A Microscopic Look At Quantum Materials

IT TAKES MANY PHYSICISTS TO SOLVE QUANTUM MANY-BODY PROBLEMS
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IN MEMORIAM

Professor Bence Csellós, Associate Professor Emeritus, passed away on January 14, 2020.

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Dear friends of Harvard Physics,
The sixth issue of our annual Physics Newsletter is here! Please peruse it to find out about the coming and goings in our department during the past academic year.

We are grateful to many of you who wrote to us last year about the previous issue of the Newsletter. We value both the accolades and the constructive criticism you have provided, and will strive to incorporate your excellent suggestions. You will find the letters on page 2, continued on the inside back cover.

I am very pleased to announce the promotion of Matthew Reece to full professorship with tenure. His profile appears on page 3.

I am to report that we lost two colleagues and friends this year: Professors Roy Glauber and Jene Golovchenko. You will find their obituaries on pages 4-6.

For the cover article in this issue, we have chosen the experiment-theory collaboration between the groups of Professors Markus Sengstock and Gregory Kohnen (pp. 8-10). Their observations are impacting our understanding of quantum materials (pages 9-13).

I hope you enjoy the article about Professor Mara Prentiss, one of the busiest people in our department. In addition to doing research in biophysics and teaching, Prof. Prentiss serves as the Director of Graduate Studies and oversees the Harvard Physics machine shop and Physics Teaching Labs. Please read her profile on pages 18-21.

While Prof. Prentiss has been in our department since 1991 (she was the second female physicist to be awarded tenure at Harvard), our next article features a faculty member who joined our department only two years ago, Professor Roxanne Guenette (pp. 22-26).

Page 27, Clarisse Plessola offers a brief introduction to the Harvard Quantum Initiative in Science and Engineering, which was launched last November. HQI is co-directed by Professors John Doyle, Mikhail Lukin, and Evelyn Hu (SEAS). Pages 28-32 are devoted to a survey of various initiatives within our department, formed over the years with the goal of building a strong community; this includes the most recent developments from the Committee on Equity and Inclusion. I am very pleased to announce that we have hired two new members to this committee: John White and Leanne Benitez (pp. 33-34).

As always, do stop by when you are in town or drop us a note if you have any questions, would like to make a comment, or just want to say hi to old friends.

Best wishes,

Subir Sachdev
Chair and Herchel Smith Professor of Physics
Letters from Our Readers

We enjoy hearing from our readers. Here is what several had to say:

ASHOK KHOSLA, Ph.D. 1970

Thanks very much for these terrific articles on so many important topics, particularly the cover story. I’m primarily writing to congratulate you on an excellent issue, as well as the long-standing leadership of the Harvard Physics department in launching outstanding women on careers in physics. I am grateful for the supportive culture that had been established by the time I arrived as a graduate student in 1992.

I did want to point out an ironic oversight, given the overall effort of the issue to highlight the accomplishments of women in physics. Near the end of the cover story, at the start of the section “The Way Forward,” the seminal work of Hazari et al., was summarized in the discussion of factors that lead to women pursuing careers in physics. I found unfortunate that the text discussion of this work mentioned only Phil Sadler by name among the authors, rather than also mentioning at least the first author, Zabra Hazari, who was a postdoc with Sadler. She has gone on to a stellar career and is presently among the leading researchers in this area.

My goal in pointing this out is solely to call attention to the missed opportunity to highlight the work of the woman who is the first author on the study and was a Harvard postdoc at the time, which seems ironic given that the article was about the accomplishments of women in physics. I do not wish at all to minimize Sadler’s essential contributions to the work and to the field; rather, I would just have recommended taking the opportunity to mention Dr. Hazari as well, as she is also someone of whom the greater Harvard community can be proud.

I appreciate that there was probably a desire for brevity and a desire to highlight the work of people such as Sadler who are known to the Harvard physics department, so I understand the possible sources of the omission, and do not suggest there were any but the best of intentions.

As I said at the start, congratulations on both a terrific issue and a terrific track record of supporting women in physics, and please take my critique in that context.

CATHARINE H. CROUCH, Ph.D. 1996
Professor of Physics, Swarthmore College

Chair’s response:

Dear Prof. Crouch,

Thank you for your comments on our newsletter. We are always happy to hear from our graduates, and have received many positive remarks on this issue.

You do make an important point on the citation of the work by Hazari et al. We will try to be more vigilant on such issues in the future. The author of this article was highlighting connections to Harvard in particular, and hence the mention of Sadler.

Thank you again.

Sincerely,

SUJIR SACHDEV

I am a member of the Harvard class of 2013 and wanted to share how grateful I am for your effort in organizing and writing this newsletter. It’s a wonderful way to stay up to date on the Harvard physics community.

JULIANA CHERSTON, A.B. 2013

Continued on the inside back cover

Matthew Reece, Harvard’s Newest Full Professor of Physics, Explores a Universe of Possibilities

As a high school student, Matthew Reece was curious about many things. However, two books he read as a teenager—first A Brief History of Time by Stephen Hawking and later The Elegant Universe by Brian Greene—drew his attention toward physics. That budding interest was reinforced when Reece, as a University of Chicago undergraduate, was introduced to the experimental particle physicist Henry Frisch. Frisch worked for four years in Frisch’s lab, analyzing data for the Collider Detector at Fermilab (CDF) collaboration among other tasks.

While the experience gave Reece a great introduction to particle physics, he learned that he’d rather be a theorist than an experimentalist. With this goal in mind, he started graduate studies at Cornell in 2004, choosing the school because it seemed like a congenial place whose physics department was small enough to allow for close working relationships between particle theorists working alone and researchers working in more abstract string theory. He’d also have the chance to work closely with his advisor, Csaba Csaki, a new faculty member who hadn’t yet accumulated a large group of graduate students.

Reece initially focused on electroweak symmetry breaking, testing out ideas involving extra dimensions. He’d hoped to investigate theories related to the Large Hadron Collider (LHC), but that machine didn’t start operating until September 2008, and by then Reece had earned his Ph.D. and started a postdoctoral fellowship at Princeton. He became a postdoc at Harvard from 2011 to 2012, staying on as an assistant professor until his promotion to associate professor in 2016 and full professor with tenure this summer.

Since coming to Harvard, Reece has explored a broad range of topics under the heading of “physics beyond the Standard Model,” including early-universe cosmology, quantum field theory, and quantum gravity. Reece has delved deeply into supersymmetry—an idea introduced in the 1970s that could resolve several longstanding puzzles tied to the so-called hierarchy problem. Many physicists thought the LHC would verify this theory by discovering supersymmetric particles, but none has been observed so far. Reece is one of the originators of a “scalable supersymmetry” model that offers an explanation for why these hypothetical particles have not yet been seen.

He’s also given considerable thought to dark matter. Reece and his Harvard colleague Lisa Randall, for instance, have proposed that a small fraction of dark matter could interact strongly with ordinary matter, forming previously unexpected “dark disks” around galaxies. Given that the nature of dark matter is still unknown, Reece says, “it’s important to consider a wider range of possibilities for the forms it might assume.”

He’s excited by the prospect of the new telescopes being built to search for primordial gravitational waves, which might offer, Reece says, “perhaps our best chance of learning about quantum gravity and probing energy scales close to the Planck scale.”

In work within a new area of theoretical physics called the “Swampland,” he’s pondering the vast number of potential string theory solutions, trying to identify common, universal features that a viable model should incorporate. On a more concrete level, he’s making the case for future particle colliders, spelling out the pivotal contributions that could still be made.

In a sense, Reece got his start in physics with A Brief History of Time. Now he’s grappling with the brief amount of time available each day to satisfy his curiosity within this exciting, fast-paced field. But that, he says, is a good problem to have.

Please stay in touch and let us know if you would like to contribute news items to the newsletter at: newsletter@physics.harvard.edu
Roy J. Glauber
by Peter Reuell

Roy J. Glauber ’46, the pioneering theoretical physicist who received the Nobel Prize in 2005 and was one of the last living scientists to have been present for the dawn of the atomic age, died on Dec. 26, 2018. He was 93.

The research that set Glauber on the path to a Nobel began with his interest in a groundbreaking 1966 experiment that confirmed a key concept of quantum physics — that light was both a particle and a wave — and laid the groundwork for the field. His landmark 1963 paper, “The Quantum Theory of Optical Coherence,” showed quantum mechanical tools to transform science’s understanding of light, which previously had only been studied using classical techniques.

“We really did not have a complete understanding of the quantum properties of light, and what Roy’s work laid out was a framework for thinking about that,” said Mikhail Lukin, the George Vasmer Leverett Professor of Physics and co-director of the Harvard Quantum Initiative in Science and Engineering. “It allowed us to think about these types of questions quantitatively … so I would argue that his work very much laid the groundwork for the field of quantum science and technology that people are talking about right now.”

Lukin said the theories outlined by Glauber opened the door for many scientific discoveries as well as next-generation technologies, including quantum computers and networks and the use of quantum cryptography, which relies on quantum mechanics to create impossible-to-crack codes.

“Those ideas all grow out of this framework that he developed,” Lukin said. “Some people refer to these new developments as the second quantum revolution — the first was about understanding the laws of quantum mechanics. But in this second revolution … the idea is that now that we understand the quantum world and we can actually control it, let’s see what we can use it for. Can we build materials with properties which you design on demand? Can we build quantum computers? Can we send information with absolute security from one side of the country to the other? These types of ideas very much depend on understanding where the classical world ends and the quantum world starts, and that’s where these ideas Roy pioneered and developed become absolutely critical.”

Glauber graduated from the Bronx High School of Science and entered Harvard as a 16-year-old freshman, but left as a sophomore when he was recruited to join the Manhattan Project, where he worked with future Nobel-winning physicist Richard Feynman to calculate the critical mass of the first atomic bomb. Glauber was later present at the first tests of the bomb.

“Some anecdotes that made him laugh when I told him were, when I first became his advisor in 1952, I told my mother about it and mentioned Roy’s name as my adviser,” Shapiro recalled. “She somehow mentioned it to his younger sister, who piped up and said, ‘Oh, Felicia’s little boy, Roy!’ I don’t know how my aunt knew Roy’s mother, but somehow they had been friends.”

Glauber is survived by his son, Jeffrey, a daughter, Valerie Glauber Fleishman; a sister, Jacqueline Gordon; Atholie Rosett, his companion of 13 years; and five grandchildren.

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In Pursuit of Discovery

“What do you think about this?” Jene Golovchenko turned to me with a twinkle in his eye. We had been discussing whether a Z pinch can occur in strongly focused electrolytic currents. Jene had just brought up a case of exploding conducting wires heated by high-power current pulses. He wondered whether the same effect contributed to energy focusing in the exploding liquids of our experiments.

This was typical of Jene: he had a knack for turning simple systems on their head, often leading to new discoveries of the behavior of

matter and revealing new insights into fundamental physics. Jene had a powerfully creative mind for experimental physics, and an incredible depth of theoretical knowledge that he wielded in pursuit of deeper understanding and inventiveness. His excitement and sense of adventure for scientific discovery permeated his research, his joy and enthusiasm were infectious, and his intensity demanded that rigor be applied to every experiment he undertook and every question he sought to answer.

Jene was the Rumford Professor of Physics and the Gordon McKay Professor of Applied Physics at Harvard University. His career spanned academia at Harvard and Aarhus University in Denmark, industry at Bell Labs, national laboratories at Brookhaven and Livermore, and at CERN in Geneva. He was renowned for seminal contributions to ion
implantation, scanning tunneling microscopy, atomic and x-ray physics, and nanopore physics. But most importantly to his students, he was our teacher, mentor, advisor, and ultimately great friend.

Crazy Ideas that Just Might Work

Often Jene would come up with an idea for a novel experiment that was based on his strong intuition for new and interesting physics. He had an uncanny sense for good, albeit crazy ideas to pursue. My thesis grew from one of these ideas. Jene had a hunch that important physics could be learned from the study of first order phase transitions using nanopores to yield detailed information on nanoscale thermal physics and fluctuation phenomena revealed by nucleation rates. This turned out to be more than true: we achieved record-breaking measurements approaching the liquid kinetic limit of stability and attained unprecedented control with spatial and temporal localization of the liquid-to-vapor phase nucleation. We effectively succeeded in harnessing the inherently random event of phase transition into a quasi-deterministic system for studying fluctuations and first-time-to-passage phenomena in thermal physics.

My research with Jene represented only one field among a stunning variety to which he contributed in his career. He undertook a wide range of experimental projects using highly controlled electron, positron, atom, x-ray, ion, and laser beams to reveal new phenomena connected with radiation-matter systems. These experiments led to the development of new probes to study matter and new techniques to modify and transform it into new forms. It was all we could do as students to keep up and learn as much as possible during our time under his mentorship.

What Music Are You Listening to?

Jene was an exceptional teacher taking great joy in sharing his vast knowledge and instilling excitement in learning of new physics. He was equally energetic while teaching undergraduate students in freshman seminar as he was mentoring his Ph.D. students. Jene took great care to train his students to be rigorous and thorough in scientific work, holding a very high standard for research undertaken. Group meetings often took hours, with debates on the results presented and the methodologies used, and it was typical for his students to publish only a few, high-quality papers during graduate tenure.

