Department of Physics

Academic year 2016 was an exciting and productive one for the Department of Physics. As one of the largest university physics departments in the world, we excel in many subfields. The department is organized into four research divisions: astrophysics; atomic, biophysics, condensed matter, and plasma physics; theoretical nuclear and particle physics; and experimental nuclear and particle physics. Since 2002, U.S. News & World Report has ranked the department at the top of graduate physics programs. The strength of the department comes from its unwavering devotion to both research and teaching. Collectively, our faculty and alumni have won 19 Nobel prizes. Eleven current faculty are members of the National Academy of Sciences and four are MacArthur Fellows.

Faculty Count, Promotions and Departures

As of July 1, 2016, the Department of Physics will have 66 appointed regular rank faculty members, consisting of 41 full professors, 8 associate professors, and 17 assistant professors.

Three faculty members were promoted this year. Markus Klute was promoted to associate professor with tenure and Nevin Weinberg and Jeremy England were promoted to associate professor without tenure. These promotions take effect July 1, 2016.

The department had a productive faculty search process in AY2016. All five offers extended were accepted. Two faculty will start in January 2017: Salvatore Vitale in astrophysics and Max Metlitski in condensed matter theory. Three others will start in July 2017: Dan Harlow in theoretical nuclear and particle physics, and Phil Harris and Or Hen in experimental nuclear and particle physics. Additionally, Kerstin Perez in experimental nuclear and particle physics, and Riccardo Comin in atomic, biophysics, condensed matter, and plasma physics will begin July 1, 2016. In the past six years, 34 offers have been made, resulting in 23 acceptances, for a success rate of nearly 75%.

Administration

For AY2016, the Physics Council membership was as follows:

Peter Fisher—department head

Nergis Mavalvala—associate department head

Deepto Chakrabarty—astrophysics division head

Vladan Vuletić—atomic, biophysics, condensed matter, and plasma physics division head

Mehran Kardar—atomic, biophysics, condensed matter, and plasma physics member-at-large

Joseph Formaggio—experimental nuclear and particle physics division head

Edward Farhi—director, Center for Theoretical Physics

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

Jacqueline Hewitt—director, Kavli Institute for Astrophysics and Space Research

Matt Cubstead—administrative officer

Bolek Wyslouch became director of the Laboratory for Nuclear Science effective July 1, 2015, replacing Richard Milner; Joseph Formaggio replaced Wyslouch as the division head of experimental nuclear and particle physics.

Faculty Awards

Following are a few of the many awards and recognitions conferred on faculty members during academic year 2016:

Robert Birgeneau received the National Science Foundation's Vannevar Bush Award.

Arup Chakraborty was elected to the National Academy of Sciences.

Joseph Checkelsky received a National Science Foundation Career Award.

Ibrahim Cissé, assistant professor, was named the Class of 1922 Career Development Assistant Professor.

Joseph Formaggio received a Breakthrough Prize in Fundamental Physics as part of the Sudbury Neutrino Observatory collaboration.

Jacqueline Hewitt was elected to the American Academy of Arts and Sciences.

Yen-Jie Lee, assistant professor, was named the Class of 1958 Career Development Assistant Professor; he also won a Sloan Research Fellowship.

David Pritchard was named an American Physical Society Outstanding Referee.

Jesse Thaler received the Harold E. Edgerton Faculty Achievement Award.

Mark Vogelsberger was awarded a Sloan Research Fellowship.

Lindley Winslow received a Breakthrough Prize in Fundamental Physics as part of the Kamioka Liquid-scintillator Antineutrino Detector Collaboration.

Rainer Weiss received the Kavli Prize in Astrophysics, The Shaw Prize in Astronomy, and a Special Breakthrough Prize in Fundamental Physics. All awards recognized his contribution to the momentous discovery of gravitational waves. The Special Breakthrough Prize was shared by members of the Laser Interferometer Gravitational-Wave Observatory (LIGO) team, including faculty members Nergis Mavalvala and Matthew Evans.

Education

For the past 10 years, 80 or more bachelor of science (SB) degrees have been awarded each year to students majoring in physics, with the 104 in 2013 being the highest number awarded since 1976. Of the 83 SB degrees awarded to physics majors in 2016, 90% chose the flexible degree option, 58% had more than one major, 25% were women (a gain of 6% over the preceding year), and 19% were elected to Phi Beta Kappa.

