by Deepto Chakrabarty. Ray Ashoori became the permanent division head of Atomic, Biophysics and Condensed Matter Physics in July 2020, replacing Martin Zwierlein.

Faculty Awards

Following are a few of the many awards and recognitions conferred on faculty members during the 2020–2021 academic year:

Daniel Harlow was awarded the Packard Fellowship for Science and Engineering.

Edmund Bertschinger received MIT's 2021 Everett Moore Baker Award for Excellence in Undergraduate Teaching.

Riccardo Comin received the 2021 US Department of Energy Early Career Research Program Award. He also received the MIT Frank E. Perkins Award for Excellence in Graduate Advising.

Netta Engelhardt received a 2021 US Department of Energy Early Career Research Program Award and was awarded a 2021 New Horizons in Physics Prize for Early-Career Achievements in Physics and Math (breakthrough prizes) for “calculating the quantum information content of a black hole and its radiation.”

Peter Fisher was named the inaugural Thomas A. Frank (1977) Professor of Physics and was elected a fellow of the American Association for the Advancement of Science.

Phillip Harris received a 2021 US Department of Energy Early Career Research Program Award.

Pablo Jarillo-Herrera received the 2021 National Academy of Sciences Award for Scientific Discovery for his “pioneering developments in nanoscience and nanotechnology.” In addition, he received the 2021 Lise Meitner Distinguished Lecture and Medal of The Royal Swedish Academy of Sciences for his groundbreaking work on twistrionics—a technique that adjusts the electronic properties of graphene by rotating adjacent layers of the material.

Phiala Shanahan received the Maria Goeppert Mayer Award of the American Physical Society (2021) for “key insights into the structure and interactions of hadrons and nuclei using numerical and analytical methods and pioneering the use of machine learning techniques in lattice quantum field theory calculations in particle and nuclear physics.” She also received the Kenneth G. Wilson Award for Excellence in Lattice Field Theory (2020) for “excellence in the study of hadrons and nuclei in lattice QCD and for pioneering the application of machine learning and artificial intelligence techniques to lattice field theory.”

Tracy Slatyer was awarded a 2021 New Horizons in Physics Prize for Early-Career Achievements in Physics and Math (breakthrough prizes) for “major contributions to particle astrophysics, from models of dark matter to the discovery of the ‘Fermi Bubbles.’”

Salvatore Vitale received a Faculty Early Career Development Program (CAREER) Award from the National Science Foundation.

Education

In AY2021, the Physics Department enrolled 199 undergraduate majors and 242 graduate students. Of these, approximately 37% of our undergraduates and 20% of our graduate students were women; also, 26% of our undergraduates and 11% of our graduate students were underrepresented minorities. We awarded 76 SB degrees and 37 PhD degrees in 2020–2021. Of the undergraduate degrees, 57 were double majors. In spring 2021, 60 first-year students declared physics as their major.

Of the 76 degree recipients in 2020–2021, 75% were double majors and 94% chose the 8-Flex degree option. Roughly 60% of 8-Flex students chose focus groups within Course 8 (Physics), Course 6 (EECS) and Course 18 (Math). Many 8-Flex majors use the flexibility to tailor a degree program that contains as much or more physics than the more traditional and formerly canonical 8-Focused degree, and they are very well prepared for graduate work in physics.

Admission to our graduate program continues to be highly competitive. In 2021, the number of applicants climbed to a new high of 1,591 (compared to 1,068 in 2020, 1,009 in 2019, and fewer than a thousand in prior years). We admitted 103 students and had an unusually high admissions yield of 64%, resulting in an entering class of 62 students in fall 2021 (after accounting for deferrals). We continue to see enormous benefit from the use of first-year fellowships to recruit the strongest students, who typically have competing offers from peer institutions. In a small number of exceptional cases, we offer multi-year fellowships as an inducement. Of the 66 students who accepted our admissions offer in 2021, 44 were admitted on a fellowship. Of these, 55% were women

and 20% were underrepresented minorities. (The corresponding fractions for the full entering class are 41% and 14%, respectively.)

With the Covid-19 shutdown, the department started a successful student mentoring program in the fall of 2020. The mentors are primarily juniors and seniors. We had over 250 first-year students sign up for this service each semester. The department will be implementing the same mentoring program in the upcoming year.