Jene also cultivated a collegial and fun environment for his group. He was an exceptional judge of character, which contributed to fostering close scientific and personal relationships between his graduate students and postdocs. He once found me in the student office wearing headphones and asked me what music I was listening to. He was quite amused when I said none so that I could focus. The very next year, everyone in the group found a new pair of sound-suppressing headphones on our desks so we could work together in peace.

This was one of many examples of the care Jene took to ensure we had an environment in which to succeed at our research. Music figured heavily into that environment, and it was not uncommon to hear Jene playing the keyboard in his office. Jene would discuss the creation of music as in the context of complex processes at play between physics, mathematics, electronics, and human perception, and he would explore the latest digital technologies for recording, playing, and synthesizing sound. These insights he shared with his freshman seminar, allowing his students to join him on his explorations of the physics of sound.

The Shoulders of a Giant…and a Friend

Jene passed away on 13 November 2018, leaving a tremendous legacy to the advancement of science and the service of the scientific enterprise. I organized the December 2018 conference in concert with Konrad Osterwalder (ETH), Victor Kac (MIT), Christopher King (Northeastern University), Eugene Wayne (Boston University), and Jonathan Weitsman (Northeastern University). Harvard physicist Christopher Stubbs, the Dean of Science at Harvard Faculty of Arts and Sciences, opened the meeting with an entertaining speech. We proceeded to have fourteen one-hour talks, presented by a number of leading mathematicians and physicists, on various topics related to mathematical physics. James Glimm—who founded the subject of constructive quantum field theory with Arthur Jaffe and was Arthur’s long-time collaborator in the 1970s—gave the first talk. Other speakers included two Fields Medalists, Vaughan Jones and Edward Witten; two Harvard physics professors, Mikhail Lukin and Cumrun Vafa; and Jennifer Chayes, the Managing Director of Microsoft Research New England in Cambridge, Massachusetts. We also had six short talks that described the latest progress in the mathematical picture language program, including talks by two Harvard undergraduates who were writing senior theses with Arthur. More details can be obtained from the conference website: https://mathpicture.fas.harvard.edu/cpmp2018.

A celebratory dinner was held at the Loeb House on the night of December 11. John Ewing, the president of Math for America and former Executive Director of the American Mathematical Society, served as the master of the ceremonies at the banquet. The many attendees at this three-day gathering included students, postdocs, collaborators, and friends of Arthur who came from all over the world, including China, Italy, England, France, German, Japan, and Switzerland.

Two special musical events were held during the celebration involving performers who happen to be Arthur’s close friends. Robert Levin, Emestus Dwight P. Robinson Professor of the Humanities at Harvard, gave a public talk, “Who cares if classical music dies,” on December 10 in Science Center C. The noted Swiss oboist, composer, and conductor Hein Holliger organized a concert at the American Academy of Arts and Sciences on Wednesday, December 12. The next day a small ceremony took place during which Holliger signed the book that placed him among the Academy’s International Honorary Members. Arthur himself has been a member of the Academy since 1978, as well as a member of the U.S. National Academy of Sciences since 2000.

We are grateful to the Templeton Religion Trust, the Natural Science Foundation, and the Departments of Physics and Mathematics at Harvard for helping to make this conference possible.

Current Progress in Mathematical Physics: Arthur Jaffe Celebrated at Three-Day Mathematical Physics Conference

By Zhangyi Liu

The conference, “Current Progress in Mathematical Physics,” was held on December 10–12, 2018, primarily in the main lecture hall of Harvard’s Jefferson Laboratory. The event, which showcased new and wide-ranging research in mathematical physics, was dedicated to Arthur Jaffe, the Landon T. Clay Professor Mathematics and Theoretical Science in the departments of mathematics and of physics.

In the course of his remarkable career, Jaffe has made crucial research contributions to the development of mathematics and physics, working in at least nine different subfields. He also served for 21 years (1979-2003) as chief editor of Communications in Mathematical Physics, the top journal in mathematical physics. In addition, he served as president of the American Mathematical Society (1997–1998) and as President of the International Association of Mathematical Physics (1991–1996). His career, clearly, has been dedicated both to the advancement of science and to the service of the scientific enterprise.

We are grateful to the Templeton Religion Trust, the National Science Foundation, and the Departments of Physics and Mathematics at Harvard for helping to make this conference possible.
Quantum Theory of Materials
Efthimios Kaxiras and John D. Joannopoulos
Cambridge, 2019
This accessible new text introduces the theoretical concepts and tools essential for graduate-level courses on the physics of materials in condensed matter physics, physical chemistry, materials science and engineering, and chemical engineering. Topics covered range from fundamentals such as crystal periodicity and symmetry, and derivation of single-particle equations, to modern additions including graphene, two-dimensional solids, carbon nanotubes, topological states, and Hall physics. Advanced topics such as phonon interactions with phonons, photons and electrons, and magnetism, are presented in an accessible way, and a set of appendices reviewing crucial fundamental physics and mathematical tools makes this text suitable for students from a range of backgrounds. Students will benefit from the emphasis on translating theory into practice, with examples explaining experimental observations, applications illustrating how theoretical concepts can be applied to real research problems, and 242 informative full-color illustrations.

The Shape of a Life
Shing-Tung Yau and Steve Nadis
Yale, 2019
Harvard geometer and Fields medalist Shing-Tung Yau has provided a mathematical foundation for string theory, offered new insights into black holes, and mathematically demonstrated the stability of our universe. In this autobiography, Yau reflects on his improbable journey as a widely celebrated mathematician. Beginning with an impoverished childhood in China and Hong Kong, Yau takes readers through his doctoral studies at Berkeley during the height of the Vietnam War protests, his Fields-Medal-winning proof of the Calabi conjecture, his return to China, and his pioneering work in geometric analysis. This new branch of geometry, which Yau built up with his friends and colleagues, has paved the way for solutions to several important and previously intransigent problems. With complicated ideas explained for a broad audience, this book offers readers not only insights into the life of an eminent mathematician, but also an accessible way to understand advanced and highly abstract concepts in mathematics and theoretical physics.
Have you heard of the “Woodstock of Physics?” Likely, some of you were there.

On March 18, 1987, at 7:30 pm, at the American Physical Society March Meeting in New York, over two thousand physicists hastily squeezed into what was clearly a very popular and special session. The program was over-stuffed, much like the room, with 51 speakers presenting their results past three in the morning. What topic could have caused such a frenzy?

High-temperature superconductors: materials that exhibit zero resistivity below a certain critical temperature, which can be high enough to be achieved by cooling with liquid nitrogen.

The discovery of high-temperature superconductors occurred only about a year before this March Meeting session, by Georg Bednorz and Alex Müller of IBM Zurich. And with this Nobel-prize-winning discovery, the field exploded. Teams of experimentalists searched for materials with higher and more easily achievable transition temperatures, while theorists sought to understand the underlying physics. The applications for materials with these properties are boundless, including high-efficiency electric power distribution and levitating trains. However, more than thirty years after their discovery, the physical mechanism for high-temperature superconductivity is still not understood. Today, this lack of comprehension stands as the main obstacle to developing high-temperature superconductors for practical use, where the biggest challenge is to raise the critical temperature.

We at Harvard are approaching these challenges from a new angle, and we are optimistic because we have a new set of tools that offer a unique perspective. In Professor Markus Greiner’s group, we have built a quantum simulator to model high-temperature superconductors. With neutral atoms cooled down to temperatures of just a few billionths of a degree above absolute zero, and precise manipulation of a dozen lasers to control these atoms, we model the quantum behavior of electrons in a solid. Moreover, we have a microscope to image every one of those atoms. This ability to control and probe single atoms opens up completely new possibilities to tackle the problem.

In a close collaboration with theorists working with Professors Eugene Demler of Harvard Physics and Michael Knaps of the Technical University of Munich, we have recently applied a pattern recognition algorithm to images of the atoms. In a second step, we used machine learning to decide which quantum theory describes the experimental data better. By developing new methods such as those to analyze the data in its entirety, we may achieve new insights into the longstanding question of high-temperature superconductivity.

But let’s start at the beginning. What are strongly correlated quantum systems and why are they so difficult to understand? A complete description of a single quantum mechanical particle is textbook physics, describing how interacting particles are much more challenging. In the same way, describing the flight path of a single bird is significantly easier than predicting the motion of every individual in an entire flock—knowing, of course, that this is an oversimplification.

A flock of birds sometimes seems to behave as a single entity that barely resembles its individual constituents. As a striking example, a flock does not turn as a whole, but instead its entire orientation changes as the front and back of the flock become the new flanks. While such complex behavior appears to be well-orchestrated by a central leader, in fact it emerges out of the interplay of many individual agents, each of which follows a simple set of rules. In the case of a flock of birds, there are three main rules: they avoid crowding their neighbors, they align with their neighbors, and they steer towards the average position of their neighbors.

In a way, the same is true of quantum many-body systems: each individual particle follows a set of rules prescribed by the system’s Hamiltonian. Through the interplay of many particles, fascinating phenomena can emerge, which cannot be predicted from the consideration of a single isolated particle.

In certain regimes, effective single-particle or "mean-field" descriptions are sufficient. In this approximation, only the average effect of all the other parts of the system on a given particle is considered. Such a description is particularly useful to describe effects that do not depend on the exact details of the system. For example, we do not need to know how every bird flies and interacts with other birds to know how the flock moves. This is akin to the great successes of statistical mechanics in deriving macroscopic properties from the microscopic.

We focus on regimes where particles are so strongly correlated with one another that mean-field descriptions are insufficient. The most famous of these systems are high-temperature superconductors. How, then, can we understand the mechanism behind high temperature superconductivity? The most direct approach is to make measurements on real materials that exhibit unconventional superconductivity. That’s how many important insights have been gained. However, these materials are very complex, and it is hard to capture all their properties. And it might not be necessary to get every detail right: it is widely believed that simpler models can capture all the interesting physics, too. One of those models—probably the simplest one—is the 2D Fermi-Hubbard Hamiltonian. Similar to the rules for the birds in a flock, it prescribes rules for the particles. At first glance, those rules are simple enough. The particles are fermions, which can never swap or down. They live on the sites of a two-dimensional square lattice. Two fermions with the same spin cannot occupy the same site. Apart from that, they gain energy of the order of the parameter $t$ when they hop from one site to another and experience an energy penalty given by the parameter $U$ if two fermions with opposite spin sit on the same site.

If the temperature of the system is lowered, the particles have to decrease their energy according to the same rules. Even though we know those rules, it doesn’t seem to be that complicated, it is surprisingly hard to predict the collective behavior that might emerge in this system. When there is one particle per site, each with spin up or spin down, a good way of minimizing the energy is—roughly speaking—to have alternating spins next to each other. This way, no energy penalty is paid, which is usually much bigger than the hopping parameter $t$, but the particles can still move around a bit by hopping on top of each other for a brief period of time. This state is known as an anti-ferromagnet. However, once we go away from this limit by removing particles from the system, there is no agreement on what the picture looks like anymore.

In 1982, before the discovery of high-temperature superconductivity, Richard Feynman proposed the concept of quantum simulation, using an actual quantum system to simulate the quantum model of interest. During the last two decades, tremendous progress has been made in the field of quantum simulation with a variety of platforms, including superconducting qubits, trapped ions, and ultracold atoms and molecules.

In fact, the idea of using ultracold atoms in optical lattices as a quantum simulator for high-temperature superconductors was first suggested at Harvard. In 2001, Professors Mikhail Lukin and Eugene Demler attended an Aspen conference that brought together physicists from condensed matter and atomic physics to find connections between the two fields. While waiting for a delayed flight at the airport, Lukin and Demler came up with the idea of studying the most difficult problems in condensed matter physics with the most sophisticated experimental tool of atomic physics. The first version of their paper on this subject was turned down by the referees on the ground that in atomic physics, one does not do experiments for which theory cannot make a definitive prediction. Fortunately, experimentalists in the field thought otherwise and were excited by the prospect of venturing into unknown territories. Since then, the idea of combining condensed matter physics and atomic physics has become mainstream.

In the Greiner group, we are turning this theoretical proposal into a reality. Our experiment cools neutral atoms down to 2 nanokelvin and holds them in a vacuum with an array of traps created with laser light. In this optical potential, atoms can tunnel between neighboring sites. Atoms with opposite spin, sitting more than one to a site, experience contact interactions—in short, they obey the rules stated by the Fermi-Hubbard Hamiltonian of condensed matter physics.

By using neutral atoms to simulate the electrons in real materials, we can work at time- and length-scales that are more accessible than in real materials. As a result, we enjoy a high degree of measurement and control over our system, while studying much of the same physics.

Our experiments go even beyond simulating the model of interest—they are quantum gas microscopes. This means that we can image the atoms with a resolution of a single site. Moreover, the measurements performed with a quantum gas microscope take into account one of the most intriguing properties of quantum systems: their ability to be in a superposition state. Loosely speaking, this means that different configurations of the particles on the lattice can be simultaneously present.
realized. The more function of the system contains the probability for all possible configurations, the number of which grows vastly with the size of the system. Every measurement with the quantum gas microscope provides a snapshot of this more function, picking out one configuration according to this probability distribution. Strikingly, this means that repeating the same experimental procedure multiple times will almost certainly lead to many different snapshots.