A total of 239 students pursued graduate degrees in physics; 41 students graduated from the department with PhD degrees. This number is the second highest in 10 years, a period during which the department averaged 33 PhD graduates per year.

Our graduate program continues to be competitive. Over time, our admissions have become increasingly selective: from a pool of 821 applicants in 2015, 81 were admitted, resulting in an entering class of 33. In 2016, after an even larger applicant pool of 911 (an 11% increase over the previous year), the department will welcome 49 doctoral students in fall 2017. This class represents a yield of 51%.

Since the founding of MITx in 2012, the Physics Department has been one of the most proactive departments in developing a coherent department-wide, faculty-led online learning program. The initiative is guided by the principle that online efforts enhance the physics education of global online learners as well as of MIT residential students. To this end, materials developed for our online offerings are incorporated into residential courses, and the department is increasingly offering hybrid versions that allow MIT students access to a mixture of online lectures and live, in-class instruction (sometimes referred to as "blended learning").

Our online education team has played a leading role in understanding how Massive Open Online Courses (MOOCs) can be used for blended learning on campus. The department has been very proactive in using data from online classes to understand students' learning habits and to develop more effective teaching methodologies.

Since the removal of the introductory physics sequence 8.01x Classical Mechanics and 8.02x Electricity and Magnetism in late 2014, the department has been working closely with the Office of Digital Learning to introduce new versions of these foundational courses. We have used this as an opportunity to revamp these courses, modernizing and modularizing them to incorporate new understanding of best teaching methodologies. These efforts, funded both by the department and by Office of Digital Learning grants, are led by faculty members who have long been involved in residential versions of online learning systems (Deepto Chakrabarty for 8.01x and Bob Redwine for 8.02x). The first modules of 8.01x will be rolled out as a MOOC in October 2016, with more modules added every few weeks; 8.02x is planned for first release in fall 2017.

In the past two years, the department developed and offered the second in our three-semester quantum sequence—8.05x Quantum Physics II—as a MOOC. This effort was led by Professor Barton Zwiebach and Dr. Saif Rayyan (our Office of Digital Learning fellow), and was a success in terms of the number of global learners who enrolled and completed one, two, or all three modules. We also offered the course as a hybrid residential version in the spring term. In this format, MIT students watched lectures and completed homework online, but received two hours of live, in-class instruction from an MIT faculty member (similar to our more traditional lecture/recitation format).

The first time this hybrid version was offered, it was a huge success in terms of learning outcomes and student satisfaction (both in its own right and also as compared to the traditional lecture/recitation format offered in the fall term). The second time was less successful, and we are working to incorporate lessons learned from these two experiences to develop a hybrid version that we can offer regularly each spring. 8.05 Quantum Physics II is one of the courses that would benefit from being offered both terms, and we are keen to develop this to the point where we can offer the traditional version each fall term and the hybrid version each spring term.

Professor Zwiebach and the online team are now developing the first in our three-semester quantum sequence—8.04 Quantum Physics I—as a MOOC, with a planned rollout in fall 2017.

In 2015, the department also introduced an online graduate course, 8.421x Atomic and Optical Physics I, the first in a two-semester sequence. This effort was led by Professors Wolfgang Ketterle and Isaac Chuang, again with support from Dr. Rayyan. We successfully offered 8.421x both as a MOOC and as a hybrid residential version in fall 2015. We are now planning to develop the second course in the sequence, 8.422 Atomic and Optical Physics II, as a MOOC and blended residential class.

8.421 Atomic Optical Physics I and 8.422 Atomic Optical Physics II are offered every two years. If 8.421 is offered one spring term, 8.422 is offered spring term a year later, and they alternate annually. This requires students taking these classes in preparation for their oral exam to be very thoughtful about their planning, or risk delaying their exam. The prospect of offering the blended version of each class annually is attractive to students and to the department, so we are quite excited about developing 8.421x and 8.422x for both global and residential students.