Diversity and Inclusion

What started in 2016 with the creation of a Physics Values Statement has turned into a Physics Values Committee, with membership consisting of faculty, students, and staff who continue to examine areas where the department can promote diversity and fairness for all members of the community. The group meets at least weekly and works on issues such as training, admissions, hiring and the Physics Department culture.

The department supports a wide range of undergraduate groups that focus on diversity efforts throughout the Institute. The Physics Department regularly gives financial support to student groups such as the MIT Black Students' Union, the Black Women's Alliance, the Society of Hispanic Professional Engineers, MAES (Latinos in Science and Engineering), LUCHA (an undergraduate group that supports students identifying with Latino culture) and the Undergraduate Women in Physics organization. Additionally, the Department covers the travel costs for undergraduates who attended the Undergraduate Women in Physics Conference and also supports other travel by undergraduates, graduates, postdocs, and faculty members who attend conferences supporting diversity in physics. We also revamped our participating in the MIT Summer Research Program to improve the experience for those who come for the summer.

This year, we offered seven multi-year fellowships to minority graduate students; five accepted our offer.

Research Highlights

Below are some of the research highlights from members of the Physics Department faculty in 2020 and 2021:

Erin Kara and other co-authors reported watching as a supermassive black hole's own corona, the ultrabright billion-degree ring of high-energy particles that encircles a black hole's event horizon, was abruptly destroyed. The discovery will be an important way of understanding how a black hole's corona is heated and powered in the first place.

Physicists at the MIT Laser Interferometer Gravitational-wave Observatory (LIGO) group, including Dean Nergis Mavalvala, have designed a quantum "light squeezer" that reduces quantum noise in an incoming laser beam by 15%. It is the first system of its kind to work at room temperature, making it amenable to a compact, portable setup that may be added to high-precision experiments to improve laser measurements where quantum noise is a limiting factor.

Martin Zwierlein co-authored a paper that proved scientists could measure sound diffusion in a perfect fluid. The perfect fluid was constructed in the laboratory. It was found that the fluid's sound diffusion was so low as to be described by a "quantum" amount of friction—given by a constant of nature known as Planck's constant—and the mass of the individual fermions in the fluid. Scientists can now use the fluid as a model of other more complicated perfect flows to estimate the viscosity of the plasma in the early universe, as well as the quantum friction within neutron stars—properties that would otherwise be impossible to calculate. Scientists might even be able to approximately predict the sounds they make.

A team led by Kiyoi Masui observed fast radio bursts (FRBs) in our own galaxy for the first time. The radio pulses are the closest FRBs detected to date and their proximity has allowed the team to pinpoint their source. It appears that the observed radio pulses were produced by a magnetar—a type of neutron star with a hugely powerful magnetic field. Physicists have hypothesized that magnetars might produce FRBs. This is the first time that scientists have direct observational proof that magnetars are indeed sources of fast radio bursts.

Wolfgang Ketterle led a group of MIT scientists who, with experiments with ultracold lithium atoms, observed different ways in which the spins of the atoms evolve. Like tippy ballerinas pirouetting back to upright positions, the spinning atoms return to an equilibrium orientation in a way that depends on the magnetic forces between individual atoms. The researchers found that these behaviors, which had not been observed until now, could be described mathematically by the Heisenberg model, a set of equations commonly used to predict magnetic behavior. Their results address the fundamental nature of magnetism, revealing a diversity of behavior in one of the simplest magnetic materials. This improved understanding of magnetism may help engineers design "spintronic" devices, which transmit, process, and store information using the spin of quantum particles rather than the flow of electrons.

Pablo Jarillo-Herrera and his research group reported observing superconductivity in a sandwich of three graphene sheets, the middle layer of which is twisted at a new angle with respect to the outer layers. This new trilayer configuration exhibits superconductivity that is more robust than its bilayer counterpart.