We achieved site-resolved imaging of fermions with lithium-6 in 2015. In the following year, we measured antiferromagnetic correlations over short distances, where a spin-up particle tends to have spin-down particles as neighbors and follow spin-up particles as next nearest neighbors. As we pushed to lower and lower temperatures, these antiferromagnetic correlations spread across the entire system. We had realized the antiferromagnet, a celebrated achievement in the community. At this point, we were perfectly set up to tackle some open questions, such as “What happens when we remove some particles from the system and thus introduce holes?”

Fabian Grusdt, then working with Eugene Demler, had been thinking about how to best describe a hole moving through an antiferromagnet since the advent of Fermi gas microscopy. This quantum impurity problem is at the heart of many strongly correlated quantum systems, laying bare an intriguing interplay of two key players: spin and charge degrees of freedom. It is hardly a new problem and has been studied extensively by the solid-state community, including the condensed matter theory groups at Harvard. Although they agreed on a starting point, through different approximations in the course of their individual analyses they arrived at different conclusions. But the prospect of new insights from quantum gas experiments raised a new perspective, and we began to resolve these conflicting theories. Drawing upon earlier work dating back to the 1960s, Fabian had developed the geometric string theory. In this theory, a hole moves through the lattice by displacing the spins along its way. While the location of the spins changes quickly, their quantum state does not adapt to this modified geometry. The hole motion therefore leaves behind a memory in the spin system, a so-called string. At one end of the string, the spinless excitation carrying the charge degree of freedom is found: the hole. At the opposite end, there is a charge-neutral spin excitation with a large effective mass: the spinon. In a nutshell, the geometric string theory describes how the hole moves around the heavy spinon, and how this motion is reflected in the surrounding spin environment. Much like a hyperactive dog on a leash, bound to its owner, the hole keeps returning to the spinon.

Along the path of the hole, all spins are displaced by one site. Their neighbors adjacent to the path, however, are not. This leads to the curious effect that an up spin suddenly finds itself to be neighboring another up spin, as opposed to a down spin. When enough holes move through the system, this effect is even visible in the average correlations over the entire system. If Fabian’s reasoning was right, some of the correlation functions should change their sign as soon as the density of holes reaches a certain value. When Fabian explained his theory to Postdoctoral fellow Daniel Greif, this statement really caught Daniel’s attention—he had seen such a sign change in their experimental measurements already! Two hours later, he checked the experimental data and confirmed the existence of a sign change, right around where Fabian had expected it.

Quantum gas microscope snapshots contain much more information beyond correlation functions between two sites, which calls for a new way of studying strongly correlated many-body systems. This motivation meshed perfectly with our desire to experimentally test the geometric string theory. Since this theory describes the quantum system in a supersposition state of string configurations, for certain quantities—like the correlations between neighboring sites—we can only see the effect of the string as an average over all possible string positions and arrangements. However, in every snapshot taken with a quantum gas microscope, only one string configuration is realized, suggesting that we may be able to find strings in individual snapshots.

So we set out to find signatures of the strings. The corresponding observables would not be as straightforward as the well-established conventional observables used in the field, such as spin correlators. Graduate students Annabelle Bohrdt and Christie Chiu developed a pattern recognition algorithm to extract string-like patterns from the images taken with the quantum gas microscope. Fairly quickly, we all realized that we would have to gather a substantial amount of data. At this point, Markus Greiner’s entire Fermi gas microscope team, which at the time consisted of Daniel, Christie, and graduate students Geoffrey Ji and Muqing Xu, put in a massive effort to take all of the data required for a thorough evaluation of the string pattern-based observables in order to see if they could be used to test different microscopic theories. Once we knew what parameters we needed, the entire dataset was collected in about two months’ time. It totaled over 30,000 snapshots, each of a different experimental realization.

Fabian made wallpapers to celebrate. Indeed, we found evidence for strings in the data. As we added more and more holes to the system, the number of string patterns we found increased. This was great news, because we expected each hole to cause a new string pattern. Moreover, the comparison to the geometric string theory showed excellent agreement without any fitting parameters. Looking for string patterns is just one way of extracting more information out of the wealth of data obtained in quantum gas microscopy. There might be other secrets in those snapshots, which we haven’t even thought about yet. In recent years, machine learning has developed as a powerful tool in data analysis. We are not yet afraid that our jobs might be taken away by machines, so we were happy to get some help from artificial intelligence: while we gave the machine access to all information, we did not specify which patterns to look for.

We trained a neural network to distinguish between two competing theories, a quantum spin liquid theory and the geometric string theory. Similar to recognizing cats or dogs in photographs, snapshots from each theory are fed into the neural network. The network parameters are then optimized to assign the right label to each snapshot—in this case they are “spin liquid” or “geometric strings” instead of “cat” or “dog.” After training, snapshots from the experiment are used as an input to the network, which has to label them as one of the two theories. In effect, the neural network decides which theory resembles the experiment more closely, based on a single snapshot at a time.

We found conceptually new ways of analyzing many-body systems using images obtained from quantum gas microscopy. We searched for patterns in quantum gas microscope images and found that they can give information beyond what one can learn from conventional correlation functions. As the result of our work, we have gained a more complete perspective on strongly correlated many-body systems, taking into account the entire richness of properties, rather than relying solely upon straightforward measurements of order parameters and correlation functions. It is similar to Rutherford’s scattering experiment—once detailed information is available from experiments, one cannot stick with something as simple as a plum pudding model. Our search for string patterns is just the first step in extracting more information out of quantum gas microscopy data. More complex structures are expected to appear when the temperature is lowered, or in dynamics experiments performed at higher energies.

We have many ideas for our next steps, but currently we are working to measure the dynamics of holes deterministically placed at a given location in an anti-ferromagnetic spin background. Under the microscope, after allowing the hole to propagate for some time, we can freeze out all dynamics and take a snapshot of the system. This allows us to gain new insights on how the hole propagates in a spin background. While this may only be a small step, we are optimistic that, through theory-experiment collaborations and combined efforts across many disciplines, we will solve the puzzle of high-temperature superconductivity.

FOR MORE INFORMATION, CHECK OUR PAPERS:
Seventy five years ago, in the chilly “cosmic-ray shed” that extended from the first floor of Lyman Laboratory, three physicists observed, for the first time, the gentle resonance of protons in a paraffin sample. Thus was born nuclear magnetic resonance (NMR), the basis of the astonishingly successful contemporary tool of medical MRI. The story of NMR is rich with human ingenuity, chance encounters, and good luck. Some of us had the wonderful good fortune to study with two of those, who generously shared their memories; and much of the history has been captured in the oral history archives of the American Institute of Physics.

FOCUS

Nuclear Magnetic Resonance:
Lyman Laboratory, December 1945

by Paul Horowitz

It was December 15, 1945 — exactly four months after Japan’s capitulation in the war in the Pacific — and Robert Pound, Edward Purcell, and Henry Torrey had been seeking the elusive resonance since the idea came up in a happenstance lunch while the three were wrapping up their work at the MIT Radiation Lab (the wartime radio project, energized by the British invention of the powerful cavity magnetron). Purcell asked, “Why couldn’t one do the Rabi-type of proton resonance in solids?” The resonance frequency in a given magnetic field was known from Rabi’s work with molecular beams at Columbia University, but the amount of time for the nuclear spins to equilibrate (what we now call “the spin-lattice relaxation time,” T1) was anyone’s guess. Their best guess was a few hours, during which the sample had to sit, undisturbed, in the magnetic field. As Pound described it, “Ed agreed to come in around seven in the morning on Saturday and turn the magnet on and let it cook until we would come in.”

They spent the rest of the day (as in the days before) in fruitless pursuit, slowly varying the magnet current through the expected value. But late in the day Pound suggested, in desperation, “why don’t we just turn the magnet all the way up?” And as we came down through 80 amperes it went bump. There it was.” They had expected it at 73 amperes, and had earlier swept nearly plus and minus 10 percent. They hadn’t miscalculated, they simply had not realized that the magnet was close to saturation; as Pound eloquently put it, “we were only off 2% in the calibration, which is pretty good for that kind of system [flip-coil plus galvanometer], but it took 19% more current to get that 2% more field.” Amazingly, their estimate of the relaxation was considerably more in error: as Purcell put it, “in the final time when the experiment was successful, I had been over here ... it must have been all day, running the magnet generator along so as to keep the field on for many hours, that being in our view a possible prerequisite for seeing the resonances. Now, it turned out later that in paraffin the relaxation time is actually 10^4 seconds. So I had the magnet on exactly 10^4 times longer than necessary!”

The field moved quickly after that: within a month Felix Bloch, William Hansen, and Martin Packard at Stanford University, not knowing of the Harvard work, succeeded in their NMR; and in Cambridge the arrival of Nicolaas Bloembergen advanced the theoretical underpinnings of NMR, most famously with their 34-page 1948 Phys. Rev. paper, “Relaxation Effects in Nuclear Magnetic Resonance Absorption” (one of the most-cited articles in physics, ever), familiarly known as “BPP” (Bloembergen, Pound, and Purcell). The “BPP Theory” addressed the effects of molecular motions in the NMR relaxation time and resonance width.

Fig. 1. NMR was first seen in this resonant cavity, filled with paraffin obtained from the First National Store on Purcell’s way to work. (Leftover wax in original box courtesy of Pound)
so we knew that paraffin had about the lowest electromagnetic absorption by ordinary dielectric laws, of anything going, you see. Paraffin was an extremely good dielectric, as we call it.” Following this “swords into plowshares” thread a bit further, a good case can be made that the wartime radar project spawned the post-war inventions of the transistor, molecular spectroscopy, and the maser/laser; see, for example, Robert Buderi’s The Invention That Changed The World (Touchstone, 1996) and Peter Galison’s Image and Logic (Univ. of Chicago, 1997); Chapter 4 of the latter is titled “Laboratory War: Radar Philosophy and the Los Alamos Man,” while the former follows the MIT Rad Lab radar project’s influence on post-war science and technology.

5. The same magnet used in Street and Stevenson’s 1937 confirmation Phys. Rev., 52, 9, 1003).

We like to think of the NMR as a Harvard Physics discovery; but it could have been an MIT discovery, Purcell remarked, were it not for the fact that “I tried to borrow a magnet down at MIT and did not succeed. That’s why we had to come back and do it here. We would have done it there if somebody had given us (a magnet).” And MIT might have another claim, because the discovery was made while they were moonlighting from their official employment at MIT (documenting their microwave technology in the legendary 28-volume “Rad Lab Series”). In fact, much of the apparatus was leftover radar gear. Happily, it was Curry Street’s cosmic-ray magnet5 that was available, and the rest is history (as was the elevation of Pound and Purcell to professorships in our department).

NMR matured rapidly — with improved resolution it became a standard tool of analytical chemistry and structural biology; revealing the local molecular environments through “chemical shifts.” But perhaps the application with the most impact was the development, beginning in the 1970s, of MRI5. This remarkable non-ionizing medical diagnostic tool produces stunning three-dimensional images, enhanced by contrast mechanisms that exploit proton density and differences in relaxation times to reveal subtle details of soft tissue. More than a billion scans have been performed, and it is no exaggeration to say that more than a million lives have been saved by MRI.

Quite apart from the satisfaction that the discoverers must have felt from those practical applications of NMR, the discovery itself was something very special. As Purcell put it in his 1952 Nobel lecture, “I have not yet lost a feeling of wonder, and of delight, that this delicate motion should reside in all the ordinary things around us, revealing itself only to him who looks for it. I remember, in the winter of our first experiments, just seven years ago, looking on snow with new eyes. There the snow lay around my doorstep — great heaps of protons quietly precessing in the Earth’s magnetic field. To see the world for a moment as something rich and strange is the private reward of many a discovery.”

With Thanks:

The author wishes to thank the Harvard University Archives, the Collection of Historical Scientific Instruments, Gerald Holton, Peter Galison, and Marina Werbeloff for assistance. On a personal note, I am forever grateful for the education I received in the footsteps of Bob Pound and Ed Purcell. Their contribution to human welfare was brought home to me memorably this year, as I succumbed to a bout of severe spinal stenosis (vividly imaged by Figure 3’s MRI, which informed a successful surgical intervention). It was an honor to know these fine gentlemen.

References:

1. Oddly, though, not a single photograph of the experiment seems to exist — a stunning contrast with our over-photographed world of today.


3. Bloch and Purcell, respective leaders of the two groups, shared the 1952 Nobel Prize in Physics. Bloch invited the Harvard group to join in a patent, but Purcell declined, evidently feeling that fundamental discoveries in physics should be openly shared. The Stanford group filed their patent application on December 23, 1946, one day short of a year after the Harvard group’s paper had been received at The Physical Review.

4. Prefaced with “The tremendous research and development effort that went into the development of radar and related technologies during World War II resulted not only in hundreds of radar sets for military (and some for possible peacetime) use, but also in a great body of information and new techniques in the electronics and high-frequency fields. Because this basic material may be of great value to science and engineering, it seemed most important to publish it as soon as security permitted.” It is undisputable that their application with the most impact was the development, beginning in the 1970s, of MRI. This remarkable non-ionizing medical diagnostic tool produces stunning three-dimensional images, enhanced by contrast mechanisms that exploit proton density and differences in relaxation times to reveal subtle details of soft tissue. More than a billion scans have been performed, and it is no exaggeration to say that more than a million lives have been saved by MRI.

