A graphical depiction of electrons in a topological insulator surface. Using circularly polarized light with appropriate helicity, one can address each spin species, selectively shown by the direction of the arrows.

Image courtesy of Prof. Nuh Gedik, MIT.
Letter from the Chair

We are pleased to deliver the second issue of the Department of Physics Newsletter to your (virtual or real) mailbox. I hope I can start calling it the annual newsletter with a straight face now.

My first year as the Department Chair has gone by in such a blur that I cannot remember exactly why it felt so busy. Flipping through this newsletter gives me a chance to look back and recognize that, yes, a lot of things did happen even though I was winging it. Which goes to show that a ship with a great crew can sail even if the captain is directionally challenged.

Forty-one prospective graduate students accepted our offer of admission this year. The matriculation rate was 61%, the highest in recent record. If 61% of the smartest students choose to pursue their dreams in our Department, we surely must be doing something right. I am also proud to note that 31% of them are women. These numbers speak to the strength of our Department. I congratulate our graduate advising team, Vinny Manoharan, Jacob Barandes, and Lisa Cacciabaudo, and the faculty members on the graduate admissions committee chaired by Tim Kaxiras.

The latest addition to our faculty is Cora Dvorkin, who is profiled on page 4. Cora, a theoretical cosmologist, is coming to our Department from the Harvard Smithsonian Center for Astrophysics. We are thrilled by her arrival, which will strengthen the intellectual connection between Physics and Astronomy.

Three members of our faculty, Jenny Hoffman, Matt Schwartz, and Xi Yin, have received tenure. Each of them represents a powerful combination of top-flight research and outstanding teaching. Our classrooms continue to change. Physically, we have new and improved teaching space in Jefferson 356 and the SciBoxes in the Science Center. Jefferson 356 used to be an ugly duckling of a classroom, but it’s now been converted into the most attractive lecture space in the Department, with comfortable seating, pleasant acoustics, and advanced audio-visual equipment. See the article on page 26 to learn more about the three SciBoxes, which offer flexible teaching spaces for interactive classes that engage students with group and project-based learning.

Pedagogically, Physical Sciences 2, 3, and 12a/b have been transformed from traditional lectures into more interactive learning experiences, led by Logan McCarty, Louis Deslauriers, Tim Kaxiras, and Chris Stubbs. The teaching laboratories for Physics 15a/b/c, now involve student-driven projects thanks to Amir Yacoby, Mara Prestin, and Markus Greiner, among others.

Before closing, I wish to express our gratitude for those who recently chose to support the Department: the Della-Pietra Fund for Theoretical Physics has been established by the gift of Stephen and Vincent Della-Pietra; and the Bershadsky Distinguished Visiting Fellowship in Physics has been established by a gift from Michael and Victoria Bershadsky. These generous donations allow us to embark on new initiatives that promote intellectual connections across the Department.

I hope you will enjoy this newsletter. As always, if you happen to be near the campus, please drop by the Department to see how we are evolving while, at the same time, striving to remain at the forefront of research and education.

Sincerely,
Masahiro Morii
Chair and Professor of Physics

Letters from our Readers

The first annual Harvard Physics Newsletter received an enthusiastic response. We were pleased to have heard from a number of delighted readers.

Writing from Santa Barbara, California, David D. Lynch (PhD Physics, ’67) said, “I have received the Fall 2014 issue of Physics and enjoyed it very much.”

“Thank you so much for the Physics Newsletter. I thoroughly enjoyed hearing about what’s going on in the department. I do hope you will keep sending it,” wrote Bill Bean (AB ’65).

Hailing from the San Francisco Bay Area, Dave Landhuis (PhD Physics, ’02), a Data Center Systems Engineer at Google, wrote: “A very nicely produced newsletter with great content. Brought back a lot of memories of people connected with the department. To all who worked on the newsletter: nice work, and thank you!”

“Thanks for your excellent publication,” added Nick Percival (AB ’64).

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

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Jennifer Hoffman  
PROFESSOR OF PHYSICS  
The Department is delighted to announce the promotion of Jennifer Hoffman to Professor of Physics with tenure. Jenny received her BA in Physics from Harvard in 1999. She went to Berkeley to study experimental condensed-matter physics with J.C. Stammus Davis, earning her PhD in 2003. After being a postdoc at Stanford, Jenny came back to Harvard as an Assistant Professor of Physics in January 2005.  
Jenny's lab, located underground in the Laboratory for Integrated Science and Engineering (LSEE), houses some of the most sensitive scanning probe microscopes in the world—ultra-delicate devices that map the surface properties of materials by bringing the tip of a probe needle to near-contact and then scanning it across the specimen in sub-atomic steps. Her scanning tunneling microscope, force microscope, and spin-polarized tunneling microscope—all hand-built at Harvard—operate at low temperatures and in high magnetic fields. With these instruments, Jenny and her team of students and postdocs study a variety of novel materials, including high-Tc superconductors and topological insulators.  
As a professor, Jenny has earned a reputation as an outstanding instructor. She is best known for her inspiring lectures in Physics 15c. She has been a Dark matter will be another important avenue for her research at Harvard. “Given the number of experimentalists engaged in taking measurements of the CMB and the universe’s large-scale structure, nothing less than to understand the physics of the FIRST MOMENTS  
Matthew Schwartz  
PROFESSOR OF PHYSICS  
The Department is delighted to announce the promotion of Matthew Schwartz to Professor of Physics with tenure. Matt received his BA in Mathematics and Biophysics at the University of Chicago in 1998. He went to Princeton, where he received his PhD in Physics in 2003. After doing postdocs at Berkeley and at Johns Hopkins, he joined Harvard as an Assistant Professor in 2008. Matt has worked on a wide variety of theoretical topics in particle physics. His recent efforts range from formal studies of the structure of quantum field theory (QFT) to phenomenological work related to the Large Hadron Collider (LHC). In the latter area, he has developed applications of effective field theory to make precise predictions of the Standard Model measurements performed at the LHC and on studies of substructures inside hadronic jets. He even joined the ATLAS Collaboration, one of the two large experiments at the LHC, as a Short Term Associate to work directly on data analysis, drawing from his theoretical ideas.  
Matt has overhauled the way quantum field theory is taught at Harvard. Students from both Harvard and MIT flock to his QFT course, Physics 253a, despite his reputation for giving hard homework and even harder exams. He has written a textbook, Quantum Field Theory and the Standard Model, which is praised highly by professors and students alike, and is fast becoming a standard textbook on the subject. At the introductory level, Matt is working with Professor Howard Georgi and Dr. David Morin to bring the Physics 15 series into the 21st century. We hope to report on the progress of this endeavor in next year’s newsletter.  
For his part, Matt admits to being “humbled and deeply honored to join Harvard’s permanent faculty. Working in a community with some of the world’s best scholars and students has been a great privilege for me,” he says, “and one that I look forward to extending for many years to come.”
uncovered a new type of holographic duality between higher spin gravity and critical vector models, and transformed previously little known theories of higher spin gravity into a new hot field of research. Among the students, Xi is admired for his enthusiastic lecture style and encyclopedic knowledge. He is best known for teaching graduate courses on string theory. Students appreciate his clear lectures, meticulous preparation, and friendly demeanor. His penchant for gym clothing in the classroom reflects his passion for sports, especially long-distance running.

Xi and Matt’s promotions represent a very significant strengthening (from 4 to 6 tenured professors) of the high-energy theory group in the Department. We are now entering another golden era of theoretical physics at Harvard.

### Faculty Prizes, Awards & Acknowledgments

*Includes awards received since the publication of last year’s newsletter.

