

## Department of Physics

Academic year 2019–2020 was unlike anything our department, or MIT, has seen in a hundred years. Rumors in January 2020 of a new coronavirus spreading in China progressed into a situation where, over ten days in March, we saw class sizes cut, gatherings prohibited, and eventually all students sent home and classes moved fully online. It was something none of us ever imagined or expected, and it was done under the umbrella of a new, deadly virus where everyone was worried about its impact on family and friends. In the end, the professionalism shown by our staff, faculty, postdoctoral researchers, and students was inspiring. On day one, none of us had ever heard of Zoom. Two weeks later we were teaching thousands of students a week through this medium. One day we were coming to work as usual, two weeks later all of us were working from home. The resiliency, creativity, and perseverance everyone showed was exemplary. As difficult as COVID-19 pandemic has been, it has brought us all closer together and shown the value and resolve of the MIT Physics community.

### Faculty Count, Promotions, and Departures

As of July 1, 2020, the Physics Department had 71 appointed regular rank faculty members, consisting of 38 full professors, 16 associate professors, and 17 assistant professors.

Seven faculty members were promoted this year. Ibrahim Cissé, Yen-Jie Lee, Mark Vogelsberger, and Lindley Winslow were promoted to associate professor with tenure. Nikta Fakhri and Michael McDonald were promoted to associate professor without tenure. Markus Klute was promoted to full professor. These promotions took effect July 1, 2020.

Min Chen, professor of Physics, retired on June 30, 2020. We appreciate his service to the department over the past decades.

Aron Bernstein, Ulrich Becker, and Thomas Dupree, all professor emeritus of physics, passed away in spring 2020. Their loss weighs heavily on all of us, as each made tremendous impacts across the department and community. They will be missed greatly and we carry on with our mission in their honor.

After having five offers accepted last year, the department made one offer in spring 2019, which was accepted. Ronald Garcia Ruiz started in nuclear and particle experimental physics in January 2019. We also made offers to Lina Necib and Soonwon Choi, both of whom will start in July 2021. The yield on faculty offers over the past ten years is near 80%, which is unprecedented over our department's history. This reflects the continued success and allure of MIT's Department of Physics. The total number of female faculty members in the department remains at 11, with one more due to arrive next year.

## Administration

For FY2020, the Physics Council membership was:

Peter Fisher—Department Head

Nergis Mavalvala—Associate Department Head

Scott Hughes—Astrophysics Division Head

Ray Ashoori—Atomic, Biophysics, Condensed Matter, and Plasma Physics Division Head

Mehran Kardar—Atomic, Biophysics, Condensed Matter, and Plasma Physics, Member-at-Large

Joe Formaggio—Experimental Nuclear and Particle Physics Division Head

Iain Stewart—Center for Theoretical Physics

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

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

Matt Cubstead—Administrative Officer

Martin Zwierlein stepped down as division head for the Atomic, Biophysics, Condensed Matter, and Plasma Physics Division in September 2019, having served on Physics Council for two years. We thank Professor Zwierlein for his service to the department and to MIT.

## Faculty Awards

Following are a few of the many awards and recognitions conferred on faculty members during AY2020:

Jackie Hewitt, Rainer Weiss, and Sara Seager were elected as 2020 legacy fellows of the American Astronomical Society.

Pablo Jarillo-Herrero was awarded the 2020 Oliver E. Buckley Condensed Matter Prize of the American Physical Society. Jarillo-Herrero also won the Wolfe Prize in Physics for his experimental contributions to breakthrough developments in twisted bilayer graphene research.

Mehran Kardar was awarded a 2020 Simons Fellowship.

Richard Milner was awarded the Tom W. Bonner Prize in Nuclear Physics.

Joe Formaggio, Matthew Evans, and Markus Klute were elected fellows of the American Physical Society.

Tracy Slatyer and Yen-Jie Lee received a 2019 Presidential Early Career Award for Scientists and Engineers.

Max Metliski was awarded a 2020 New Horizons Prize for Early-Career Achievement in Physics by the Breakthrough Prize Foundation.

Phiala Shanahan received a 2020 Early Career Research Award from the US Department of Energy.

## Education

In AY2020, the Physics Department enrolled 245 undergraduate majors and 270 graduate students. Of these, approximately 35% of our undergraduates and close to 25% of our graduate students were women. This year, we awarded 79 SB degrees and 46 PhDs. Many physics majors maintain strong academic records at MIT; 18% of physics degree recipients were nominated and inducted into Phi Beta Kappa.