5. Unanticipated even by NMR’s inventors; in the Foreword to Magnetic Resonance Imaging (Partain et al., Saunders, 1988) Purcell wrote: “NMR imaging is so powerful, so general, and at the same time so gentle a diagnostic procedure that it is likely to become part of most people’s experience. That seems obvious now, even to an antiquated NMR expert like myself who did not foresee it.”
Mara Prentiss: SOLVING PROBLEMS IN BIOLOGY THROUGH PHYSICS AND INGENUITY

by Steve Nadis

Mara Prentiss, the Mallinckrodt Professor of Physics, is not shy about building things, be it new devices, new experimental techniques, or new solutions. Her father was a carpenter, her grandfather a gardener, and as a child growing up in Cleveland, Prentiss was encouraged to work with tools, making use of whatever materials were available to her. When she was a teenager, she built a library in back of the family house, doing all of the carpentry and even digging a ditch more than four feet deep, as required by local building codes. The passion to design things, which Prentiss believes she inherited from her father, has carried through into her successful and unconventional career in physics.

After receiving a Ph.D. in physics from MIT in 1986, Prentiss took her first job at AT&T Bell Laboratories where she worked under the direction of the future Physics Nobel laureate, Steven Chu. At the time, Chu was developing methods for using laser light to slow down a beam of atoms, which would, among other benefits, give researchers more time for their measurements. “Light carries momentum,” Prentiss explains, “so if an atom ‘grabs’ the light, it gets pushed back and will slow down.” Chu’s approach was more sophisticated than that, as he’d devised a trap that worked by drawing atoms that interacted with light toward places where the light was brightest—places where the laser beam was, in fact, focused to less than a micron in diameter. The main problem with the trap was that it heated the atoms, which would speed them up, so the light had to be turned off intermittently to let the atoms cool and then turned back on again, off again, and so forth.

At a July 1986 conference in Helsinki, the French physicist Jean Dalibard suggested a different way of confining atoms that wouldn’t heat them up, using magnetic fields in place of lasers to push atoms toward the center of the trap. Hence the notion of a “magneto-optical trap” was born. The MIT physicist David Pritchard, who also participated in the Helsinki conference, did some calculations with his then student, Eric Raab, showing that Dalibard’s idea could work. Pritchard contacted Chu, whose lab was well equipped to test out a magneto-optical trap. “But Steve was located in Japan at the time, so it fell to me and Alex Cable, who was a Bell Labs technician at the time, to give it a try,” Prentiss says. She and Cable succeeded in making the first-ever magneto-optical trap. “It took a lot to make that happen,” she notes, “but after some fudging it worked—quite well, in fact, confining atoms for seconds instead of milliseconds. And that was transforming from the standpoint of scientific research.” The paper she coauthored with Cable, Chu, Pritchard, and Raab, “Trapping of Neutral Sodium Atoms with Radiation Pressure,” appeared in a 1987 volume of Physical Review Letters—one year after Prentiss began a professional career that had clearly gotten off to a fast start.

Prentiss joined Harvard’s physics faculty in 1991 and, four years later, became the second woman in the department (after Melissa Franklin) to receive tenure. Initially, she continued her work in “atom lithography,” which involves harnessing light to control and manipulate atoms. She and her colleagues have used this approach, for instance, to engrave circuitry in silicon chips to very high precision.

Soon after arriving at Harvard, she explored a new avenue, guiding atoms with magnetic fields in a manner similar to the way fiber optic cables transmit light. These atomic wave guides could have various applications as research tools and perhaps in navigation. Prentiss looked, for instance, into making a kind of gyroscope that could measure rotation. To get an idea of how this might work, imagine a beam of sodium atoms that’s shot at a circular merry-go-round. If the object is stationary, the atoms will meet exactly halfway (180 degrees) around from where they started, but if the object is rotating, the atoms will meet somewhat off-center. The rotation can be assessed by determining the exact location of the rendezvous point or the time delay between the beams’ arrivals at the 180-degree point.

Prentiss did not continue this work long enough to build a functioning gyroscope but did demonstrate some key elements: she could take a group of atoms traveling in a pack, change the magnetic field so that they split apart and then change the magnetic field to bring them back together. That was a big advance in itself. She also showed that she could direct atoms down specific paths, as if they were following a fiber, and guide them over substantial distances. Prentiss might have carried these ideas much further had her career not veered off, sometime in the early-to-mid-1990s, in an entirely different direction—toward problems biological in nature. The transition, she says, happened rather generally as a result of a couple of things coming together. One motivating factor grew from her desire to give undergraduates more research opportunities, but experiments in atomic physics were quite expensive in those days and the instrumentation was delicate and easily broken. That prompted her to make inexpensive but effective “optical tweezers”—devices that use light to trap cell-sized particles and hold them still. She came up with a way to build such a device, cheaply and simply, for about $1000—something students could do themselves—and she then started to consider the kind of measurements that might be made.

Around the same time, she crossed paths with the eminent Harvard chemist George Whitesides. That came about after Prentiss asked a question to a Cornell researcher who told her Whitesides was the person she should be talking to. She and Whitesides began...
“The teaching world in general is moving toward more hands-on experiences. At the same time, students are coming here with much less mechanical knowledge than they did 20 years ago, perhaps owing to a shift in culture and all the time spent on screens. We’re trying to address that in the instructional labs and machine shops.”

Collaborating around 1995, coauthoring roughly 20 papers over the next two decades. Whitesides was particularly intrigued by the potential for optical tweezers, pointing out that a lot of interesting research in biology was impeded by the fact that biological materials often tended to stick together; perhaps the tweezers could pull them apart. In an early collaboration, the Prentiss and Whitesides groups studied the adhesion of E. coli bacteria to man-made surfaces, using optical tweezers to measure the strength of adhesion.

“George has been a great mentor, and the first project we did together opened up a whole new area for me,” Prentiss notes. Whitesides told her, early on, that “physicists often make incredibly precise measurements of completely uninteresting quantities.” The second bit of advice he passed on to her was this: “Don’t give me an equation for something I already know.”

Sometime around 2000, Prentiss got on a project initiated by Whitesides concerning urinary tract infections. He wanted to figure out how uropathogenic (E. coli) bacteria find the urinary tract and how the infection progresses. It was generally known that the bacteria look for places with lots of sugar, their preferred food, but beyond that the details were murky. Whitesides realized from his previous work with Prentiss that an experiment involving optical tweezers could clarify the picture.

He proceeded a strain of bacteria (isolated from patients with acute pyelonephritis) and a form of urinary tract infection) from researchers at Massachusetts General Hospital. He and Prentiss then created surfaces with varying concentrations of the sugar that the bacteria attached themselves to. The next step was to pull the bacteria off the surfaces with tweezers while determining the amount of force required to do so. That measurement was of keen interest because the strength of adhesion of microorganisms to biological surfaces often correlates with pathogenicity. Blocking adhesion or weakening it, conversely, could be an effective strategy for limiting the onset of disease.

“We found that the force required to separate the bacteria from the sugar-coated surfaces was quantized,” Prentiss explains. At low sugar concentrations, they could pull off the bacteria with a force of, say, two piconewtons whereas at higher concentrations, exactly twice as much force (four piconewtons) was required. The explanation for this was fairly straightforward: The bacteria have hundreds of feet, each with two “binding sites” that act like grabbers. Each grabber can hold one sugar molecule. If only one grabber out of the pair is able to latch on in places where sugar is sparse, the bacteria come off almost immediately. In denser sucrose regions, both grabbers can latch on, which gives the other legs a chance to latch on as well. In places where the bacteria do stick, people will get infected—a process that optical tweezers helped shed light on.

Prentiss has also forged a long and fruitful partnership with Harvard biologist Nancy Kleckner. “Nancy is a creative person who, like George, tends to think outside of the box. That’s why she’s open to working with physicists and why she brings me problems she hasn’t been able to solve solely with biological methods—a practice that many biologists don’t seem to be comfortable with.”

She and Kleckner looked, for instance, at the motions of chromosomes in cells, which were commonly assumed to be thermally generated. They discovered—reported with two other colleagues in a 2008 paper in the Journal of Cell Science—that the chromosomes were attached to the wall of the cell’s nucleus that was being pulled, in turn, by the protein actin. The chromosomes’ motions, in other words, were not random but were instead the result of prentiss moving them.

In another study—published in the Biophysical Journal in 2010 (again with two other colleagues)—Prentiss and Kleckner investigated the shape of chromosomes in E. coli bacteria. The prevailing view held that the chromosomes were somewhat formless, lacking a clear-cut geometry, but Prentiss and Kleckner found that they had, in fact, a distinct helical structure. “By bringing physics into biology,” Prentiss says, “I’ve been able to answer some of Nancy’s questions, and that’s been very satisfying for me.”

After getting her start in biology-based problems with Whitesides and Kleckner, Prentiss has continued this line of inquiry with physicists in her own lab where the study of RecA protein has been a major focus over the past decade. One of RecA’s principal functions is the repair and maintenance of DNA, and Prentiss and her colleagues have gained insight into how those tasks are carried out. Her team has put forth explanations for how RecA quickly searches DNA to find a place where the double strand is broken and how it then inserts itself into that spot, removing the broken portions of genetic material and replacing them with the correct sequences.

Understanding this procedure is of critical importance because cancers can arise when RecA malfunctions.

Prentiss has many responsibilities in the department in addition to her main research. Since the fall of 2018, she’s served as the Director of Graduate Studies, working closely with Co-Director Jacob Barandes and Graduate Program Administrator Lisa Cacciabaudo. The program has been growing rapidly, from about 130 Ph.D. students in 2000 to about 240 at present, bringing physics the largest graduate program within the Faculty of Arts and Sciences division at Harvard. With the increased number of students, Prentiss says, “comes more special cases and challenges. I like helping people, which is why I went into teaching in the first place, and this position gives me even more opportunities to do that.”

In her helping capacity, Prentiss has spent more than a decade overseeing the operation of the department’s machine shops, which have been superbly run by Stan Cotreau since 1993. She’s also headed the Instructional Physics Labs over the past five or so years. “The teaching world in general is moving toward more hands-on experiences,” Prentiss says. “At the same time, students are coming here with much less mechanical knowledge than they did 20 years ago, perhaps owing to a shift in culture and all the time spent on screens. We’re trying to address that in the instructional labs and machine shops.”
Neutrinos are the least understood particles of the Standard Model, despite being the most abundant constituent of matter in the universe. The discovery that neutrinos oscillate, or shift forms, between three “flavors” (electron, muon, and tau) represented a paradigm shift, implying that neutrinos have mass—a possibility that was forbidden in the earliest versions of the Standard Model. This discovery posed a significant challenge to theorists, while providing a strong indication that neutrinos are peculiar. Since then, neutrino oscillations have been closely investigated to yield a reasonably good picture of the phenomena. Pursuing higher precision studies of neutrino oscillations could furnish important clues regarding physics beyond the Standard Model.

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**MicroBooNE**

The MicroBooNE experiment was proposed for three main reasons. First, to investigate a puzzling anomaly observed by the previous Liquid Scintillator Neutrino Detector (LSND) and MiniBooNE experiments, which both found curious excesses above predicted values in the number of neutrinos of a certain flavor. These excesses were not significant enough to be considered a discovery, but they intrigued the scientific community nevertheless. The most exciting hypothesis put forth to explain these puzzling excesses was the presence of a new exotic particle, the sterile neutrino, which would not interact with regular matter but could still be observed via neutrino oscillations. In this case, the beam of neutrinos would mostly produce muon neutrinos, which would eventually transform into the other two flavors. However, if sterile neutrinos exist, it’s possible that these neutrinos will transform into sterile neutrinos, which in turn will transform into electron neutrinos, producing an excess of electron neutrinos in the detectors well above expected levels. If such an excess were confirmed, it would be the first discovery of physics beyond the Standard Model as sterile neutrinos are not incorporated in that model. And even if MicroBooNE fails short of that discovery, the experiment is still advancing our understanding of how neutrino interactions work.

In recent years, it has become apparent that neutrino interactions with heavy nuclei targets (required to increase the neutrino interaction rates) are far more complex than previously thought. Current theoretical nuclear models cannot successfully describe the experimental data, especially as the precision of that data has steadily increased. However, MicroBooNE’s high-resolution detector could shed light on this issue due to its exquisite capabilities for imaging neutrino interactions. Yet another goal of MicroBooNE has been to demonstrate that it is possible to construct complex detectors on such a large scale and operate them successfully. Since the detectors needed to address the questions currently facing our field will need to be about 450 times bigger than MicroBooNE’s detector, it is essential that we test the viability of these ambitious devices.