- **Raymond and Beverly Sackler International Prize in Biophysics, 2014:**
  - **PROF. HOWARD BERG**
  - ‘Distinguished Scholar’ at the Max Planck Institute of Quantum Optics, 2015:
  - **PROF. EUGENE DEMLER**
  - **PROF. ADAM OCKFORD**
  - **PROF. AMIR YACOBY**

- **2015 Gutzwiller Scholar, Max Planck Institute for the Physics of Complex Systems:**
  - **PROF. ERIC HELLER**

- **Canada Excellence Research Chair in Quantum Materials and Devices, 2015:**
  - **PROF. JENNIFER HOFFMAN**

- **2015 Breakthrough Prize in Fundamental Physics:**
  - **PROF. ANDREW STROMINGER**

- **2015 Simons Fellow in Theoretical Physics:**
  - **PROF. EUGENE DEMLER**

- **2015 Simons Investigator in the Mathematical Modeling of Living Systems:**
  - **PROF. MICHAEL DESAI**

- **2015 AFOSR Young Investigator Program Award:**
  - **PROF. KANG-KUEN NI**

- **2015 Simons Investigator in the Mathematical Modeling of Living Systems:**
  - **PROF. EUGENE DEMLER**

- **Elected Vice President of OSA, The Optical Society, 2015:**
  - **PROF. ERIC MAZUR**

- **National Medal of Technology and Innovation, 2014:**
  - **PROF. CHERRY MURRAY**

- **Museum of Science Walker Prize, 2015:**
  - **PROF. LISA RANDALL**

### In Memoriam

**Douglass Goodale**

Douglass (Doug) Goodale, who had been a member of the Natural Sciences Lecture Demonstration Service group since 1989, passed away at the age of 66 on March 18, 2015 after a brief illness.

Doug joined the Lecture Demo group in 1989, and worked as a lecture demonstrator and machine shop supervisor. Many of us either as students or members of the teaching staff, remember watching with great anticipation and amazement as Doug worked his magic in the Science Center lecture halls. As the machine shop expert-in-residence, Doug built many lecture demos that still educate and entertain students in physics courses at all levels. He also served as head teaching assistant for Physics E-1 at the Harvard Extension School from 1997 through 2014.

Doug’s meticulous workmanship and keen knack for science education made him an indispensable part of the Lecture Demo team. We will miss Doug as a friend for his generosity, unassuming smile, and dry sense of humor.

**Andreas Koehler**

Andreas (Andy) Koehler, who was a Director of the Harvard Cyclotron Laboratory (HCL), passed away on May 16, 2015 at the age of 85.

Born in Germany in 1930, Andy studied physics at Harvard and then became a technical assistant at the HCL, which he would later lead as the Director. In the early 1960s Andy was instrumental in the joint effort with the Massachusetts General Hospital to use the Cyclotron for cancer treatment. The pioneering work on proton-beam therapy at the HCL continued for many years. All told, more than 9,000 patients were treated over four decades until the Cyclotron was decommissioned in 2002.

Andy’s contributions to radiology research at the HCL are wide-ranging but not as widely appreciated outside of Harvard as they should be. Nevertheless, the legacy of his work lives on at numerous particle-therapy facilities around the world. We are grateful to have had among our colleagues such a dedicated scientist as Andy.
Edwin Abbot, in his 19th-century satirical novel, Flatland: A Romance of Many Dimensions, describes life in two dimensions. The narrator, named Square, is a knowledge-able scholar in his two-dimensional flatland.

Through the course of the novel, he realizes that many scientific mysteries in Flatland can be elegantly explained through the addition of an extra third dimension. Out of this elucidation, Square says, “Three Dimensions seems almost as visionary as Land of One or None.”

Similarly, physicists have been considering the concept of a multi-dimensional universe in order to explain the mysteries of our own three-dimensional world. The idea of a four-dimensional space-time provided the foundation for Einstein’s theory of relativity. Today, in efforts to explain the underlying structure of the universe, physicists are considering as many as ten or more dimensions. However, through the study of these “extra” dimensions we might have missed the intricacy and beauty of the physics that happens at the other extreme: the reduced two- or one-dimensional worlds.

The notion of reduced dimensionality is often considered a purely mathematical idea and is seen as an abstract concept that cannot be realized in an actual physical or material world. Yet, quantum physics teaches us how to effectively describe a three-dimensional object within the confines of a reduced dimensional system. Imagine a particle confined to a box. If we start to flatten the box, quantum mechanics tells us that the energy of the spatially confined particle becomes discontinuous. The separation between energy levels increases as the box is flattened even further. Eventually, the particle’s motion along the direction in which the box is flattened freezes as the discrete and quantized energy scale becomes larger than any other characteristic energy in the system. Thus, in our flattened box, the particle is restricted to two dimensions—essentially an object in Abbot’s Flatland, although it still exists in the three-dimensional world.

It turns out that these reduced dimensional systems are already crucial to modern electronic devices. Transistors, the core element of today’s electronics, employ electrons in an effective, two-dimensional space formed at the interface between the silicon surface and its oxide layer. The reduced dimensionality of the space electrons inhabit often enables an unusual quantum mechanical effect. In particular, in a strong magnetic field and at ultra-low temperatures, the electron orbit can be completely quantized. In this case, the resistance along the direction of the current vanishes completely, indicating a non-dissipating flow of electrons, just like in superconductors. Additionally, the Hall effect—a characterized by the resistance measured perpendicular to the current (see details in the latter part of this article)—exhibits discrete steps with defined plateaus over large intervals of magnetic fields. This quantization is called the quantum Hall effect. Two Nobel prizes have been awarded in this subject, one for the discovery of the quantization at integer multiples of $e^2/h$ in 1985 (von Klitzing) and another for fractional multiples in 1998 (Stormer/Tsu/Laughlin).

Over the years, Harvard’s condensed-matter physics group has also made important contributions to the study of these beautiful quantum mechanical effects.
In order to create low-dimensional semiconductor structures, physicists often borrow microfabrication technology developed over the past half century. Microfabrication, combined with nanotechnology, produces effectively 2-dimensional (2D) or even 1-dimensional (1D) semiconducting devices in the forms of the quantum wells, quantum wires, and quantum dots. Ironically, to create these tiny structures we often need to access huge facilities, properly equipped with sophisticated instruments for material manipulation, fabrication, and characterization. Harvard physicists enjoy world-class microfabrication facilities at the Center for Nanoscale Systems (CNS), which provides shared research space dedicated to the fabrication and characterization of nanometer-scaled devices. (See the sidebar, “Center for Nanoscale Systems.”)

Historically, reduced dimensional semiconducting structures have been fabricated in a top-down method in which a larger system splits into smaller ones. A completely different approach, the bottom-up assembly method of nanotechnology, was first used in nanoscience and technology starting in the 1990s. The bottom-up method, when applied to materials science and chemistry, assembles molecules to create larger material structures. Among these material structures, carbon-based nanostructures have attracted the most interest. The first kind of carbon nanomaterial was the C60 “buckyball.” This spherical molecule consists of 60 carbon atoms forming a cage connected via hexagonal and pentagonal rings of carbon. Richard Smalley and his colleagues, who discovered C60 in 1985, were awarded the Nobel Prize in Chemistry in 1996, celebrating the arrival of this new type of chemical nanomaterial. Within a few years, the buckyball was followed by carbon nanotubes, a 1D form of the tubular-shaped hexagonal carbon ring that was discovered in 1991 by Sumio Iijima. Unlike their predecessor, nanotubes immediately attracted the attention of many physicists as an idealization of quantum wires that can confine electrons in a 1D system. Nanotubes also carry the promise of many potential applications. Their excellent electronic, optical, thermal, chemical, and mechanical properties, resulting from reduced dimensionality, have inspired the use of this technique in the development of a wide variety of devices. Interestingly, the 2D form of carbon nanomaterial, graphene, was theoretically hypothesized by the Canadian physicist, Philip W. Anderson, more than 60 years ago. However, the actual experimental discovery was made only 10 years ago. In late 2004, Andre Geim and Konstantin Novoselov at Manchester University experimentally demonstrated the existence of 2D graphene, later winning the 2010 Nobel Prize in Physics.