Diversity

The department continues to support a wide range of undergraduate groups that focus on diversity efforts throughout the Institute. The department regularly provides 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 (La Unión Chicana por Aztlán), an undergraduate group that supports Mexican American culture, and the Undergraduate Women in Physics organization. Additionally, the department covers travel costs for undergraduates who attended the Undergraduate Women in Physics conference, and also supports other travel by undergraduates, graduates, postdocs, and faculty who attend conferences supporting diversity in physics.

This year, six of seven offers for multiyear fellowships to minority graduate students were accepted. One of two five-year fellowships offered to the top women candidates was accepted.

Research Highlights

Below are some research highlights from members of the Department of Physics faculty in AY2016.

In one of the most significant discoveries in the history of physics, the LIGO team—led by Rainer Weiss and including Nergis Mavalvala and Matt Evans, as well as numerous scientists, postdocs, and graduate and undergraduate students—announced the detection of gravitational waves in February 2016. The measurement of two black holes that collapsed into one another 1.3 billion years ago confirmed a major prediction of Albert Einstein's general theory of relativity, and opens an unprecedented window into our cosmos. Later in 2016 it was announced that a second detection of gravitational waves had also been measured.

Marin Soljačić led a group of researchers who confirmed by direct observation, for the first time, a massless particle that features a singular point in its energy spectrum (known as the Weyl point). According to the team, the finding could lead to new kinds of high-power single-mode lasers and other optical devices.

Nobel Prize winner Wolfgang Ketterle led a team of researchers who created a superfluid gas, known as the Bose-Einstein condensate, for the first time in an extremely high magnetic field. This experiment opens up a new window into the quantum world, where materials with new properties can be studied, and could help connect the research to important frontiers in materials research, including quantum Hall physics and topological insulators.

Marin Soljačić and John Joannopoulos worked on a team that showed that a sheet of graphene—a two-dimensional form of pure carbon—could be used to generate surface waves called plasmons when the sheet is struck by photons from a laser beam. These plasmons in turn could be triggered to generate a sharp pulse of radiation, tuned to wavelengths anywhere from infrared light to X-rays. The group showed that the radiation produced by the system would be of a uniform wavelength and tightly aligned, similar to that from a laser beam. According to the team, this could potentially enable lower-dose—and therefore safer—X-ray systems in the future.

Michael McDonald worked with a group of astronomers who detected a massive, sprawling, churning galaxy cluster that formed only 3.8 billion years after the Big Bang. Located 10 billion light years from Earth and potentially comprising thousands of individual galaxies, the megastructure is about 250 trillion times more massive than the sun, or 1,000 times more massive than the Milky Way galaxy. The cluster is the most massive cluster of galaxies yet discovered in the first four billion years after the Big Bang.

Pablo Jarillo-Herrero and Nuh Gedik were part of a team that developed a technique to manipulate electrons in graphene within the first few femtoseconds of photo-excitation. With this method, the researchers can redirect these high-energy electrons before they interact with other electrons in the material. The team's ultrafast control of high-energy electrons may ultimately lead to more efficient photovoltaic and energy-harvesting devices, which capture photo-excited electrons before they lose their energy to thermalization.

Nikta Fakhri, along with other biophysics researchers at the University of Göttingen, Ludwig Maximilian University of Munich, the Free University Amsterdam, and Yale University have developed a noninvasive data analysis technique that can discern whether an object's random motion is actively or thermally driven. These results will help scientists to uncover "hidden" active processes that drive a cell's constituents to move in seemingly random ways while providing an experimental method to identify active, nonequilibrium processes in observations of biological systems.

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. 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 59 fellows. Nearly 35% of all Pappalardo Fellows have been women, and the program has proved to be a strong source of our own faculty recruiting, as five members have joined the MIT Physics Department.

Community and Events

The Physics Department strives to create a community of scholars and endeavors to create opportunities for faculty, students, and alumni to come together to share and explore ideas. The department continues 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 research talk from one of their colleagues.
- An afternoon colloquium series is held each week at which a physicist, often from outside MIT, is invited to present 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 the department's outstanding faculty presenters.
- During MIT's 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 varied 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 Pappalardo Distinguished Lecture in Physics.
- The department head holds a monthly lunch with all of the administrative and support staff to talk about major issues facing the department and highlighted research topics in physics.

Peter Fisher
Professor of Physics
Department Head