Since first joining the MicroBooNE project in late 2010, Guenette led the design and construction of the experiment’s time projection chamber. The 170-ton MicroBooNE detector was constructed, assembled, and commissioned, taking its first neutrino data in the Booster Neutrino Beam at Fermilab in October 2015. After working on understanding the new detector, Guenette and her graduate student, Marco Del Tutto, focused on studying neutrino interactions with an argon target. They have obtained the first “double-differential” measurements of this sort in the low-GeV range, determining both the energy and angle of all the particles involved in this interaction. This work, comprising the first high-impact physics result from the MicroBooNE collaboration, has been described in a paper just submitted to Physical Review Letters.

More recently, Guenette’s team has been focusing on MicroBooNE’s primary mission, which is to continue the search for an excess of neutrino events. Drawing at first upon a small data set, they established the soundness of their analytic approach and presented their preliminary results in the summer of 2018. The team members hope to present the results of their analysis of the full data set by the end of 2019.

**DUNE**

Guenette and a few members of her group are also heavily involved in the design of the most ambitious neutrino experiment ever attempted, DUNE, which is currently in the prototype stage. This long-baseline experiment, shown in Figure 3, will detect neutrinos from the world’s most powerful neutrino beam to study the change of flavor, or oscillations, during the 1300-kilometer journey between the source and the detectors. Four very large liquid argon detectors (10 kilotons of argon each), located 1.4 kilometers underground, will observe neutrinos with unprecedented sensitivity. In addition to studying neutrino oscillations to search for CP violation, DUNE will be ready and waiting in the event of a rare galactic supernova explosion, where thousands of neutrinos could be observed, potentially shedding light on poorly understood supernova neutrinos. From these ubiquitous and elusive particles that appear to harbor the potential of a new exotic particle, the sterile neutrino, which would double beta decays—a kind of radioactive decay in which two neutrons are transformed into two protons, or two protons into two neutrons, and only electrons (but no neutrinos) are emitted. Observing this peculiar decay process, which would occur without the release of neutrinos, is currently the only known experimental strategy that could reveal the true nature of neutrinos. It could tell us, specifically, whether neutrinos are “Dirac particles,” which are different from their antiparticles, or Majorana particles, which are their own antiparticles. Unambiguous evidence of neutrinoless beta decay would essentially constitute proof of the existence of Majorana neutrinos.

Using a different version of a noble element time projection chamber, the Neutrino Experiment with a Xenon TPC (NEXT) collaboration is hunting for Majorana neutrinos from double beta decays of xenon nuclei. The high-pressure gas time projection chamber offers the energy resolution needed to identify the sought-after decay, as well as a unique and powerful ability to determine the “topology” or shape of all events, which can clearly identify the signature of neutrinoless double beta decay. Based on recent results from the NEXT collaboration, this technology appears to be very promising and is being proposed for a next generation ton-scale detector that would be even bigger than any used in double beta decay searches before.

Guenette’s group is working on two aspects of the NEXT experiment. The first consists of analyzing data from their already running prototype, NEXT-White. The second task they’re pursuing involves the development of new detector technology with enhanced performance—namely better background control, energy resolution, and scalability. Given that several limitations were identified in the prototype design, it is essential to develop new technical solutions before proceeding to build a ton-scale detector. Guenette’s group is planning to develop a new readout plane for detecting charged particles. This device will be made only of low-radioactivity photon detectors that can still provide the excellent energy resolution required while offering the same imaging capabilities to efficiently screen out background signals. This research and development project, which is aimed at significantly improving detector performances, could offer the perfect solution for the next-generation detector.

**Summary and conclusions**

Understanding neutrinos is, without a doubt, a high priority for the scientific community, and it’s surely one of the top priorities in the nuclear and particle physics program of the United States. By investigating the different properties of neutrinos, Guenette’s group is charting out uncharted territories in particle physics, and any of these research avenues could potentially lead to transformative discoveries. By pushing ahead with state-of-the-art detection techniques, this group is working hard to extract as much information as possible from these ubiquitous and elusive particles that appear to harbor many of nature’s most important and closely held secrets.
Roxanne Guenette: A Short Jaunt for Neutrinos, a Giant Leap for Science?

It’s a long journey from the hardscrabble Quebecois town of Mont-Saint-Michel to Harvard University—about 460 miles by car though much farther in terms of the cultural differences.

Assistant Professor of Physics Roxanne Guenette grew up in that remote rural outpost, where winters are harsh and few thoughts are expended on something as ethereal as higher education. Her father is a carpenter, and her three brothers followed closely in his footsteps. No one in Guenette’s extended family has gone to college except for an aunt who worked her way through community college while helping her mother take care of eight younger siblings.

A main childhood outlet for Guenette and her brothers was the quarter-mile-long racetrack her father created in a field near their home. When she was 12 and the boys even younger, they started driving beat-up cars around the track. Bigger races were sometimes held before hundreds of spectators, and Guenette worked at these events in what constituted her first official job.

Yet she had more ambitious plans, resolving in high school to study science in college and choosing the University of Montreal simply because she wouldn’t have to speak English there. Although she received some scholarship money, she also got key financial assistance from a generous aunt, which enabled Guenette to realize her academic dreams.

One thing rural Quebec had afforded her was spectacular, star-filled skies, along with the occasional meteor shower and aurora—and by Steve Nadis

Harvard Quantum Initiative in Science and Engineering (HQI)

Its strategic direction and programming priorities are shaped by an Executive Committee of faculty in Physics, Chemistry, Applied Physics, Electrical Engineering, and Computer Science. HQI is foremost a community of researchers, drawn from a wide array of disciplines and subfields, with an intense interest in advancing the science and engineering of quantum systems and their applications. Its mission is to help scientists and engineers explore new ways to transform quantum theory into useful systems and devices. HQI has grown out of Harvard’s extraordinary scientific community and builds on a rich legacy of research conducted here that was pivotal in revealing the laws of physics that govern the behavior of atoms and molecules. Today, HQI brings together scientists and engineers across diverse sectors to leverage quantum effects such as superposition and entanglement in ways that will profoundly impact how information is acquired, stored, sent, and processed.

HQI’s priorities include the recruitment and development of faculty focused on both the science and engineering aspects of quantum systems, the development of an innovative education program and interdisciplinary research program, and the formation of a “quantum ecosystem,” centered at Harvard, that will bring together scientists and engineers in quantum information science, nanotechnology, electrical and mechanical engineering, computation and mathematics, and will link universities, industry, and government labs. Current programs include the HQI Prize Postdoctoral Fellowship, that welcomed its first class of fellows in Fall 2019; the weekly Joint Quantum Seminar series, co-sponsored by HQI, the Max Planck-Harvard Research Center for Quantum Optics (MPHQ), and the Institute for Theoretical Atomic, Molecular, and Optical Physics (ITAMP), which features speakers whose work is of particular interest to theoretical and experimental physics, applied physics, and engineering groups working in quantum-related research; and a seed funding program to support pioneering QSE research at Harvard. To stay abreast of HQI’s activities, please visit www.quantum.harvard.edu.
That won’t happen overnight and therefore has to be regarded as more of a long-term goal. Part of the E&I committee’s focus in the short run has been to draft a yet-to-be-released code of conduct that spells out the kind of behaviors that are expected within the department and those that won’t be tolerated, while at the same time increasing the diversity of students, researchers, faculty, and staff, while at the same time promoting the academic and professional advancement of all parties concerned, is an essential though formidable challenge—not only for the Harvard Physics Department but for most physics departments throughout the country. National statistics show that underrepresented minorities (including African Americans, Hispanic Americans, and Native Americans) collectively earned only about 13 percent of all Bachelor degrees granted in physics in 2017 and about 8 percent of the Ph.D. degrees.

Harvard is hoping to boost those numbers within the Physics Department, as well as to enhance the culture and overall climate, through an Equity and Inclusion (E&I) initiative started in early 2018 that’s charged with augmenting the department’s diversity and cultivating a more equitable and inclusive environment for all community members. “The E&I Committee is composed of three subcommittees: Recruitment and Access, headed by third-year graduate student LaNell Williams; Retention and Success, headed by third-year graduate student Cari Cesaretti; and Assessment and Tracking, headed by Donner Professor of Science John Huth.

At the moment, says Williams, “Harvard Physics, like most predominantly white institutions, doesn’t fare well in terms of the number of underrepresented minorities.” As of this writing, there are just five Black/African American graduate students making up just 2 percent of the department total, along with a comparable number of non-white Hispanic students—a stark illustration in itself that much more needs to be done. “It’s not simply a matter of increasing the number of minority students,” Williams affirms. “We also have to ensure the well-being of those students once they get here.”

By establishing the E&I program, Harvard has acknowledged the importance of this issue, which, she notes, “is a step that many departments across the country have yet to take. And we have started to have conversations. But conversations alone will not be enough.” While there are people within the department who truly care about improving diversity and equity, Williams adds, “much of the acknowledgement and commitment needs to come from the people most able to make the needed changes—people in positions of privilege and power.”

As the leader of the retention subcommittee, Cesaretti has to grapple with issues like the following: “Just because someone has been accepted into this school doesn’t mean the atmosphere and environment is presently set up in a way that affords them the best chance to succeed.” Therefore, she says, “it’s crucial to maintain an environment where everyone feels welcome and supported.”

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Fostering Community In The Pursuit Of A Common Goal — Physics

Physics at Harvard is a pretty big enterprise, involving well over 400 students (graduate and undergraduate), nearly 300 postdoctoral fellows and other research scholars, more than 60 faculty, and about 35 staff members.

It’s safe to assume that everything works better—in terms of research, scientific advances, learning, and the communication of knowledge—when people are getting along with one another and are reasonably content. Achieving that is, of course, a tall order, but the department is trying in a number of ways—some lighthearted in nature, like the annual fall pumpkin drop (a 16-foot plunge from an open window of Jefferson 450), and others of significantly greater gravity (though still subject to the same 9.8 meters per second squared gravitational acceleration). Here’s a brief look at some of the initiatives underway aimed at building and strengthening a sense of community, starting with the weightiest and proceeding to outings that are designed mainly for fun while still serving important purposes.

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“What needs to happen for principles of Equity and Inclusion to gain widespread support, Cesarotti adds, “is for people to come to understand that there is merit in diversity, merit in having different ways of thinking—recognizing that everyone doesn’t have to fit the same template of what has traditionally been considered successful.”

Events like this and the foregoing can clearly offer benefits as well as boost spirits among participants. And there certainly are things to cheer about. Admittance numbers have gone up in the department so that women now make up roughly 40 percent of the graduate student body, according to Cesarotti. Nevertheless, she and others still recognize that the inclusion of women in physics—at Harvard and beyond—is at different stages for Asian and white women than it is for non-white Hispanic and black women. Therefore, Cesarotti points out, increasing the representation of women in the department is not a uniform measure that can, in itself, address all long held disparities at once.

On a separate front, Williams has cofounded (with Lavontria Miché Huth is not alone in welcoming the news. “There’s hope in the long run,” he says, “provided we keep working on these issues, steadfastly and diligently, over the years.”

In the meantime, there are a variety of parallel efforts going on in the department. Cesarotti, for example, is a member of the Women in Physics (WIP) group, which holds monthly dinners and runs occasional book group discussions. In the spring, as part of Harvard’s academic fair known as Advising Fortnight, graduate students led interest undergraduates on physics lab tours and discussions of theoretical research. After going to physics conferences in which more than 90 percent of the participants are male, Cesarotti really looks forward to the WIP dinners. “It’s nice to go into a room where everyone is a woman and a physicist,” she says, “and where you can always find a sympathetic and empathetic ear.”

In May 2019, 30 female graduate students and postdocs from the Harvard physics, applied physics, and astronomy departments spent three days on a professional development retreat in Cape Cod during which they honed their writing, negotiation, and communication skills. The retreat was sponsored by the Heising-Simons Foundation (HSF) and organized by Professor Jenny Hoffman, who serves on HSF’s Physics and Astronomy Leadership Council. Participants of the Retreat for Women in Physics and Astronomy at Harvard, May 2019

Earlier this year (in February 2019), Williams and Delilah Gates, a fifth-year graduate student, ran a Black History Month movie series. “We did this informally in 2018, and since people liked it so much, we brought it back this year with funding from the Physics Graduate Student Council,” says Gates, who picked this year’s movies—Get Out, BlacKkKlansman, The Tuskegee Airmen, and Black Panther—and arranged for the food. Things went well enough that she plans to organize a film series next year too.

The movies, which are open to and attended by students of all racial and ethnic backgrounds, are followed by a discussion. “There’s often a feeling people have that if you’re going to talk about race, they might worry that they don’t know enough to attend and participate,” Gates says. “But the movies provide a good jumping-off point, allowing people to see how the struggles one group has faced might be similar to struggles their own group has gone through. It makes you appreciate how connected we all are.”

With support from the Heising-Simons Foundation, the program provided free travel, lodging, and meals to the 20 students accepted to the October event out of 150 applicants. Williams is now trying to help other universities hold similar workshops to benefit underrepresented women in physics and redress the aforementioned Ph.D. imbalance.