Graphene is a two-dimensional, hexagonally-arranged layer of carbon that is only a single atom thick. In a way, graphene, which you can find in pencil lead, can be regarded as a three-dimensional (3D) stack of graphene sheets that are held together by weak interactions, often referred to as van der Waals bonding. It is this weak van der Waals binding that allows graphite to be cleaved easily. In fact, the Nobel duo at Manchester University initially used scotch tape to exfoliate a piece of graphite down to the thickness of a few atomic layers to demonstrate the existence of graphene—a procedure that fully exploited the weak interaction between graphene layers.

It turns out that the electronic properties of graphene are exceptional, as well as unique. Although the electrons in graphene are the same electrons that we find in free space, their behavior in graphene is drastically different. The quantum mechanical description of the Bloch wave of electrons in graphene renders a new kind of quasiparticle—a concept used in condensed-matter physics to describe the alteration of the original particle’s properties. Quasiparticles move like electrons that have completely lost their mass, following an analogous description of the Dirac equation. The idea of massless Dirac particles has been used to describe the relativistic quantum mechanical behaviors of spin-1/2 fermions traveling at the speed of light, independent of their energy or momentum. Similar to these relativistic particles, quasiparticles in graphene always move at a constant speed, about 1/300th the “real” speed of light. Except for the scaled down “speed of light,” the quantum dynamics of graphene’s quasiparticles are completely relativistic. This analogy mapping to the Dirac equation of electrons in graphene, however, can be rather intriguing since many “high-energy” experiments can be realized in the setting of a condensed-matter physics laboratory. For example, the Klein tunneling of Dirac fermions, a relativistic quantum tunneling through a barrier, enables a perfect tunneling of Dirac fermions through any barrier due to the particle-antiparticle pair generation at the interface. Experimentally, Klein tunneling has already been observed in graphene devices fabricated using the microfabrication techniques described above.

Following the discovery of graphene, several other crystals, also only one atomic layer thick, have been created in laboratories using similar experimental approaches. In fact, it turns out that nature provides us with many different “flatlands.” In these layered systems, as we’ve seen in graphene, strong covalent chemical bonds exist within the single atomic layer, and weak van der Waals (vdW) forces hold the different layers together. This exciting news is that these vdW materials can exhibit very diverse electronic behaviors. Some of these materials are semiconductors with exceptional magnetic properties, some are superconductors at relatively high temperatures, and some are strongly correlated metals exhibiting exotic charge density waves. Building on graphene research, we are now exploring the new world of physics enabled by this emerging class of reduced dimensional material systems.

Furthermore, the recent advent of vdW material systems has also given rise to a new type of heterogenous quantum material with atomically sharp interfaces. As discussed above, one unique feature of vdW materials is their rich functionality in 2D electronic systems. Historically, reduced dimensional semiconducting structures have been fabricated in a top-down method in which a larger system splits into smaller ones. A completely different approach, the bottom-up assembly method of nanotechnology, was first used in nanoscience and technology starting in the 1990s. The bottom-up method, when applied to materials science and chemistry, assembles molecules to create larger material structures. Among these material structures, carbon-based nanostructures have attracted the most interest. The first kind of carbon nanomaterial was the C60 “buckyball.” This spherical molecule consists of 60 carbon atoms forming a cage connected via hexagonal and pentagonal rings of carbon. Richard Smalley and his colleagues, who discovered C60 in 1985, were awarded the Nobel Prize in Chemistry in 1996, celebrating the arrival of this new type of chemical nanomaterial. Within a few years, the buckyball was followed by carbon nanotubes, a 1D form of the tubular-shaped hexagonal carbon ring that was discovered in 1991 by Sumio Iijima. Unlike their predecessor, nanotubes immediately attracted the attention of many physicists as an idealization of quantum wires that can confine electrons in a 1D system. Nanotubes also carry the promise of many potential applications. Their excellent electronic, optical, thermal, chemical, and mechanical properties, resulting from reduced dimensionality, have inspired their use in the development of a wide variety of technologies. Interestingly, the 2D form of carbon nanomaterial, graphene, was theoretically hypothesized by the Canadian physicist, Philip W. Anderson, more than 60 years ago. However, the actual experimental discovery was made only 10 years ago. In late 2004, Andre Geim and Konstantin Novoselov at Manchester University experimentally demonstrated the existence of 2D graphene, later winning the 2010 Nobel Prize in Physics.

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The Hofstadter butterfly is a butterfly-shaped fractal energy spectrum. Fractals are infinitely repeating, self-recursive geometrical structures. They often appear in complex classical systems but rarely in the quantum mechanical world.

Capitalizing on the weak vdW interaction between two separate single-atom-thin vdW layers, we can simply stack them to form a heterogeneous blend of materials. This atomic stack can provide ample opportunities for the realization of novel collective interfacial quantum phenomena.

One interesting example of these new interfacial phenomena is our recent experimental realization of “Hofstadter’s butterfly.” Predicted by Douglas Hofstadter in 1976, the Hofstadter butterfly emerges when electrons are confined to a 2D sheet and subjected to a periodic potential and a strong magnetic field. The Hofstadter butterfly is a butterfly-shaped fractal energy spectrum. Fractals are infinitely repeating, self-recursive geometrical structures. They often appear in complex classical systems but rarely in the quantum mechanical world. In fact, the Hofstadter butterfly was one of the first quantum fractals theoretically postulated in physics. In the past, experimental efforts to study the Hofstadter butterfly attempted to use artificially created structures to achieve the required periodic potential energy. In our experiment, we used an effect called a moiré pattern that arises naturally when two similar atomic lattices overlap. We stacked a single atomic layer of graphene on top of a boron nitride (BN) substrate, which has the same honeycomb atomic lattice structure as graphene, to create a vdW heterostructure with a periodic potential. (See figure page 10.) We mapped the graphene energy spectrum by measuring the electronic conductivity of the heterostructure at very low temperatures in extremely strong magnetic fields. For this experiment, we had to travel to the National High Magnetic Field Laboratory, where we could use a large magnet with immense magnetic fields—up to 35 Tesla, consuming 35 megawatts of power. Remarkably, our measurements showed the predicted fractal energy spectrum pattern, providing the strongest direct evidence to date of the Hofstadter butterfly.

From the early days of graphene and other 2D materials research, Harvard has been a powerhouse in exploring reduced-dimensional materials and their heterostructures. Recently our research has been further accelerated by the Center for Integrated Quantum Materials (CIQM), a science and technology facility funded by NSF. The mission of CIQM is to study extraordinary new quantum materials with striking nonconventional properties. (See the CIQM sidebar for further details.) My research group, located in the Laboratory of Integrated Science and Engineering (LISE), one of Harvard’s most advanced laboratory buildings, has been an active participant in CIQM-sponsored programs. At CIQM, we are developing functional heterostructures of different 2D vdW materials to investigate the interaction between various correlated vdW layers.

In condensed-matter physics, fundamental discoveries can often be directly applied to engineering. Professor Edwin H. Hall, the discoverer of the Hall effect, joined the faculty in 1881 and served as a Professor of Physics at Harvard University from 1895 to 1921. His seminal work on measuring Hall resistance, the ratio between the transverse voltage to the longitudinal current, experimentally confirmed the existence of a magnetic force on a moving charge. It also gave rise to many practical applications. The Hall effect is one of the essential tools in characterizing semiconductors in the electronic industry. His work also provided the basis for the discovery of the integer and fractional quantum Hall effects a hundred years later, as mentioned before.

