Department of Physics

Academic year 2015 was another exciting and extremely productive one for the Department of Physics. MIT has one of the largest university physics departments in the world; it excels 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, MIT's Physics department has been ranked at the top of graduate physics programs by *US News and World Report*. The strength of the department comes from its unwavering devotion to both research and teaching. Together, the department's faculty and alumni have won 19 Nobel Prizes. Eleven current faculty are National Academy of Science members and four are MacArthur Fellows.

Faculty Count, Promotions, and Depatures

As of July 1, 2015, the Physics Department will have 68 appointed regular-rank faculty members, consisting of 42 full professors, seven associate professors, and 18 assistant professors.

Four faculty members were promoted this year. Nuh Gedik and Pablo Jarillo-Herrero were promoted to associate professor with tenure and Jeff Gore and Jesse Thaler were promoted to associate professor without tenure. These promotions take effect July 1, 2015.

The department had another productive faculty search process in 2014–2015, making three offers, two of which were accepted. One new faculty member, Michael McDonald (astrophysics) will start on July 1, 2015. The other, Kerstin Perez (experimental nuclear and particle physics) will start on July 1, 2016. Additionally, Lindley Winslow (experimental nuclear and particle physics) and Nikta Fakhri (biophysics) joined the department in January 2015. The past five years of searches have resulted in 18 new junior faculty members and an acceptance rate of 68%.

Stan Kowalski retired effective June 30, 2015, after years of dedicated service to MIT and the department. We greatly appreciate his contributions.

The department was saddened by the loss of Emeritus Professors Benjamin Lax and Michel Barenger. Both of them were wonderful colleagues, researchers, and teachers. Their contributions to the department still resonate today.

Administration

For AY2015, the Physics Council membership was as follows:

Peter Fisher—department head

Krishna Rajagopal—associate department head through January 2015

Nergis Mavalvala—associate department head from January 2015 to June 2015

Deepto Chakrabarty—astrophysics division head

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

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

Boleslaw (Bolek) Wyslouch—experimental nuclear and particle physics division head

Eddie Farhi—director, Center for Theoretical Physics

Richard Milner—director, Laboratory for Nuclear Science

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

Matt Cubstead—administrative officer

Nergis Mavalvala became the new associate department head in January 2015. She replaces Krishna Rajagopal, who will become the chair of the MIT Faculty on July 1, 2015. Richard Milner stepped down from the position of director of the Laboratory for Nuclear Science on June 30, 2015. He will be replaced by Bolek Wyslouch. Because of this, the new division head of experimental nuclear and particle physics will be Joseph Formaggio. Both changes are effective as of July 1, 2015.

Faculty Awards

Following are a few of the many awards and recognitions conferred on faculty members during academic year 2015:

- John Belcher won the MIT Excellence Award.
- Mildred Dresselhaus won the Presidential Medal of Freedom.
- Jeremy England was named a Thomas D. and Virginia W. Cabot Career Development Assistant Professor.
- Anna Frebel was named a Silverman Family Career Development Assistant Professor.
- Liang Fu won the Packard Fellowship.
- Thomas Greytak was elected to the American Academy of Arts and Sciences.
- Aram Harrow won the Early Career Research Award from the US Department of Energy (DOE) and the Faculty Career Early Development Award from the National Science Foundation (NSF).
- John Joannopoulos was elected to the American Academy of Arts and Sciences.
- Yen-Jie Lee won the Early Career Research Award (DOE) and the Faculty Career Early Development Award (NSF).
- Sara Seager was elected to the National Academy of Sciences.
- Tracy Slatyer won the Early Career Research Award (DOE) and the Faculty Career Early Development Award (NSF).

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 degrees awarded in 2013 being the highest number awarded since 1976. Eighty-two SB degrees were awarded to physics majors in 2015. The department's current three-year average of 91 SB degrees awarded per year is the highest in the country. Of the 82 degree recipients in 2015, 88% chose the flexible degree option, 54% had more than one major, 19% were women, and 21% were elected to Phi Beta Kappa.

Some 244 graduate students pursued degrees in physics and 39 students graduated from the Department of Physics with PhD degrees. This number is the second highest in 10 years, a period during which the department has averaged 36 PhD graduates per year.

The department's graduate program continues to be competitive. In 2013 and 2014, the program achieved almost unprecedented yields: 51% in 2013, resulting in an entering class of 48 students, and 55% in 2014 (despite having made fewer offers than in 2013) for an entering class of 45 students. In 2015, admissions became even more selective: from a pool of 821 applicants, 81 were admitted. The department looks forward to welcoming the September 2015 class of 33 new PhD students.

Over the past three years, the department's online educational activities have grown dramatically. Colleagues from the department have run several online courses, including 8.01X and 8.02X, the first two ventures, which were built around the freshman physics courses. In AY2015 the department offered two new online courses, 8.EFTX, an advanced graduate course on effective field theory taught by Iain Stewart, and 8.05x, a course in quantum mechanics taught by Gunther Roland. To date, more than 3,900 learners have received MITx certificates for completing a physics course online.

Starting in November 2013, the department has made a substantial effort to use MITx technology to improve the way in which on-campus students in MIT's 8.02 and 8.01 subjects are taught. This effort is possible only because of the investments that the Department of Physics and the Office of Digital Learning made in 8.02X and 8.01X. The traditional reading assignments and reading questions that the students were expected to do before coming to each class are being replaced with a suite of online materials for the students to choose from, followed by online questions that the students have to answer by 8:30 am on the day of each class. With support from the Office of Digital Learning and from the D'Arbeloff funds, the department is also working to use online tools from MITx to improve how teach the so-called Junior Lab courses, particularly 8.13 Experimental Physics I. Tablet lectures are used later in the semester, when the students are doing experiments, which provides instant feedback on their progress through the online analysis exercises. This initiative is the department's first use of MITx technologies to improve how students majoring in physics are educated. Its success means that it will not be the last.