Another thing the department does to build community is to put all first-year graduate student offices together in the so-called G1 area. “Having the offices together is a wonderful idea,” Gates says. “People in my cohort got to know each other early on and many of us have become close. Some of us have ended up living together in off-campus houses, and a few of my classmates have played Dungeons and Dragons together for years straight. We also come to learn about broader areas of physics than if we only interacted with students in our research subgroups.”
Apart from these social gatherings, the PGSC carries out the aforementioned climate survey and a mental health survey that started in 2018. Seventy-six percent of the students responded to the latter survey; according to third-year graduate student Zoe Zhu who is overseeing this effort with another graduate student Jonathan Haefner, “We want to increase awareness of mental health issues among graduate students and provide a channel for people experiencing problems,” says Zhu. “Resources exist and all they need to do is ask for help.”

The survey has shown, for instance, that depression among physics graduate students is not better or worse than in other departments, though women in physics tend to be much lonelier than men. The survey also revealed that most students are not exercising enough, so the plan is to introduce team sports within the department both to forge new ties within the community and to improve physical and mental well-being. There’s also a plan to introduce graduate-only seminars soon, possibly as early as this fall, to build confidence among inexperienced presenters and make students more comfortable speaking up in group settings.

Meanwhile, there are journal clubs in various fields of physics where graduate students get to introduce papers written by others in the field. “It’s good practice for the presenters and also for audience members who get to learn about new research,” says Zeys Hao, a third-year graduate student who regularly attends the weekly sessions of the condensed matter journal club. The high-energy theory journal club meets once a week too. “It’s a non-threatening environment,” comments fifth-year graduate student Scott Collin. “One of the best parts about being at Harvard is having the chance to interact with so many excellent students. We really learn a lot from each other.”

There are some events intended for the entire department—undergraduates, graduate students, postdocs, fellows, faculty, and staff—that hundreds of people typically attend, including the annual physics barbeque held in September and the winter party held in December. Everyone is also welcome for the tea times that precede the weekly physics colloquia.

The faculty typically hold meetings every Monday, eating lunch together beforehand. About nine times a year, undergraduates and graduate students join in during the lunch hour, which allows them to talk with professors in a casual setting. Director of Administration Annie Truitt also meets with graduate students on a regular basis for lunch at the Harvard Faculty Club—in this way reaching out to students who might not otherwise have much occasion to come to the department’s staff offices. In a recently introduced program, a professor will periodically meet with the staff to give informal talks on the physics topics they specialize in. “In response to the first two ‘Let’s Talk Physics’ events has been really enthusiastic,” says Mary McCarthy, associate director of administration. “These introductory physics lectures foster an inclusive vibe and support a deeper understanding of the research going on around us.”

Faculty and staff also get together in annual gatherings organized by Professor Commun Fys, who especially enjoys meeting the families of his colleagues and coworkers—something that’s not possible in the course of a normal business day. “There’s always great food and fun games,” says Atlantic Davis, Administrator to the Department Chair. “Events like this are good for the department and also good for the families.”

David manages the undergraduate program in the Physics and Chem/Phys concentrations and teaches undergraduate courses (most recently, 15A: Introductory Mechanics and Relativity, and 125: Widely Applied Physics). He has channeled his formidable expertise as an educator and his deep knowledge of the subject into several very popular physics textbooks, including Introduction to Classical Mechanics. He has also co-authored the 3rd edition of Ed Purcell’s classic Electricity and Magnetism and, most recently, published a book of mathematical puzzles, The Green-Eyed Dragons and Other Mathematical Monsters.

In recognition of their outstanding contributions and generous dedication to our undergraduate concentrations and graduate students, Dr. David Morin and Dr. Jacob Barandes have been named as Co-Directors of Undergraduate and Graduate Studies, respectively, in May 2019. David was also promoted to the rank of Senior Lecturer.

The two Co-Directors both graduated from the Harvard Physics program in high-energy theory. David defended his Ph.D. in 1996 (advisor: Howard Georgi), Jacob in 2011 (advisor: Frederick Denef). The pull of Harvard Physics remained so strong on both that they stayed after graduation and now devote their attention to teaching physics classes, running our department’s academic programs, and engaging in scholarly pursuits.

While there is still a need for greater connectivity and inclusion, the Department is demonstrating a strong commitment to making the pull of Harvard Physics remain strong on both that they stayed after graduation and now devote their attention to teaching physics classes, running our department’s academic programs, and engaging in scholarly pursuits.

Jacob oversees the Department of Physics graduate program and admissions process, and considers it one of his most important duties to provide empathetic guidance to students working through various challenges of graduate school. As the Director of Graduate Studies for the FAS Science, he works across the graduate programs that make up Harvard’s Division of Science on admissions, best practices, and finances.

Jacob also teaches graduate classes: Physics 232: Advanced Classical Electromagnetics; 245: General Theory of Relativity; and 302A: Teaching and Communicating Physics, a required course that offers new graduate students practical advice and hands-on experience in becoming teachers. In addition, as of Fall 2019, Jacob’s innovative course Physics 19: Introduction to Theoretical Physics (previously Physics S–10 and Physics 101), has been made part of the freshman sequence for aspiring undergraduate physics concentrators. This introductory course covers a wide set of first-principles and foundational topics for theoretical physics, and it is intended to give a broad preview of more advanced physics courses. Jacob is currently finishing a book based on this course and also working on papers exploring several topics at the nexus of physics and philosophy.

David and Jacob have been honored with Prizes for Excellence in Teaching by the undergraduate members of Alpha Iota, the Harvard College chapter of the Phi Beta Kappa Society, and both feature frequently on the list of Derek Bok Center’s Excellence in Teaching awardees. “Best professor ever” is a persistent refrain in their course evaluations.
The Society of Physics Students (SPS) was active again last year with many events, including the ever-popular pumpkin drop and a vibrant liquid nitrogen ice cream party. Numerous social events were held in the Undergraduate Study (Jefferson 251), ranging from a welcome event for first-year students to a dinner following the senior picture. Carol Davis, the Undergraduate Student Coordinator, maintains the Study as an inviting space for concentrators to gather, which often entails stocking it with treats. On the more academic side, the SPS helped organize the annual Harvard-MIT SPS Research Conference and held a panel on grad schools hosted by graduating seniors. In recognition of its efforts, Harvard’s SPS chapter was presented with an Outstanding Chapter award by the National SPS Council.

This past summer, Samuel conducted research at Cambridge University in England through the Harvard-Cambridge Summer Fellowship. Working in the lab of Professor Michele Vendruscolo at the Centre for Misfolding Diseases, his projects focused on two aspects of Alzheimer’s disease: first, quantification of the toxic model, in patients with Alzheimer’s. Samuel is currently pursuing a master’s in Physics and a bachelor’s degree in Chemistry and Physics through the advanced standing program at Harvard. In addition to his interests in the field of research, Samuel spends his time participating in a number of faith-based groups on campus and seeks to promote dialogue between different religious organizations. Motivated by his experiences in undergraduate research, Samuel plans to enter a Ph.D. program and continue research after graduating from Harvard.

PRIZES & AWARDS

Vibhav Mohanty won a Marshall Scholarship and is studying theoretical physics at Oxford (followed by the Harvard/MIT M.D.-Ph.D. program). Rodrigo Cordoba was awarded a Gates Cambridge Scholarship and is pursuing archaeology at Cambridge (followed by grad school in astronomy at Princeton). Ela Alonso-Moncada won a Harvard-Cambridge Scholarship and is studying mathematics at Cambridge (followed by grad school in physics at MIT). Three students were awarded National Science Foundation Graduate Research Fellowships: Madeline Bernstein, Cameron Kowalski, and Enrico Lee. Brian Marinelli was the recipient of the Physics Department’s Sanderson Award, given to the graduating Physics concentrator with the highest grade average in concentration courses.

STUDENTS’ RESEARCH

This past summer, roughly 40 Physics and Chem/Phys concentrators engaged in full-time research on campus. Each year, this research is made possible by generous funding from a number of sources: the Program for Research in Science and Engineering (PRISE), the Harvard College Research Program (HCRP), the Haase Family Fund, the Stephen Brook Fife Fund, the Hertz Smith Fellowship, and individual lab funds.

NEW CONCENTRATORS

The Physics Department welcomed a new group of 56 sophomores who signed up for the Physics and Chem/Phys concentrations, many of them pursuing joint concentrations or secondaries in other fields. These fields include computer science, philosophy, astrophysics, mathematics, earth and planetary sciences, comparative study of religion, engineering, and statistics.

CAREER PATHS

This past year’s graduating class consisted of 47 Physics and Chem/Phys concentrators. Eighteen of these students moved on to graduate school. They are now attending 13 different institutions (MIT leads the way with four students) to study physics, chemistry, astronomy, mathematics, engineering, and computer science. Others are attending medical school and law school, one student is performing as an opera singer, and another is training with the US men’s national rowing team. Still others have entered the workforce in software, consulting, data science, finance, and filmmaking.

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STUDENT PROFILE

Samuel Detmer ’20 enjoys studying the application of chemistry and physics to a wide variety of research topics. He has been studying the quasi-one-dimensional surface of lithium purple bronze (LPB) since the start of his junior year in the lab of Professor Jennifer Hoffman. LPB is unique because of its anisotropic electrical conductivity and unusual behavior as a one-dimensional superconductor. After presenting his research at the March meeting of the American Physical Society, Samuel is now writing a paper on the discovery that chains of atoms on the surface of LPB tend to resonate, or “turn on,” at various energies. These resonances may indicate the presence of fermionic particles trapped within the chains of atoms, thus providing insight into causes for LPB’s unusual transition to superconductivity at low temperature.

As a sophomore, Samuel worked with Professor Gerald Gabrielse on the ATRAP project at CERN. ATRAP combines antimatter protons with positrons to form the antimatter equivalent of hydrogen atoms. The energy levels of these antimatter atoms are then measured through laser spectroscopy and compared with those of normal hydrogen atoms. The comparison is a precise test of CPT invariance, a symmetry that is foundational to the Standard Model but also suspect because of the matter-antimatter imbalance in the universe. With support from the Harvard College Research Program, Samuel worked to design a new quench detection system for the superconducting magnets used to trap antimatter atoms in the ATRAP experiment. After working in laboratories at Harvard and Northwestern to design and test his device, he finished the equipment at CERN.

FUN STUFF

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PHYSICS AT HARVARD

Graduate Program

THE PH.D. CLASS ENTERING IN 2019

The incoming students entering the Physics Ph.D. program in Fall 2019 hail from a remarkable set of places, including the American states of Arizona, California, Colorado, Connecticut, Illinois, Iowa, Maryland, Minnesota, New Jersey, New York, Pennsylvania, and Texas, and the countries of Australia, Canada, China, Croatia, Denmark, Germany, India, Iran, Israel, Mexico, Spain, South Korea, Switzerland, and Taiwan.

THE PHYSICS GRADUATE STUDENT COUNCIL

Created by our Physics Ph.D. students in the spring of 2009, the Physics Graduate Student Council is an important part of the Physics Department. The council provides a forum for graduate students to propose new initiatives and discuss issues of common concern. It organizes social events like the popular biweekly Friday afternoon social hour and monthly movie nights. The council also administers annual surveys to graduate students on advising and the school’s overall climate. The council’s new president this year is Delilah Gates, and its other members (in alphabetical order) are Jonathan Haefner, Ian Kivlichan, Nathaniel Leitao, Cole Meisenhelder, Noah Miller, Aditya Parikh, Ana Maria Raclariu, Yanting Teng, and Zoe (Ziyan) Zhu.

On November 14, the Physics Graduate Student Council held a panel event on internship opportunities for graduate students. On the panel were four of our current physics Ph.D. students: Ishita Dasgupta, who talked about her work on artificial intelligence at DeepMind; Ruffin Evans, who discussed his internship working on self-driving cars at Waymo; Ian Kivlichan, who shared his experiences working in quantum computing at the Google Quantum AI Lab and Microsoft Research; and Gopi Velluru, who spoke about his internship working in baseball research and development for the Tampa Bay Rays.

On March 29, the department hosted a panel for graduate students on applying for post-doctoral fellowship positions. On the panel were post-doctoral fellows representing a variety of research groups in the physics department in areas ranging from quantum gravity and astrophysics to condensed matter and particle physics.

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PHYSICS AT HARVARD
Goldhaber Prize

The Maurice and Gertrude Goldhaber Prize fund was established in honor of two great physicists: Dr. Maurice Goldhaber, who was an experimental nuclear physicist and one of the pioneers of modern physics, and his wife Dr. Gertrude Scharff Goldhaber, a physicist who contributed to scientists’ understanding of nuclear fission and the structure of atomic nuclei.

Georges Obied
2019 GOLDHABER PRIZE WINNER

Before joining the Harvard Physics Ph.D. program, Georges Obied was an international student from Syria at Johns Hopkins University, where he received his B.S. and M.A. in physics and mathematics. Now, as a fourth-year graduate student, Georges is interested in questions about fundamental physics that can be assessed by cosmological observations. His work, under the supervision of Prof. Cumrun Vafa, focuses on differentiating low-energy effective field theories that admit an ultraviolet completion within a quantum-gravity framework from those that don’t. The latter set is called “the Swampland” (a term coined by Prof. Vafa in 2006). In particular, Georges explores Swampland criteria that have cosmological implications for the past, present, and future universe.