Interestingly, Professor Hall’s experiment was made possible by using what was then considered a “thin” metal film to increase the current density to amplify weak signals. The thin specimen that brought him his initial success was gold leaf, which was about a micrometer thick and was probably the thinnest material that physicists could reliably access in his time. Today, we are investigating a much thinner specimen—only a monolayer thick—and possibly the thinnest material we can ever find. Just as the Hall’s gold leaf was the lynchpin to his success, the heterogeneous vdW quantum structures have given us a glimpse of exciting new interfacial quantum effects and potential applications. These promising new findings have hinted at the prospect of “stacked Flatlands,” which could yield both exciting new physics and many technological advances in the coming years.

The Science & Technology Center for Integrated Quantum Materials was created in October 2013 through a 5-year renewable grant from the National Science Foundation.

**MISSION**

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For Philip Kim, Small is Beautiful—and Interesting
by Steve Nadis

Physics Professor Philip Kim has long been fascinated by the behavior of materials, and, for him, the smaller those materials get the more fascinating that behavior becomes. At really small scales—approaching the level of individual atoms and molecules—quantum effects become significant, and that’s when the story gets even more interesting.

In the late 1980s, Kim was just starting college at Seoul National University in Korea when high-temperature superconductivity was discovered. Superconductivity is a quantum mechanical property of certain materials, which lose all electrical resistance when cooled below a critical temperature. Kim stayed in Seoul to pursue graduate work in high-temperature superconductors, earning a master’s degree in 1992.

Two years later, after fulfilling his mandatory military requirements in Korea, Kim started an applied physics doctoral program at Harvard, hoping to continue this same line of research. He joined the laboratory of Harvard chemist Charles Lieber. “It was a natural fit for me in terms of interest,” Kim says. “But back then, in the mid-1990s, it was somewhat unusual for a physics student to work in chemistry.” Although some people told him that would be an unwise career move, he notes, “I was naive enough not to worry about that. And, in hindsight, I was lucky to be there.”

During his time in Lieber’s lab, Kim shifted his focus from superconductors to new nanomaterials of “low dimensionality,” such as one-dimensional carbon nanotubes. He learned, among other things, how to grow these materials from scratch.

Meanwhile, across Oxford Street in the physics complex, researchers led by Michael Tinkham and Robert Westervelt were pursuing a different approach: They started with relatively large semiconducting and superconducting materials and carved them down until they reached the nanometer scale. Kim was intrigued by that strategy, and after getting his PhD in 1999, he decided to investigate these so-called “mesoscopic” methods during a postdoc at Berkeley.

Before completing his postdoctoral studies, where he developed new microfabrication techniques for measuring thermal properties of carbon nanotubes, Kim contemplated the next stage: opening up the tubes into two-dimensional sheets called graphene, a material that was still hypothetical. He explored this notion at Columbia, following his appointment as an assistant professor in 2002. Graphene, if it could be made, would be like a single atomic sheet of graphite, consisting of hexagonal rings of carbon arranged in a surface.

Finally, he and his graduate student hit upon an idea: Perhaps they could lay down a sheet of graphite simply by writing with a mesoscopic scaled carbon pencil. Their paper on this subject came out in 2004, but a team from Manchester University in the UK, headed by Andre Geim, had carried out similar experiments, achieving somewhat better results, as Kim put it. Within a year, however, both his team and Geim’s team independently observed some remarkable features of graphene, including the fact that its electrons move as if they have no mass and can thus be treated as relativistic particles.

This discovery, the first demonstration of the “quantum Hall effect” in graphene, offered a novel way to study relativistic physics in tabletop experiments. A boon in graphene research ensued, with Kim helping to lead the charge.

While this work has been “really exciting,” he says, “graphene is just a beginning, as nature provides many other examples of low-dimensionality.” For example, he has synthesized organic crystals that come in layers. The crystals can then be pared down to single layers, which are stable enough to be studied. “You can take these layers and stack them together to create new materials that have never been seen before,” says Kim.

After hearing about the latest, exciting direction that Kim’s research had taken, Harvard asked him to come back. Kim accepted the offer, joining the faculty in 2014. “And here I am,” he says, “setting up shop on the other side of Oxford Street”—the physics side, which had been his intention all along.
Before embarking on graduate study, he wrote to several universities, but money was tight. "Well, I had to get a scholarship. So I wrote letters and again I think Lark-Horovitz helped me there and wrote to two or three different places for a graduate scholarship and got a reply from Harvard that said I forget what they called it... but it was just first tuition. I think it was $400. I had to consult my parents and see if they thought they could swing the rest of it. So... I knew where I was going to be the next year. I was coming to Harvard."

Once there, Ed first took a mathematics course (Math 13) and nearly couldn’t do anything. "I couldn’t solve a quadratic equation."

"Oldenberg’s lab course I remember. That was a nice course. In fact, for me again that course was something so new and lovely in that we didn’t have to write lab reports. And there at Purdue, God, as an engineering student, I had to write lab reports all the time. And I don’t like lab reports."

He also audited a course in cosmology by A. N. Whitehead, who was still here, "a beautiful gentleman. I didn’t get very much out of it. I did see if they thought they could swing the rest of it. So... I knew where I was going to be the next year. I was coming to Harvard."
This year, the Harvard Graduate Women in Science and Engineering (HGWISE) program celebrated its 10th anniversary. Since its creation in 2005, HGWISE has grown into an organization with over 2000 members, including over 50 active board members across more than 30 departments from both the Cambridge and Longwood campuses.

From informal social and networking events to workshops and career panels, HGWISE focuses on career development, community involvement, and advocacy for women and other minority groups. HGWISE also runs the largest mentoring program at Harvard, with mentors including Harvard faculty, postdocs, and alumni working in different industries in the Boston area.

HGWISE EVENTS

HGWISE is known for the numerous and diverse events it organizes on campus. HGWISE holds informal coffee hours that allow students to talk with interesting female faculty members and women working in science outside of academia. These exchanges provide opportunities for students to ask and learn about ways to succeed in their professional and personal lives. Some notable figures who have participated in these sessions include Professor Melissa Franklin, the previous chair of the physics department, as well as Professor Cherry Murray when she was the Dean of the Harvard School of Engineering and Applied Sciences. HGWISE organizes career panels to inform students of a wide array of career options, including academia, teaching, management consulting, data science, and other niche areas such as technological consulting. HGWISE holds professional development workshops on topics such as assertiveness, networking, negotiation, and “imposter syndrome.” In addition, there are numerous personal enrichment and social activities throughout the year, including pumpkin carving, strength training, belly dancing, beer tasting, ice cream socials, and more. In both professional and social settings, HGWISE has fostered a community where women scientists and engineers can discuss their interests and support one another.

ADVOCACY EFFORTS

In addition to creating a community among women graduate students, HGWISE also advocates for the interests of graduate students at large. HGWISE has been a major force in raising the awareness of gender issues and driving policy changes at Harvard. In particular, HGWISE worked with the GSAS administration and the Graduate School Council to establish a paid parental time-off policy for graduate students in 2013. It has also been pushing for improvements to the sexual harassment policy at the university level, in addition to working with GSAS to better educate students, faculty members, and staff members about these policies. Over the past two years, a growing number of departments have been provided with relevant resources on sexual harassment. The topic of harassment was also addressed at the Graduate School of Arts and Sciences incoming students’ orientation for the first time in 2014 Fall. The continuing effort of HGWISE on advocacy has led to gradual improvements in graduate student life.