We expect the number of SB degrees in physics to continue at around 75 to 80. In fall 2020, 61 of AY2020's class of first-year students will become physics majors, but this number will be augmented in the spring term as some sophomores declare a second major in physics. Usually there is another increase in second majors during senior year. After several years of observing incoming sophomore classes, we find that with the exception of 2016–2017, when 86 new majors joined the Physics Department, an average incoming class will now generally be between 55 and 70 students. Declines in the number of declared majors have been reported by almost all departments at MIT over this same period, as the number of computer science majors continues to increase.

Of the 79 SB degree recipients in 2020, 60% were double majors and 93% chose the 8-Flex degree option.

Our graduate program continues to be competitive. In 2020 the number of applicants climbed to a new high of 1,062. Of the students to whom we offered admission to our program, 50% accepted, leading to an entering class of 47. We continue to be proud of our high yield of PhD candidates. In AY2020, 46 students graduated from our department with PhD degrees. We typically have more PhD graduates per year than any other department in the country.

The impact from the COVID-19 pandemic shutdown was difficult on our all students. Most had to return home. Many of those from foreign countries face an uncertain future as to when they can return. We will work hard in the fall to create a sense of community, on the assumption that we will likely not have all (if any) students on campus. Edmund Bertschinger is working to create a student mentoring program to help students who are struggling, and we worked over the summer to create kits to mail to students for experimental learning.

## Research Highlights

Researchers led by Pablo Jarillo-Herrero showed that rotating layers of hexagonally structured graphene at a particular “magic angle” could change the material’s electronic properties from an insulating state to a superconducting state. Now researchers in the same group and their collaborators have demonstrated that in a different ultra-thin material that also features a honeycomb-shaped atomic structure—chromium trichloride ( $\text{CrCl}_3$ )—they can alter the material’s magnetic properties by shifting the stacking order of layers.

Riccardo Comin and his research team were part of a group which discovered for the first time fractal-like patterns in a quantum material—a material that exhibits strange electronic or magnetic behavior as a result of quantum atomic-scale effects. This understanding of how a material’s magnetic domains arrange at the nanoscale, and

knowing that they exhibit memory, is useful for designing artificial neurons and resilient magnetic data storage devices.

Nuh Gedik and Pablo Jarillo-Herrero's teams demonstrated that when a pattern called a charge density wave in a certain material is hit with a fast laser pulse, a whole new charge density wave is created—a highly ordered state—instead of the expected disorder. The surprising finding could help to reveal unseen properties in materials of all kinds.

Jeff Gore led a team of physicist which demonstrated how a transient invasion can occur in bacterial populations, provoking a shift from one stable community state to another, while the invader itself disappears. The findings help shed light on how transient invaders affect real-world ecosystems.

Or Hen and his colleagues performed an extensive data analysis on previous particle accelerator experiments and found that as the distance between protons and neutrons becomes shorter, a surprising transition occurs in their interactions. Whereas at large distances the strong nuclear force acts primarily to attract a proton to a neutron, at very short distances the force becomes essentially indiscriminate: interactions can occur not just to attract a proton to a neutron, but also to repel or push apart pairs of neutrons. This is the first detailed look at what happens to the strong nuclear forces at very short distances. The researchers believe this transition in the strong nuclear force can help to better define the structure of a neutron star.

Liang Fu was part of a group that developed a blueprint for a device they believe would be able to convert ambient terahertz waves into a direct current—a form of electricity that powers many household electronics.

MIT physicists, led by Wolfgang Ketterle, were part of a group of researchers who found a way to cool molecules of sodium lithium down to 200 billionths of a Kelvin, just a hair above absolute zero. They did so by applying a technique called collisional cooling, in which they immersed molecules of cold sodium lithium in a cloud of even colder sodium atoms. The ultracold atoms acted as a refrigerant to cool the molecules even further. This could enable researchers to use molecules as complex bits for quantum computing, tuning individual molecules like tiny knobs to carry out multiple streams of calculations at a time.

Researchers at MIT and elsewhere, led by Ronald Garcia Ruiz, have combined the power of a super collider with techniques of laser spectroscopy to precisely measure a short-lived radioactive molecule, radium monofluoride, for the first time. This may help scientists to measure symmetry-violating phenomena and identify signs of dark matter.

### **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 71 fellows. Nearly 40% of all Pappalardo Fellows have been women (we just had our first class of all women fellows) and the program has proved to be a strong source of our own faculty recruiting, as six members have joined the department. We planned to celebrate the 20th anniversary of this distinguished program in spring 2020, but the pandemic required us to postpone this event to a future date.

**Peter Fisher**  
**Head**  
**Professor of Physics**