Ann Wang
2019 GOLDHABER PRIZE WINNER

Ann Wang entered college thinking that she was going to go into medicine and major in bioengineering, but she switched to physics after a freshman electromagnetism course. Her interest in experimental high-energy physics grew after conducting research with Prof. Maria Spiropulu in the Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider (LHC). Ann graduated with a B.S. in physics from Caltech in 2015. After beginning her graduate studies at Harvard, Ann joined the ATLAS experiment, one of the four other experiments on the LHC ring. Advised by Prof. Melissa Franklin, the majority of Ann’s Ph.D. work has involved upgrading the muon detectors for future LHC collisions. She has recently joined an effort to search for long-lived particles that deposit a large ionization energy in the inner tracker of ATLAS.

Stephen Carr
2019 GOLDHABER PRIZE WINNER

Stephen Carr studied undergraduate physics and mathematics at Columbia University, while also exploring experimental atomic, molecular, and optical physics and condensed-matter research. In his last year, he worked on numerical PDEs and Density Functional Theory, and continued those interests at Harvard by joining Prof. Efthimios Kaxiras’ research group. During Stephen’s first years in the Ph.D. program, he collaborated closely with visiting mathematicians to study electronic structure in twisted 2D materials, or “twistronics.” These systems are challenging to model because their characteristic size is orders of magnitude larger than any of the constituent crystals. But the mix of exciting physics and computational challenge was a good fit.

Harry Levine
2019 GOLDHABER PRIZE WINNER

Harry Levine received his undergraduate degree in physics and mathematics from Stanford University. He did undergraduate research in the Schleier-Smith lab, working on laser physics and two-photon absorption in atomic vapors. More recently, the team demonstrated new approaches to engineer entanglement within the system and showed the creation of a 20-atom “Schrödinger cat” state, which is the largest fully entangled quantum system to date. Harry hopes to continue experiments with this platform, focusing on applications in quantum information processing and in particular on using this quantum system to solve real-world optimization problems.
GRADUATE PROGRAM

GSAS Merit Fellowship

The Merit Fellowship is awarded by GSAS to Ph.D. students based on the quality of their academic work and research. To be eligible, students must be in their fourth year or earlier and have passed their qualifying exams. Students must be nominated by their home departments, and the Physics Department typically nominates one or two Ph.D. students for the award each year. Students who win the award receive partial or complete stipend support from GSAS for one semester.

Hofie Hannesdottir
2019 GSAS MERIT FELLOWSHIP WINNER

Hofie Hannesdottir completed her B.S. in physics at the University of Iceland in Reykjavik. She spent her senior year at the University of California, Santa Barbara, as an exchange student. At Harvard, Hofie joined Prof. Matthew Schwartz’s research group and is currently a fourth-year Ph.D. candidate working in high-energy particle theory. Hofie is interested in understanding the fundamental laws of nature that govern how particles interact. In particular, she is trying to figure out a consistent way to define particles in quantum field theory (QFT). To approach these questions, she studies infrared (IR) divergences, which arise in QFT calculations as infinite probabilities for certain processes to occur. These infinite probabilities are unphysical since measurements are always finite and probabilities are at most 100%. IR divergences are believed to be a result of an inaccurate description of particles in QFT. To see the problem, consider the electron. It seems to be a particle, but wherever it goes, it drags around an electromagnetic field with it. This field is made up of other particles, called photons. So what part is the electron and what part is the photon? If one tries to strip off all the photons from the electron, the resulting theory is pathological. Instead, Hofie is using insights into the universality of long-distance interactions among charged particles to derive a practical method to isolate the electrons from their photon cloud. Doing so could lead not just to a solid foundation for quantum field theory, but also to more precise predictions that can be compared to data from the Large Hadron Collider.

Trond Andersen
2019 GSAS MERIT FELLOWSHIP WINNER

Trond grew up in Norway and represented the Norwegian team at the International Physics Olympiad (IPhO) in Bangkok in 2011. A year later, he began his undergraduate degree at MIT, doing research on two-dimensional materials in Pablo Jarillo-Herrero’s group. In particular, Trond studied graphene optoelectronics, photonic polaritons in hexagonal boron nitride, and vibrational modes in transition metal dichalcogenides. For this work, presented in six publications, Trond received the Joel M. Orloff award for best undergraduate research, and was MIT’s nominee for the APS LaRoy Apter award. Now Trond is a fourth-year graduate student in the Larkin group, using atomic-scale defects in diamonds to locally probe current fluctuations in graphene devices. With this new technique, his group recently discovered an instability in biased graphene that occurs when the electronic drift velocity exceeds the speed of sound. The effective electronic population inversion causes high rates of stimulated phonon emission, known as Cerenkov amplification. This occurs when the electronic drift velocity exceeds the speed of sound. The effective electronic population inversion causes high rates of stimulated phonon emission, known as Cerenkov amplification. This can lead to a solid foundation for quantum field theory, but also to more precise predictions that can be compared to data from the Large Hadron Collider.

Graduate Student Awards and Fellowships*

Frederick Sheldon Traveling Fellowship
Ann Wang
Harvey Fellowship
Daniel Ang
Hartt Foundation Fellowship
Alex Atanasov
Dolev Bluvstein
IBM Fellowship
Charlotte Boettcher

NDSEG Fellowship
Alex Atanasov
Madejyn Cain
Michelle Chalupnik
Brandon Grinkemeyer
Patrick Ledwith
Nathaniel Vilas
Neekeyfar Award for Graduate Study
Alek Bedrya
NSF Graduate Research Fellowship Program
Alex Atanasov
Oscar Araiza Bravo
Dolev Bluvstein
Carri Cesarotti
Taylor Contreras

Hofie Hannesdottir
Spencer Doyle
Patrick Forrester
Lev Kendrick
Sarahrens Premrabu
Kenneth Wan
Paul & Daisy Soros Fellowship for New Americans
Grace Pan
Grace Zhang

Harvey Fellowship
Patrick Ledwith
Monica Pate
Nathaniel Vilas
Abigail Plummer
Rhine Samajdar
Elliot Schneider

Fellowship for New Americans
Barbara, as an exchange student. At Harvard, Hofie completed her B.S. in physics at the University of Iceland in Reykjavik. She spent her senior year at the University of California, Santa Barbara, as an exchange student. At Harvard, Hofie joined Prof. Matthew Schwartz’s research group and is currently a fourth-year Ph.D. candidate working in high-energy particle theory. Hofie is interested in understanding the fundamental laws of nature that govern how particles interact. In particular, she is trying to figure out a consistent way to define particles in quantum field theory (QFT). To approach these questions, she studies infrared (IR) divergences, which arise in QFT calculations as infinite probabilities for certain processes to occur. These infinite probabilities are unphysical since measurements are always finite and probabilities are at most 100%. IR divergences are believed to be a result of an inaccurate description of particles in QFT. To see the problem, consider the electron. It seems to be a particle, but wherever it goes, it drags around an electromagnetic field with it. This field is made up of other particles, called photons. So what part is the electron and what part is the photon? If one tries to strip off all the photons from the electron, the resulting theory is pathological. Instead, Hofie is using insights into the universality of long-distance interactions among charged particles to derive a practical method to isolate the electrons from their photon cloud. Doing so could lead not just to a solid foundation for quantum field theory, but also to more precise predictions that can be compared to data from the Large Hadron Collider.

Recent Graduates

Jesse Amato-Grill
Thesis: A Fast ‘Li Based Quantum Simulator
Advisor: Markus Greiner

Victor Buzu
Thesis: Constraining Primordial Gravitational Waves Using Present and Future CMB Experiments
Advisor: John Kovac

Andrew Chael
Thesis: Simulating and Imaging Supermassive Black Hole Accretion Flows
Advisor: Cora Dvorkin

Christie Chiu
Thesis: Quantum Simulation of The Hubbard Model
Advisor: Markus Greiner

Karri DiPietrillo
Thesis: Search for long-lived, massive particles in events with a displaced vertex and a displaced muon using sqrt(s) = 13 TeV p-p collisions with the ATLAS detector
Advisor: Melissa Franklin

Shiang Fang
Thesis: Multi-scale Theoretical Modeling of Twisted van der Waals Bilayers
Advisor: Effrosynis Kaxiras

Ping Gao
Thesis: Traversable Wormholes and Regenerisim
Advisor: Daniel Jafferis

Jinwoo (Monica) Kang
Thesis: Two Views on Gravity: F-theory and Holography
Advisor: Daniel Jafferis

Jae Hyeon Lee
Thesis: Prediction and Inference Methods for Modern Astronomical Surveys
Advisor: Douglas Finkbeiner

Patrick Jefferson
Thesis: Geometric Deconstruction of Supersymmetric Quantum Field Theories
Advisor: Cumrun Vafa

Continued on next page
Recent Graduates continued

Andrei Levin
Thesis: Single-Electron Probes of Two-Dimensional Materials
Advisor: Amir Yacoby

Lee Liu
Advisor: Kang-Kuen Ni

Xiaomeng Liu
Thesis: Correlated electron states in coupled graphene double-layer heterostructures
Advisor: Philip Kim

Alexander Lukin
Thesis: Entanglement Dynamics in One Dimension — From Quantum Thermalization to Many-Body Localization
Advisor: Markus Greiner

Mason Marshall
Advisor: Gerald Gabrielse

Baurzhan Mukhametzhanov
Thesis: Bootstraping High-Energy States in Conformal Field Theories
Advisor: Daniel Jafferis

Cristian Panda
Thesis: Order of Magnitude Improved Limit on the Electric Dipole Moment of the Electron
Advisor: Andrew Strominger

Sabrina Pasterski
Thesis: Implications of Superrotations
Advisor: Andrew Strominger

Monica Pate
Thesis: Aspects of Symmetry in the Infrared
Advisor: Andrew Strominger

Avishek Patel
Thesis: Transport, Criticality, and Chaos in Fermionic Quantum Matter at Nonzero Density
Advisor: Subir Sachdev

Zhaoxi (Charles) Xiong
Thesis: Classification and Construction of Topological Phases of Quantum Matter
Advisor: Ashvin Vishwanath

Yuchen (Lily) Shi
Thesis: Analytical Steps Towards the Observation of High-Spin Black Holes
Advisor: Andrew Strominger

Oleksandr Shykh
Thesis: Designing Single-Electronic Dispersions
Advisor: Eugene Demler

Tatiana Webb
Thesis: The Nanoscale Structure of Charge Order in Cuprate Superconductor Bi2201
Advisor: Jenny Hoffman

Mohulajit Williams
Thesis: Biomolecules, Combinatorics, and Statistical Physics
Advisor: Vinny Manoharan

Zhaoxi (Charles) Xiong
Thesis: Classification and Construction of Topological Phases of Quantum Matter
Advisor: Ashvin Vishwanath

Liqun Zou
Thesis: An Odyssey in Modern Quantum Many-Body Physics
Advisor: Subir Sachdev

By Bonnie Currier, Research Scholar Coordinator

During the 2018-2019 academic year, we continued our research scholar development series by offering a variety of panel discussions. This series rotates every two to three years, and we welcome new panel recommendations from our research scholars.

A panel on “Patents and Intellectual Property” was held on October 12, 2018. This panel was composed of faculty from inside and outside the Physics Department, along with representatives from Harvard’s Office of Technology Development.

Two panels on “Getting a Junior Faculty” position were held this year. The first panel, which took place on November 16, 2018, was composed of former postdocs and graduate students who currently hold junior faculty appointments at Harvard and other institutions, so that attendees could hear from people who may have been, quite recently, in a similar position as their own. The second panel, which took place on November 29, 2018, was composed of senior faculty, inside and outside of Harvard, to provide viewpoints from people at more advanced stages in their career.

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The committee members also advise the Research Scholar Advisory Committee, composed of scholars who have current appointments with Harvard Physics faculty, helps organize the Annual Retreats. The Committee members also advise the Research Scholar Advisory Committee, composed of scholars who have current appointments with Harvard Physics faculty, helps organize the Annual Retreats. The Committee members also advise the Research Scholar Advisory Committee, composed of scholars who have current appointments with Harvard Physics faculty, helps organize the Annual Retreats. The Committee members also advise the Research Scholar Advisory Committee, composed of scholars who have current appointments with Harvard Physics faculty, helps organize the Annual Retreats.

We invite you to connect with graduate students and former research scholars of the Department by agreeing to be listed on our confidential list of physics alumni administered by Bonnie Currier, Research Scholar Coordinator (bcurrier@fas.harvard.edu).
Alumni Notes

1948
Frank R. Tangherlini (S.B.): Although I retired in 1994, in 2018 I published two papers in the Journal of Modern Physics, and a letter in Physics Today about the problem of the electron's mass. My main research has been in Cosmology, and secondarily in SR & GR. Since 2015, I have been publishing on a possible alternative to the accelerating universe. This led to the second 2018 paper that gives a possible solution to the long-standing Hubble constant disagreement. It was followed up by a contributed talk at the 2019 April APS meeting in Denver. In 2018 I attended my 70th Harvard Class Reunion.

1954
John McLeod (A.B.): I earned a Ph.D in experimental nuclear physics at Princeton University and did my duty to the nation for 35 years at the Los Alamos National Laboratory working on various projects which we could not afford not to try, such as a nuclear rocket engine and microscopic hydrogen bombs driven by lasers that could be harnessed to produce power. None of these actually worked, at least not yet. I am now retired for 24 years and enjoying the climate at high altitude in New Mexico. I try to keep up with current research and am particularly concerned about global warming.