Empowering Female Graduate Students in Physics and Science Through Advocacy and Mentorship

by Jean Fan, Julia Rogers, and Jing Shi
EMPOWERING FEMALE GRADUATE STUDENTS

MENTORING PROGRAM
One of the highlights of HGWISE is its Mentoring Program. When navigating a career in the male-dominated realm of science, female graduates often face challenges that are not present for their male counterparts. On the other hand, it is also difficult for female graduate students to connect with suitable female mentors due to the relatively small number of women in professorships and higher-up industry positions in a wide range of science, technology, engineering, and mathematics (STEM) fields. The HGWISE mentoring program matches graduate students with mentors in a variety of careers and positions. It also provides resources for support for mentoring groups by organizing workshops on effective mentoring and by hosting other informal get-together events on campus for mentoring groups.

Since its inception in 2008, the program has grown dramatically to include 73 mentors and 137 mentees in the 2014-2015 academic year. Mentors include female faculty members, alumni working in different industries, postdoctoral scholars, and a few male faculty members. Mentoring teams are paired up based on responses to detailed questionnaires concerning the backgrounds and preferences of both mentors and mentees.

Mentors advise mentors and provide academic support in various ways by giving advice for qualifying exams, attending the student’s talks, and generally acting as an outside sounding board on scientific matters. Mentors from outside academia help mentees explore career options and can connect them with contacts in different areas. To recognize the dedication of exceptional mentors, the Mentor of The Year award is given out at the annual mentoring program dinner in May. As one of the mentors noted during the nomination of her mentor this year: “She shows us what’s behind the curtain of being a professor ... and most of all, she truly listens to us, cares about us, makes time for us, and is thoughtful about guiding the mentoring group to discuss topics that matter to us. She’s been a steady, calming, inspiring, insightful, nonjudgmental presence throughout my graduate career.” The HGWISE mentoring program fosters personal relationships within mentoring groups that can continue well beyond graduation.

OUTLOOK
Over the last few decades, the environment for women in STEM has improved tremendously, but obstacles still remain. Research studies point to persistent unconscious biases resulting from decades of cultural conceptions of women and their capabilities. These biases tend to arise in the initial hiring and selection stages, resulting in a lower representation of women in a number of industries, including those in STEM fields. HGWISE strives to level the playing field for women in science by raising awareness of unconscious biases and other factors that create subtle and not-so-subtle barriers for women in STEM fields. HGWISE continues to empower women and minorities in overcoming adversity through collaborations with groups such as Women in Science at Harvard-Radcliffe (WISHR) and Minority Biomedical Scientists of Harvard (MBSH), as well as with outside nonprofit organizations such as cuSTEMized (cuSTEMized.org) that encourage young girls interested in STEM fields. Beyond these collaborations, HGWISE advocates for the implementation of university policies that support women in academia, including improved sexual harassment education, increased parental leaves, and access to affordable childcare options. Through these efforts, HGWISE acts as a wide-reaching network that is active within Harvard and the surrounding community, working toward improving the STEM work environment for all genders and creating a fairer gender balance.

HGWISE
www.hgwise.org
hgwise@gmail.com
HGWISE mailing list: To register for weekly emails about upcoming HGWISE events, outreach opportunities, and off-campus women-in-science events, please visit: http://listserv.usc.harvard.edu/subscribe/hec

Mentoring program:
HGWISE is always looking for mentors from both academia and different industries outside academia. If you would like to join our mentoring program as a mentor, please contact: hgwisementors@fas.harvard.edu

HGWISE is grateful for the support from the Harvard Graduate School of Arts and Sciences (GSAS), Harvard Integrated Life Sciences (HILS), Graduate Student Council (GSC), Harvard College Women’s Center (HCWC), and Biomedical Graduate Student Organization (BGSO).

Against the backdrop of the crimson brick walls, new theories are born, cultivated, and disseminated. This is where Andy Strominger, a pioneer in quantum gravity, black holes, and string theory, as well as an avid and caring teacher, works with graduate students and postdocs to tackle problems in modern physics.

Strominger believes we are in the middle of an exciting and revolutionary era of physics, reminiscent of the early twentieth century when general relativity and quantum mechanics gradually supplanted Newtonian classical mechanics. He has recently been instrumental in exciting new developments in black hole physics and quantum field theory (QFT). In particular, he uncovered an infinite number of exact symmetries of nature that had previously gone unnoticed. Interpreted correctly, these symmetries simplify our understanding of the universe and provide us with powerful new computational tools. The Strominger group is exploring their rich mathematical structure, tracing out physical implications, and actively exploring ways in which upcoming experiments may test these new symmetry principles. This line of investigation promises to have applications in a broad range of contexts, including the black hole information paradox, jet physics at the LHC, string theory, the holographic structure of spacetime, gravity wave experiments, and the Event Horizon Telescope.
Black holes are among the most fascinating objects in our universe. They result from the collapse of sufficiently massive stellar objects. Nothing, not even light, can escape their gravitational pull, and the surface delineating the point-of-no-return is called the event horizon.

Critical Behavior of Spinning Black Holes

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Graduate students Temple He, Pratik Mitra, and Monica Pate are currently studying soft theorems and symmetries in quantum electrodynamics and non-abelian gauge theories, while Daniel Kapou, Shauna Paskert, and Ana Racaita are studying soft theorems and symmetries in quantum gravity. These projects continue to expose surprising new connections between scattering theory in particle physics and the asymptotic symmetries first explored in general relativity, efficiently bridging the two disparate fields.

Soft theorems and asymptotic symmetries in gravity are alternate manifestations of yet a third phenomenon, discovered by Zeldovich and Polnarev in the 70s, known as gravitational memory. When a gravity wave passes through a detector, it locally warps space and time, causing oscillating distortions in clocks and measuring sticks. Interestingly, even after the wave has passed and the oscillations have ceased, there remains a net spatial displacement at the end of the interferometer: they retain a “memory” of the gravitational wave’s passage. Panstrui, Strominger, and postdoc Alexander Zhukov successfully showed that classical memory effects of general relativity are also consequences of the soft scattering theorems and hence have their origin in symmetry principles as well. This insight led them to the discovery of a new type of gravitational ‘spin’ memory. Experimentalists hope that a new generation of detectors, such as the proposed evolved Laser Interferometer Space Antenna (eLISA), will observe some of these effects.

Critical Behavior of Spinning Black Holes

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While Strominger is well known for studying the thermodynamics of string theoretic black holes, he is currently investigating more realistic astrophysical black holes. Such black holes generically rotate, and in the process drag spacetime around with them: the closer one comes to the black hole, the harder it is to maintain a fixed angle relative to a distant observer. A black hole that rotates at its maximally allowed velocity exhibits an infinite-dimensional geometrical symmetry, known as conformal symmetry, in the high-redshift region near its horizon. This constitutes an example of critical behavior in astrophysics. The same infinite-dimensional conformal symmetry emerges, in much the same fashion, in a wide variety of condensed matter systems near low-energy critical points. Our group hopes to find observable signals of this critical behavior.

Graduate students Bruno Baldizan, Alex Luponawa, Achilles Polychroniadis, and Lily Shi, together with postdocs Sam Girado and Maria Rodrigues, are exploiting this symmetry to obtain exact, analytical solutions describing a wide range of black hole phenomena. This analytic symmetry-based approach also proved fruitful in a related astrophysical problem. The sky contains a variety of objects, such as pulsars and quasars, that produce extravagantly energetic signals like collimated jets of electromagnetic radiation. In many cases, the energy source powering these signals is suspected to be a rapidly rotating black hole where the energy extraction takes place. Once again appealing to the conformal symmetry, new exact solutions to these equations were found. As an application of these results, and with help from colleagues in the astronomy department, Strominger’s group hopes to predict what the Event Horizon Telescope will see when it images the supermassive black hole at the heart of the nearby galaxy M87. These techniques are also being employed to predict the luminosity as a function of redshift for the iron line emission from the rapidly spinning black hole at the center of the nearby galaxy MCG-6-30-15.