In FY2015, the department is working to recreate the 8.01X and 8.02X courses. The initial foray into these courses used lectures that were more than 10 years old. The new versions will incorporate new lectures that are centered on the technology-enabled active learning teaching format. The department plans to have the courses available by the fall of 2016.

Diversity

The Department of Physics continues to support a wide range of undergraduate groups that help focus on diversity efforts throughout the Institution. The 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, Latinos in Science and Engineering, La Unión Chicana por Aztlán (an undergraduate group that supports Mexican American culture) and the Undergraduate Women in Physics organization. Additionally, the department covers the travel costs for undergraduates who attend the Undergraduate Women in Physics Conference and supports other travel by undergraduate students, graduate students, postdoctoral associates, and faculty who attend conferences supporting diversity in physics.

This year, the department offered four fellowships to minority students, but no one accepted. The department is in the process of understanding why this happened and will continue to make these offers in the future. The department offered four five-year fellowships to the top women candidates and had one accept. Several students were considered for the bridge program, but there were no suitable candidates. The bridge program will continue next year. In the coming year, the department is providing support for Dr. Chanda Prescod-Weinstein, an MLK Fellow who needed some additional time to complete work to be competitive for faculty positions.

Research Highlights

Below are some of the research highlights from members of the Department of Physics faculty in 2014 and 2015:

Martin Zwierlein led a group of researchers who successfully cooled molecules in a gas of sodium potassium to a temperature of 500 nanokelvins — just barely above absolute zero, and over a million times colder than interstellar space. The researchers found that the ultracold molecules were relatively long-lived and stable, resisting reactive collisions with other molecules. The molecules also exhibited very strong dipole moments — strong imbalances in electric charge within molecules that mediate magnet-like forces between molecules over large distances.

A research group co-led by Leonid Levitov succeeded in creating a new "whispering gallery" effect for electrons in a sheet of graphene, making it possible to precisely control a region that reflects electrons within the material. They say the accomplishment could provide a basic building block for new kinds of electronic lenses, as well as quantum-based devices that combine electronics and optics.

A group of MIT researchers led by Joe Formaggio worked with other groups to form a tabletop particle detector that is able to detect single electrons in a radioactive gas. As the gas decays and gives off electrons, the detector uses a magnet to trap them in a magnetic bottle. A radio antenna then picks up very weak signals emitted by the electrons that can be used to map the electrons' precise activity over several milliseconds. It is the group's hope that this detector may help detect the elusive mass of neutrinos.

Vladan Vuletic co-led a group that developed a new technique that can successfully entangle 3,000 atoms using only a single photon. The results, published in the journal *Nature*, represent the largest number of particles that have ever been mutually entangled experimentally. The researchers say the technique provides a realistic method to generate large ensembles of entangled atoms, which are key components for realizing more precise atomic clocks.

Nuh Gedik and Liang Fu helped lead a group that studied tungsten disulfide's ability to provide a pathway toward a kind of two-dimensional microchip that would make use of a characteristic of electrons other than their electrical charge, as in conventional electronics. The new approach is dubbed "valleytronics" because it makes use of properties of an electron that can be depicted as a pair of deep valleys on a graph of their traits.

Professor Jacqueline Hewitt of the MIT Kavli Institute is leading a new effort to study the epoch of reionization—the period, just after the Big Bang but before the first stars formed, that tells us about the large-scale structure of the universe. This has not been much studied. Professor Hewitt and her collaborators have developed important analysis techniques to measure how long this period was and how the first proto-stars would form. Her team has deployed a first version of a planned low-frequency radio telescope, the Murchison Widefield Array, to make some first measurements and prove the technique. The team is now proceeding, with probable support from the Moore Foundation, to a large version of a low-frequency radio telescope called the Hydrogen Epoch of Reionization Array (HERA). HERA is an international effort, with collaborating institutions in the United States, the United Kingdom, and South Africa.

Researchers at MIT's Laboratory for Nuclear Science, including Paulo Zuccon and Sam Ting, have released new measurements that promise to shed light on the origin of dark matter. The MIT group led an international collaboration of scientists that analyzed two and a half years' worth of data taken by the alpha magnetic spectrometer (AMS)—a large particle detector mounted on the exterior of the International Space Station—that captures incoming cosmic rays from all over the galaxy. Among 41 billion cosmic ray events (instances of cosmic particles entering the detector), the researchers identified 10 million electrons and positrons, stable antiparticles of electrons. The new AMS results may ultimately help scientists narrow down the origin and features of dark matter.

Pappalardo Fellows

A. Neil Pappalardo has made possible a program in the Department of Physics to attract people of exceptional promise who recently received their PhDs. 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; since then, the program has supported 48 fellows. Nearly 35% of all Pappalardo Fellows have been women. The program has proved to be a strong source of faculty recruiting, as five Pappalardo Fellows have joined the MIT Physics Department.

Community/Upcoming 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 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 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 Department of Physics community.
- Monthly luncheons are held for faculty, postdoctoral associates, graduate students, and staff members to discuss broad topics associated with diversity and inclusion.
- Twice a semester, alumni are invited to a breakfast to hear about physics research done by one of the department's outstanding faculty presenters.
- During Independent Activities Period, the department offers a lecture series that is open to the MIT community. The series covers a wide range of topics, including research highlights from selected faculty members and as talks by alumni that highlight varied career paths.
- The Pappalardo Fellowship program sponsors a weekly lunch that brings Pappalardo Fellows and Department of Physics faculty together for conversation.
- Each fall, the department hosts a Distinguished Pappalardo Lectureship.
- 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