1957

1958

1963
Michael H. Goldhaber (A.B.): The April 29, 2019 New Yorker, page 72 says this about me: "More than 20 years ago, the writer Michael Goldhaber observed, in Wired, that the Internet drowned its users in information while constantly increasing information production; this makes attention scarce and desirable resource—the natural economy of cyberspace. Goldhaber speculated that, when the attention economy had matured nearly everyone would have their own Web site, and he worried readers that "increasing demand for our limited attention will keep us from reflecting, or thinking deeply (let alone enjoying leisure). In other words, he roughly outlined the social-media age."

1965
Louis J. Lanzenteri (Ph.D.): Over the decades I have done many things, including being elected to the NAE (1988), serving on the National Science Board and receiving the NAE Bouace Award.

1966
Stephen G Bown (A.M.): After Harvard, I went on to medical school (Cambridge, UK), specialized in gastroenterology and later set up the National Medical Laser Centre in University College London (UCL), a translational research group for the scientific and clinical development of techniques using light, particularly lasers, for the detection, diagnosis and treatment of human disease. We pioneered a range of endoscopic and image guided laser techniques, particularly Photodynamic Therapy (PDT), for various pre-malignant, malignant and non-malignant conditions from basic biology to routine clinical practice, many in collaboration with Harvard Medical School (Wellman Laboratories of Photobiology).

1969
Carl M. Bender (Ph.D., advisor: Coleman and Weil): I received the Dana Heineman Prize in Mathematical Physics (awarded annually jointly by the APS and the AIP) in 2017. I was awarded in 2019 a research award from the von Humboldt Foundation.

1967
Kevin Cahill (Ph.D., Thesis advisor: Gladstone): Cambridge University Press will publish the second edition of my book Physical Mathematics late this summer. The book is meant for precocious undergraduates, graduate students, and working physicists.

1968
Frederick Cooper (Ph.D., Thesis Advisor: Sheldon L. Glashow): This past year I have won a Lifetime Achievement award from Manipal Who’s Who. I have given talks on the Use of Collective Coordinates to study solid waves and their stability at the University of Texas, Arlington and at the University of Delhi, and was asked to write a book on Solid Dynamics by World Scientific. I have also published several papers on Exact solutions to the Nonlinear Schrödinger equation and Nonlinear Dirac equation in different external complex potentials. I have been a visiting Scientist at Harvard and Boston University and I am on the external Faculty of the Santa Fe Institute. I also am a Guest Scientist at Los Alamos National Labs. I also travel around the world giving workshops on Meditation in the Tibetan Buddhist tradition.

1970
Adsk Khodah (Ph.D.) recently stepped down after serving for ten years as the founding Co-Chair of the United Nations’ International Resource Panel. He was awarded an honorary Doctor of Laws by Simon Fraser University of British Columbia and the UNEP Science-Policy Lifetime Award for his services to the environment.

1975
Peter B. Kramer (Ph.D.) Pete left Harvard for a Post Doc in Rai Weiss lab at MIT developing the first prototype LIGO detector over 40 years ago. He left LIGO and Physios after a few years for a career in biopharmaceuticals. Now in retirement, Pete started writing iPhone apps to relive old adventures. Go Game Connect let him once again spend an afternoon playing Go with his fellow graduate student Stephen Lendrum after 44 years even though they are 2000 miles apart. His latest, Gravitational Wave Events, takes the LIGO Open Public Alerts and broadcasts each new gravitational wave event to anyone with an iPhone. Who said you could never go back?

1976
Alan J Cohen (Ph.D.): Alan recently joined Belmont Technology - as an AI startup - in Houston, as Executive Advisor - Industry Solutions.

1977
David Schnitzer (A.B.): In February 2019, I retired from AT&T after 34 years of employment. My positions at AT&T included systems engineer, supervisor, and data scientist.
Kelly Chance (Ph.D.) is Principal Investigator on the NASA-funded Tropospheric Emissions: Monitoring of Pollution satellite (TREMAP; tempoe-st.eu), which has been delivered and is in storage awaiting launch. Upon launch to geostationary orbit, TEMPO will measure North American air pollution hourly in the daytime, at 10 square kilometer ground resolution, from Mexico City and Cuba to the Canadian tar sands, and from the Atlantic to the Pacific. In addition, he has published Spectroscopy and Radiative Transfer of Planetary Atmospheres, with Prof. Randall Martin (Ph.D., Engineering Sciences, Harvard University, 2002), Oxford University Press, ISBN-13: 978-0199662104, 2017.

Larry Bum (A.B. Chem/Phys): I’ve done biomedical research since graduating and now study genetics and mechanisms of brain diseases like Alzheimer’s disease and depression as a research officer at the University of Hong Kong. For scientific fun, I compile a free weekly science humor list which I welcome you all to enjoy at tinylunches.com/top1science.

Deborah R. Corn (A.B.): Thank you for asking for announcements for your alumni newsletter. I’d like to share the news of the publication of my latest book, Climate in Motion: Science, Empire, and the Problem of Scale (Univ. Chicago Press, 2018).

David Zelson (A.B.): I love being a children’s books author. My first novel, Log. Dance of the Ice Age, was published by Egmont for ages 8-11. It satirized mankind’s response to climate change and Al Gore called it “a great combination of humor and powerful insight.” One of my recent picture books, The Universe ate My Homework, was published by Lerner Books for ages 4-7. NPR science journalist and Radiolab host Robert Krulwich wrote about the book: “Don’t try this at home, just bring it home. The Universe Ate My Homework is totally safe (and delightful) to read.” I can be reached at davidzeltzer.com.

Talal A. Deha (A.B.): My main update with respect to physics is that I published a book on Group Theory and Scientific Representation which has been getting good reviews since it was published (now over 10 years ago - hard to believe). I would be interested to hear what my old Harvard classmates think of it; the book is Objectiveview, Invariance and Convention: Symmetries in Physical Science (Co-authored with Michael Redhead, HUP, 2007).

Alix Guerrier (A.B.): In November 2018, Alix started a new role as the CEO of GlobalGiving, the largest global crowdfunding community connecting nonprofits, donors, and companies in over 170 countries. He was previously President and Chief Product Officer at LauraDillon, the education technology company he co-founded (he is now a board member). GlobalGiving’s model addresses a wide range of themes, including over 2,300 projects focused on science education. He hopes that some members of the next generation of physicists around the world are among the beneficiaries of these projects.

Josh Goldman (Ph.D.) founded KoboBol Metals, which is exploring for mineral deposits containing cobalt and nickel, which are critical for making high-performing lithium-ion batteries for electric vehicles. KoboBol is aggregating large datasets and using a combination of basic science and machine learning to identify properties that are highly prospective for discovering new ore deposits, and then acquiring and exploring their portfolio of properties. Fellow physics alumna Elizabeth Main Ph.D `11 recently joined to lead KoboBol’s technology program. KoboBol is backed by Breakthrough Energy Ventures and Andreessen Horowitz. Our company was also featured in a recent article in Bloomberg.

Tony Pan (Ph.D., CEO at Modern Electrons) was recognized by the Puget Sound Business Journal with the “40 under 40” award for my company’s work in energy.

Christian You (A.B.): 2019 has been an incredible year. I have had the honor and privilege of completing five and a half years of service in the US Navy as a Surface Warfare Officer and Nuclear Engineer, Officer. I am excited to matriculate into MIT’s Ph.D. program in Nuclear Engineering, where I will conduct research in the area of plasma physics and nuclear fusion as a sustainable and carbon-free source of energy. And I am incredibly happy and lucky to have recently married my best friend, Serena Tong, a fellow graduate of Harvard’s Class of 2013.
Celebrating a Phenomenal Department
by Mary McCarthy

One of the best things about working in the Department of Physics is being surrounded by world-class physicists who are forever pushing the limits of discovery in the physical world. This propensity can also pose a challenge, however. How can the administration keep pace with brilliant scholars whose research contributions lie in a domain that few can fathom?

Fortunately, the staff in the Department of Physics is singular in its dedication, focus, and effectiveness—so we’re able to keep pace just fine. In a 2012 staff retreat, a resounding message came through: it was high time for the staff to be celebrated for their accomplishments. A group of administrators then partnered with the faculty in developing the Physics Phenom Reward and Recognition Program. Once a year, the entire department—including faculty, students at every level, and staff—are invited to nominate members of the staff for this esteemed status. After nominations are gathered, the faculty and staff are invited to cast a vote for the staff member who has best met the criteria of having delivered “meaningful and special contributions ‘above and beyond’ standard job responsibilities...persons who demonstrate concrete achievement and contributions to the department in areas that may include: collegiality, innovation, mentorship, professionalism, special projects, and teamwork.” Since its inception, eight staff members have won the award.

One of the first named Phenoms was Barbara Drauschke, now a 40-plus-year seasoned veteran of the Department, who claimed that winning the award “made me feel that my efforts are noticed and appreciated by my peers and the department. I have nominated people, motivated by the way it made me feel about my work in the department, and a want for them to be acknowledged as well.”

Our most recent season yielded 18 nominations for 21 staff members—the highest participation yet. And the voting rolls demonstrated tremendous enthusiasm for the program. The full transcript of nomination statements are posted online for all to see, with one past winner, Adam Ackerman, noting, “sharing the nomination text is a great way to show how many colleagues are valued even though only one “wins” each year.”

Another past winner, Hannah Belcher, a faculty assistant for Professors Yacoby and Kim and their labs, shared this comment: “Receiving the Physics Phenom award was incredibly meaningful to me. I care deeply about the Physics Department as a whole—my colleagues and the faculty, students, and researchers I support. Knowing that the work that I do is meaningful enough for them to reach out and submit a nomination was immensely validating. Receiving the award was an incredible honor and made me want to continue to offer the best support that I can.”

This year’s Phenom, Lisa Cacciabaudo, the Graduate Program Administrator, reflected: “I think it’s really important to have a staff recognition program like this. It is all too easy to get caught up in our day-to-day work in this environment, and this program gives us a chance to think about our colleagues and to recognize their contributions and their value to the department in a meaningful way.”

Letters from Our Readers
Continued from page 2

Thank you for sending me this newsletter—the first I’ve received. It’s fascinating to see how women have progressed in physics. I was a lowly undergraduate in physics in 1964. There were 3 women in my class who majored in physics. I do not recall any female professors or graduate students. I wound up in medicine which was perfect for me. I was interviewed for medical school on the day I delivered my second child. I am quite certain I was admitted because I held a degree in physics from Harvard. Many thanks!

JUDITH PAUL OSHA, A.B. 1964

It has been 50 years since I did any physics, but I very much enjoyed the latest newsletter.

One story about Prof. Schwinger struck a chord. Cooper said that at the Nobel ceremony, Schwinger told the audience, “I woke up this morning, and the problems I couldn’t solve yesterday, I can’t solve today.” I was an undergraduate when he won the prize. I didn’t attend the first class he conducted after the announcement (I wasn’t as advanced as my classmate Howard Georgi), but I had friends who did. The classroom in Jefferson was standing room only. He began the lecture, or so I was told at the time, by saying, “I woke up this morning, and the problems I couldn’t solve yesterday I can’t solve today. And that’s all I’m going to say about it.” Those standing then departed.

HARRIS HARTZ A.B. 1967

Thank you for your work in putting the newsletter together and keeping all of us up-to-date on what is happening with Physics at Harvard. It’s great to be able to keep some connection to the program.

NOAH BRUEGMANN, A.B. 2010
(Chemistry and Physics)

I read the emailed Newsletter you sent me with mounting amazement. It is a prime example of what it takes to be one of (or the) top departments of physics, biologically and today, as well as being one of Harvard’s most distinguished departments. I also appreciated greatly the humanistic emphasis on the many people featured.

GERALD HOLTON, M.A. 1946, PH.D. 1949
Departmental Events

Our weekly colloquia with invited speakers are held at 4:30 PM in Jefferson 250, preceded by an all-community tea at 3:45 PM in the Physics Reading Room, Jefferson 450. Among the colloquium speakers this academic year are Immanuel Bloch, Lawrence Bacow, Charlie Marcus, and Margaret Kivelson. If you are ever in town, we would be delighted for you to join us.

Our next Loeb Lecturers will be Zhi-Xun Shen (Stanford) on Nov. 4-6, 2019. The Lee Historical Lecture speaker will be David Ruelle, emeritus Professor at the Institut des Hautes Études Scientifiques, on April 27, 2020.

For more details about our upcoming colloquia, lectures, and other events, please consult the Harvard Physics Calendar webpage: www.physics.harvard.edu/events/gencal.

Stay Connected

We would love to hear from you. Please stay in touch and let us know if you would like to contribute news items to the newsletter at: newsletter@physics.harvard.edu.

Check out our website: www.physics.harvard.edu.

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Like us on Facebook: facebook.com/pages/ HarvardPhysics/154322267832284.

Join us on LinkedIn: https://www.linkedin.com/ groups/4740923/.

Watch the videos of various events on our website: https://www.physics.harvard.edu/events/videos.

Don’t miss the April 3, 2020, Physics Graduate Alumni Symposium and Reunion! More information is forthcoming.