Black Hole Information

Fundamental new scientific challenges arise when the effects of quantum mechanics on black holes are considered. As famously shown in the 1970s, a quantum black hole has an entropy proportional to the area of its event horizon. In this respect, black holes are radically different from other physical systems, whose entropies typically scale with their volumes. A longstanding open problem in quantum gravity is to count black hole microstates and hence derive the area entropy law from statistical mechanics. This is related to the ‘infamous’ so-called “black hole information puzzle” — the apparent conflict between quantum mechanical unitarity and the impossibility of retrieving information from behind an event horizon.

Progress in this direction was made in 1997 when Strominger and his colleague Cumrun Yafa famously calculated the black hole entropy statistically for a special class of supersymmetric black holes in string theory. Yafa and Yafa showed that string theory and supergravity imply conformal symmetry, and in turn used universal properties of conformal systems to count microstates. The next challenge is to repeat this success for astrophysical black holes. Recently it has been understood that in the case of rapidly rotating black holes, the emergence of conformal symmetry can be deduced, and microstates thereby counted, without assuming string theory. Currently, graduate students Abhishek Pathak and Achilles Polychroniadis, along with postdoc Oscar Yanda, are subjecting this proposal to stringent tests through an analysis of quantum corrections. The insights into asymptotic symmetries and soft theorems are also highly relevant to the black hole information puzzle. The conservation laws associated with the symmetries impose an infinite number of constraints on the Hawking radiation emitted by the black hole, thereby enhancing its information-carrying capacity. In the process, they reveal the existence of an infinite amount of quantum “hair” on all black holes. The evident implications for the black hole information puzzle are currently under investigation by Strominger, in collaboration with Cambridge colleagues Stephen Hawking and Malcolm Perry.
“Never trust anyone over 30” was a popular saying from the 1960s, although graduates of that era may now have a different perspective. The theorist Andrew Strominger, Harvard’s Gwill E. York Professor of Physics, is a former member of the “Flower Power” generation who turned 60 this past summer. A conference in his honor—attended by scores of physicists from all over the world—was held on July 30th, his actual birthday, and on July 31. (See box, “Andy Fest 2015.”)

As a kid, the younger Strominger and his brothers spent hours playing in their father’s various labs in the U.S. and England. As a high school student, Strominger read the Feynman Lectures on his own and was also inspired by an enthusiastic physics teacher, an immigrant from Mexico. Despite his interest in the subject, Strominger says, “it was hard to focus on physics in the era of sex, drugs, and rock & roll.”

Strominger finished high school early, at the age of 15, and joined a commune in New Hampshire where he grew organic vegetables. “I wasn’t planning to be a physicist,” he says, “but the knowledge that physics and math came easily to me was something I didn’t forget.” He entered Harvard as an undergraduate but went back to the commune after his freshman year, staying for about a year-and-a-half until the commune collapsed. He returned to Harvard for another year, studying Chinese and general relativity, among other things, before heading to China where he worked on a commune, in a factory, and as a reporter for a communist newspaper. He had hoped to understand the communist system, but after six months abroad he found the experience confounding. “I came out of that not knowing how I could contribute to the world through social movements,” he says.

Strominger returned to Harvard again, at the age of 19, this time determined to become a theoretical physicist. A self-professed “seeker,” he concluded that he was unlikely to figure out the meaning of life but might still make some inroads into deep questions about the physical universe. “My advisors didn’t think I had what it takes, because I had strayed too long,” he says. “But I didn’t listen to them.”

As a physics graduate student at MIT, Strominger also ignored the counsel of his thesis supervisor, Roman Jackiw, who told him that if he pursued his interest in quantum gravity—an attempt to merge quantum mechanics and general relativity—he would never get a job. But Strominger has fared spectacularly well in this area, turning out a steady stream of advances in string theory—a proposed theory of quantum gravity—and related topics. While introducing Strominger at an MIT colloquium, Jackiw admitted to being grateful his former student had disregarded that advice, with many important developments in physics occurring as a result.

**ANDY FEST 2015**

In late July, some 180 physicists from fourteen countries in North America, Europe, and Asia joined a gathering at Harvard to honor Professor Andrew Strominger on the occasion of his 60th birthday. The event was officially called “Black Holes, Holography, and Strings” though more affectionately referred to as “Andy Fest 2015.” Attendees came from as far as India and China—and from as near as the office across the hall from Strominger’s—to celebrate his scientific contributions and passion for physics. Speakers included several current Harvard physics faculty (Cumrun Vafa and Xi Yin) and former faculty (Nima Arkani-Hamed, Frederik Denef, Juan Maldacena, and Shiraz Minwalla). Current and former students (including Dimitris Anninos, Thomas Hartman, Alexander Maloney, Giam-Seong Ng, and Sabrina Paterski) also spoke on their mentor’s behalf. Peng Gao, a mathematical physicist at Harvard, called Strominger “a role model for many people in the field, certainly myself” and someone whose presence was “both very moving and scientifically enriching.”
Imagine you’re sitting in a classroom learning physics—you might be in a lecture hall, with fixed seats, or perhaps in a small classroom surrounded by chalkboards. Everyone is seated, except the instructor. Now picture yourself in a research lab or workshop, surrounded by all kinds of equipment, with students wandering around, tinkering, soldering, building, measuring, computing. The space is humming with activity. Can you imagine a classroom with that kind of energy and vitality?

This was the question that Professor Melissa Franklin and I considered back in 2011 when she was department chair. During the previous several years, we had worked with other faculty to create innovative lab experiences for students in our key introductory physics sequence (Physics 15). Students were no longer doing “cookbook” labs: they were working on independent projects, building models, writing computer simulations, and presenting their work to their peers.

So we wanted a “black-box” classroom that could inspire innovation both in teaching and in learning. With a generous grant from the Harvard Initiative for Learning and Teaching (HILT), and additional support from the Faculty of Arts and Sciences, we tore down (asbestos-laden) walls that had previously divided our teaching lab spaces on the third floor of the Science Center and created a new, 2500-square-foot open space. This space, dubbed “SciBox,” has three rules: First, it must remain unfinished, with mostly unpainted walls and exposed utilities in the ceiling. Students should feel free to build things, including drilling into the walls or ceilings. Picture, for example, a warehouse or garage where entrepreneurs might start a new tech company. Second, everything on the floor must be on wheels, including the lab benches. Nothing is fixed or permanent. Third, and most important, anyone can use the space for anything, with priority given to activities that actually take advantage of the flexible nature of the classroom.

Since the fall of 2012, SciBox has been in nearly constant use. The new Physics 15 labs meet here: students can seamlessly move between lab benches, discussion tables, chalkboards, and presentation screens. Since the fall of 2012, SciBox has been in nearly constant use. The new Physics 15 labs meet here: students can seamlessly move between lab benches, discussion tables, chalkboards, and presentation screens. So we wanted a “black-box” classroom that could inspire innovation both in teaching and in learning. With a generous grant from the Harvard Initiative for Learning and Teaching (HILT), and additional support from the Faculty of Arts and Sciences, we tore down (asbestos-laden) walls that had previously divided our teaching lab spaces on the third floor of the Science Center and created a new, 2500-square-foot open space. This space, dubbed “SciBox,” has three rules: First, it must remain unfinished, with mostly unpainted walls and exposed utilities in the ceiling. Students should feel free to build things, including drilling into the walls or ceilings. Picture, for example, a warehouse or garage where entrepreneurs might start a new tech company. Second, everything on the floor must be on wheels, including the lab benches. Nothing is fixed or permanent. Third, and most important, anyone can use the space for anything, with priority given to activities that actually take advantage of the flexible nature of the classroom.