Anna Frebel was part of a group that detected stars at the edge of Tucana II (an ultra-faint dwarf galaxy 163,000 light-years from Earth), in a configuration that is surprisingly far from its center but nevertheless caught up in the tiny galaxy's gravitational pull. This is the first evidence that Tucana II hosts an extended dark-matter halo—a region of gravitationally bound matter that the researchers calculated to be three to five times more massive than scientists had estimated. This discovery of far-flung stars in an ancient dwarf galaxy implies that the very first galaxies in the universe were also likely extended and more massive than previously thought.

Riccardo Comin led a team from MIT which found that by doping extra electrons into an antiferromagnetic material they can turn its collective anti-aligned arrangement on and off in a controllable way. They found this magnetic transition is reversible

and sufficiently sharp, similar to switching a transistor's state from 0 to 1. The results demonstrate a potential new pathway to use antiferromagnets as a digital switch.

MIT's LIGO group recorded the most massive black hole merger yet, when gravitational waves were detected between the merger of two black holes, creating an "intermediate-mass" black hole with a mass between 100 and 1,000 times that of the sun. The LIGO team also detected the first gravitational waves created by the merger of a black hole and a neutron star.

Riccardo Comin was also part of a team that reported the first experimental evidence to explain the unusual electronic behavior behind the world's thinnest superconductor, a material with myriad applications because it conducts electricity extremely efficiently. Not only did the physicists detect spin excitations, but among other things, they showed that the spin dynamics in the ultra-thin sample were dramatically different from those in the bulk sample. Specifically, the energy of the fluctuating spins in the ultra-thin sample was much higher—by a factor of four or five—than the energy of the spins in the bulk sample. The resulting data could help guide the development of better superconductors. These, in turn, could transform the fields of medical diagnostics, quantum computing, and energy transport, which all use superconductors.

Pappalardo Fellows

A. Neil Pappalardo has made possible a program in the department to attract recent PhDs of exceptional promise. The purpose of the Pappalardo Fellowships in Physics is to identify and support unusually talented young physicists and to provide them with the opportunity to pursue research of their own choosing. The Pappalardo Fellows have complete freedom in their choice of research and are matched with a mentor chosen on the basis of their research interests. Fellows have special status in the department and are invited to attend faculty events. The first three fellows arrived in September 2000, and since then the program has supported 75 fellows. Thirty-five percent of all Pappalardo Fellows have been women, and the program has proved to be a strong source of our own faculty recruiting as seven members have joined the MIT Physics Department. We celebrated the 20th anniversary of this distinguished program in the spring of 2020. Unfortunately, our large event for this had to be cancelled due to the pandemic, but we look forward to being able to bring back all past fellows for a celebration soon.

Community and Upcoming Events

The Physics Department strives to create a community of scholars and endeavors to create opportunities for our faculty, students, and alumni to come together to share and explore ideas. It was difficult this past year to keep this up, given the Covid-19 restrictions and the fact that so many of us were not on campus. We handled this by having numerous research talks on Zoom (including weekly faculty lunch talks, colloquium speakers, and Pappalardo lunch talks). One nice aspect of this was the fact that a much larger audience was available to attend. The department plans to continue to sponsor the following events designed to foster the exchange of ideas:

- Faculty lunches are held each week during the fall and spring semesters. All faculty are invited to join their colleagues for an informal meal and to hear a talk from one of their colleagues on their research.
- An afternoon colloquium series is held each week at which a physicist, often from outside MIT, is invited to give a talk on a topic of interest. This event is open to the MIT community.
- Each division also has its own weekly seminar series open to all.
- Each fall, the department has an awards ceremony where it acknowledges outstanding teaching among its undergraduates, graduates, and faculty members. This ceremony is open to the entire physics community.
- Each year, alumni are invited to a breakfast to hear about physics research done by one of our outstanding faculty presenters.
- During the Independent Activities Period, the department offers a lecture series open to the MIT community that covers a wide range of topics, including research highlights of select faculty members as well as talks by alumni that highlight various career paths.
- The Pappalardo Fellowship program sponsors a weekly lunch that brings Pappalardo Fellows and Physics faculty together for conversation.
- Each fall the department hosts a Distinguished Pappalardo Lectureship.
- The department head holds a monthly lunch with all administrative and support staff to talk about major issues facing the department as well as to highlight research topics in physics.

Peter Fisher
Head
Professor of Physics