With the success of the original SciBox, we have created two similar spaces—two other SciBoxes—on the first floor of the Science Center. Now all of our introductory labs are taught in these flexible spaces, and we have had visitors from across Harvard and from other institutions who want to adopt similar designs for their classrooms. The idea of a totally flexible classroom isn’t new: As a recent participant in a teaching conference pointed out, this is how kindergarten rooms have been designed for years. But by creating this space at Harvard, we have inspired our teachers and students to think differently about what it means both to teach physics and to learn physics.
New methods for experiments with ultracold atoms in optical lattices enable the characterization and manipulation of complex quantum systems on the level of individual particles. Achieving such an exquisite level of control allows researchers in the Greiner group to engineer novel quantum states of matter and explore the fundamentals of quantum mechanics.

Experiments with ultracold atoms in optical lattices are tackling some of the most pressing questions in physics: the emergent phase and collective behavior of quantum mechanical systems with many strongly interacting constituents. Such phases, which are notoriously difficult to treat theoretically due to the breakdown of classical numerical simulations for large quantum systems, can now be realized directly in experiments. Using the highly specialized tools and techniques from atomic physics research, physicists build correlated quantum systems in a particle-by-particle manner and even engineer novel, “synthetic” quantum matter with unusual properties not found in nature.

The creation of quantum, many-body systems with neutral atoms has established a new connection between atomic physics and condensed-matter physics. Theoretical tools originally developed for solid-state systems are now used to understand the properties of ultracold atomic systems. Conversely, experiments with optical lattices can implement condensed-matter Hamiltonians with new features and tunable parameters. This continuous exchange has brought two fields of research together, leading to extremely fruitful experimental and theoretical efforts.

Markus Greiner’s group has pioneered quantum gas microscopy that enables high-resolution readout and manipulation of cold atomic gases in optical lattices. Using a special microscope setup pioneered in our lab, we can directly image individual atoms in their many-body environment. Recently, our group has developed novel methods based on holographic beam shaping and adaptive optics to create arbitrary potential landscapes and even to manipulate single atoms in the optical lattice.

This leads to the unprecedented situation in which a system of many interacting particles can be controlled and imaged on the level of individual quanta. Attaining ultimate control over many particles combines the wealth of many-body quantum mechanics with the high level of control of quantum information processing devices, thereby providing a unique platform to explore the fundamentals of many-body quantum mechanics.

To enter the world of quantum mechanics, where coherent motion dominates over thermal fluctuations, atomic gases have to be cooled to the lowest temperatures ever achieved. Our experiments are performed at temperatures on the nanokelvin scale, one billionth of a degree above absolute zero. Clouds of about 10^4 atoms at these ultra-low temperatures can be produced by laser and evaporative cooling. Throughout the experiment the atoms are held in magnetic or purely optical traps in an ultrahigh vacuum to keep these fragile quantum states isolated from the environment. Meeting the requirements for successful cooling and trapping of atoms is a formidable challenge, which requires control over frequency-stabilized lasers, high-power electronics, vacuum technology, and control electronics. Teams of three to four graduate students and postdocs run the experiments to ensure that scientific ideas and technical developments come together to open new research directions.

With all these tools in hand, there are many ways to get creative and elicit interesting quantum states. Cold atoms in a lattice can be shaken, stirred, exposed to disorder, coupled to different internal states, or driven to excited manifolds—and often these tools can be combined to yield surprising new results. We were very excited to find that applying a strong gradient to Mott insulating states can realize a spin model, where the position of each atom encodes a spin state. Based on theoretical work by Subir Sachdev and collaborators, we were able to observe a quantum phase transition within this spin model: As an external field is tuned, quantum fluctuations, which persist even at zero temperature, drive the system from one spin phase to another through highly correlated states at the phase transition point.

One of the most exciting aspects of quantum gas microscopes is their ability to manipulate individual atoms in the lattice. This technique lets us assemble the building blocks of quantum systems one particle at a time, and allows us to play a “quantum Lego” game: We place atoms in the optical lattice in an interesting configuration, and then let them evolve and interact with each other as we track their motion under the microscope. This gives rise to some very curious scenarios. For example, two non-interacting bosons placed next to each other will “bunch up” and be detected close to each other with much higher probability than can be explained classically. This interference effect, a unique signature of the quantum statistics of the particles, can be observed very cleanly in the quantum walks of two particles. Interestingly, when the particles are allowed to interact with each other, this behavior is completely reversed, and the particles avoid each other over long distances.
Quantum gas microscopy has become widespread worldwide. Within the last few months alone, eight new quantum gas microscopes have been completed," he says, "That is fantastic, because I want other people to use this technology." His goal, all along, has been to encourage experimentation in this area—and thereby create a dynamic, interactive environment—rather than to stifle it. That philosophy has paid off. He and his fellow practitioners have conjured up a range of novel materials, affording insights into quantum physics and other areas. Applications in quantum computers, high-temperature superconductors, and materials science in general may be just around the corner.

In some ways, the origins of this work can be traced back to his high school days, when Greiner started experimenting with light waves and holograms and seeing how two different waves interfere with each other, either constructively or destructively. "I later learned that quantum mechanics is just the same," he says. "Matter waves also interfere constructively and destructively." From there, his interest in the interplay of entanglement and particle number fluctuations, with interesting connections to fields as far removed as cosmology. This continuous interaction between theory and experiment, sparked by the implementation of new observable tools, is one of the major appeals of studying many-body systems in optical lattices.

In the coming years, novel experimental systems will take center stage in research with ultracold atoms. A major breakthrough has recently been achieved by our team working on a Fermi gas microscope. While lithium’s small mass and its atomic structure make it very challenging to image, the team has now reached single-atom resolution in a two-dimensional lattice geometry and is excited to start experimenting with strongly interacting Fermi systems. Such experiments are closely linked to current research in condensed-matter Fermionic atoms in an optical lattice directly mimic the physics of electrons in a solid moving through a crystal lattice formed by ionic ions. The new experiment in our group will study microscopic observables and correlation functions in the Fermi-Hubbard model and explore the formation of magnetic order at extremely low entropies. Entirely new Hamiltonians can be implemented with particles that interact over long distances. Promising candidates include atoms with large magnetic moments and dipole-dipole interactions, such as the Rb atoms being used in a current experiment in our group.

The availability of such techniques will open new frontiers for ultracold atoms, including the quantum simulation of models from high energy physics, and establish connections to even more diverse fields of research.

Markus Greiner’s Research is Ultra Cool

by Steve Nadis

While we can learn a great deal from such small, well-controlled systems, the really interesting and counterintuitive features of quantum mechanics emerge when many particles are allowed to interact. Through their coherent motion, such many-body systems can become entangled: parts of a quantum mechanical system can be perfectly correlated over arbitrarily large distances, appearing to interact via “spooky action at a distance”—type phenomena. In many-body systems, entanglement arises to create highly unusual and fragile states of matter—a feature that makes it the main resource required for quantum information processing and quantum communication.

By exploiting the ability to control the dynamics of individual particles, we are working toward a very general scheme to measure the amount of entanglement in many-body systems. Entanglement and quantum correlations can be associated with a type of entropy, resulting in the paradoxical, and classically impossible, situation whereby a part of a system carries more entropy than the system as a whole. Allowing two copies of the same quantum mechanical state to interfere can enable direct measurements of this entropy in a one-dimensional bosonic system and its constituent parts, allowing us to place bounds on the entanglement in different many-body phases. Such measurements can address important questions regarding the interplay of entanglement and particle number fluctuations, with interesting connections to fields as far removed as cosmology.
As Cambridge emerged from the deep freeze last spring, our undergrad concentrators in physics and in chemistry and physics came together twice—first to educate interested freshmen about the concentrations and then a couple of weeks later, on Visitas weekend, to give prefrosh the real scoop. It is always wonderful to see this terrific group of young science students share their enthusiasm for physics.

NEW CONCENTRATORS
The Physics Department welcomed a new group of 47 sophomores who signed up for the Physics and Chem/Phys concentrations this past year, many of them pursuing joint concentrations or secondaries in other fields. In addition to subjects like Astrophysics, Mathematics, and Computer Science, these fields include Sociology, Literature, and English.

PRIZES & AWARDS
Emma Dowd, AB ’15 received a National Science Foundation Fellowship and will be studying physics at Berkeley. John Sturm, AB ’15 will be studying Economics at Cambridge as Harvard’s annual Paul Williams Fellow. John was also last year’s recipient of the Physics Department’s Sanderson Award, which is presented to the graduating Physics concentrator with the highest grade average in concentration courses.

STUDENTS’ RESEARCH
This summer, the number of Physics and Chem/Phys concentrators who stayed on campus to undertake full-time research hit an all-time high of 40. These students worked in physics, chemistry, engineering, and related fields. Year after year, the funding for physics undergraduate summer research is made possible, in no small part, due to the generous gifts of James Neuber, AM 1955, PhD 1960, who established the Haase Family Fund, and the family and friends who established a fund in memory of Stephen Brook Fels, AB 1962, AM 1963, PhD 1968.

Andrew Lin, a rising junior, pursued exciting research last summer. Continuing work he had done during the past year in the laboratory of Professor Robert Westervelt, Lin focused specifically on condensed-matter physics and quantum nanomaterials. Working under the supervision of Dr. Sagar Bhandari, Andrew’s project centered on the fabrication of graphene-on-boron nitride heterostructures for analysis via scanning-probe microscopy. A two-dimensional hexagonal lattice of carbon atoms, graphene has made waves in the world of physics due to properties such as its uniquely tunable band-gap and high electron mobility. Characteristics like that make graphene ideal for studying the fundamental physics of electron motion in two-dimensional electron gas layers (2DEGs). This research could ultimately lead to tremendous advances in computing technology: graphene is touted as a future successor to the silicon-based, complementary metal-oxide semiconductor (CMOS) systems used in present day computing. Graphene acquires special significance in medical research as well, with potential applications for nanoscale power sources, biosensors, and circuits in truly nanoscale medicine. In this way, the opportunity to work with the Westervelt Group has played a central role in solidifying Andrew’s interest in continuing with research in a medical post-graduate program.

CAREER PATHS
This past year’s graduating class consisted of 48 Physics and Chem/Phys concentrators. Fourteen of these students headed off to graduate school at ten different institutions to study Physics, Astrophysics, Applied Math, Chemistry, Biochemistry, and Economics. Others are now attending medical school, and still others have joined the workforce in software, consulting, aerospace, finance, teaching, and various startups.

FUN STUFF
The Society of Physics Students was active again last year with many events, including numerous physics-minded movie nights on the big screen in Jefferson 250, the annual pumpkin drop, a hugely successful liquid nitrogen ice cream party during the Visitas weekend, a Harvard/Yale SPS board game mixer, as well as a Women in Math and Physics board game event co-sponsored with the Harvard Undergraduate Mathematics Association. Plans for this year include a graduate mentor program and the reintroduction of the Physics Table—a regular dinner at which students present talks on physics topics they find interesting.
THE PHD CLASS ENTERING IN 2015

The new students entering the Physics PhD program in Fall 2015 were remarkable for their geographic diversity, hailing from the American states of Alaska, California, Connecticut, Florida, Illinois, Indiana, Massachusetts, North Carolina, New Jersey, New York, Texas, Virginia, Washington, and Wisconsin. Incoming students born outside the United States came from Canada, China, Germany, India, Italy, Norway, Romania, Serbia and Montenegro, South Korea, Syria, and Taiwan.

THE PHYSICS GRADUATE STUDENT COUNCIL

Created by Physics PhD students in the spring of 2009, the Physics Graduate Student Council has continued to be an integral 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 current president is Jae Hyun Lee, and its other members (in alphabetical order) are Erin Dahlstrom, Nick Langellier, Olivia Miller, Joe Olson, Anna Patej, and Arthur Safira.

NEW INITIATIVES

To help new graduate students learn more about research going on in the department and make connections with more senior graduate students in a variety of labs, the Physics Graduate Student Council put together a new annual poster session on January 26 in the department’s library. The council held a second poster session on March 31 during the open house for prospective PhD students. Following another proposal by the Physics Graduate Student Council, the department also organized its first annual graduate student panel on research and the qualifying exam. Held on February 23 and moderated by Dr. Jacob Barandes, Associate Director of Graduate Studies, the panel members (in alphabetical order) were graduate students Ruffin Evans, David Farhi, Elizabeth Jerison, Sarah Kostinski, Tomo Lazovich, and Alex Lupsasca. The panelists—who were all in either their fourth or fifth year of the PhD program and represented fields including biophysics, atomic physics, quantum gravity, applied math, and particle physics—talked about their experiences getting into research, finding advisors, and taking the qualifying exam. They also fielded questions from the first- and second-year graduate students in the audience.

2015 CONFERENCE OF THE NATIONAL SOCIETY OF BLACK PHYSICISTS (NSBP)

The departments of Physics and Applied Physics, joint co-sponsors of this year’s conference of the National Society of Black Physicists (NSBP), were represented at this event by several faculty members, staff members, and students. In attendance this year from Harvard’s Physics department were Prof. Vinothan Manoharan (Director of Graduate Studies), Dr. Jacob Barandes (Associate Director of Graduate Studies), Lisa Cacciabaudo (Graduate Program Administrator), Carol Davis (Undergraduate Program Coordinator), as well as PhD students Patrick Jefferson (quantum gravity) and Rodrick Kuate Defo (computational physics), and undergraduate sophomore Olumakinde Ogunnaike (physics-math joint concentrator). Representing Harvard’s Applied Physics department were Dr. Kathryn Hollar (Director of Educational Programs), Gloria Anglou (Assistant Director of Diversity and Student Engagement), as well as PhD students Serrel Massenburg (soft-matter physics) and Suhare Adam (material science).

2015 NORTHEASTERN SATELLITE CONFERENCE FOR UNDERGRADUATE WOMEN IN PHYSICS (CUWiP)

The annual Conference for Undergraduate Women in Physics (CUWiP) consists of several satellite conferences, all run simultaneously in different regions of the country. The department was represented at the 2015 northeastern satellite conference on January 18 by Dr. Jacob Barandes (Associate Director of Graduate Studies) and Lisa Cacciabaudo (Graduate Program Administrator), as well as by PhD students Ellen Klein (soft-matter physics) and Elise Novitski (atomic and low-energy particle physics).
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.

Dennis Huang

2015 GOLDHABER PRIZE WINNER

Dennis Huang received his BSc in Physics and Mathematics at the University of British Columbia in Canada, where he was awarded the Governor General’s Silver Medal in Science. His first exposure to condensed-matter experiments came about in his sophomore summer, when he spent hours using a microscope to search for 2D graphene flakes in Prof. Joshua Folk’s lab. He went on to further work fabricating gated graphene devices and investigating quantum transport in these systems at cryogenic temperatures.

At Harvard, Dennis has continued his research in condensed-matter physics in Prof. Jennifer Hoffman’s lab, but this time in the context of a 2D high-temperature superconductor: single-unit-cell FeSe, grown on SrTiO3. He spent the first part of his PhD setting up a combined molecular beam epitaxy (MBE) and scanning tunneling microscope (STM) system, housed in a floating room for vibration isolation in the basement of LISE. He distinctly remembers the slightly overwhelming experience of standing in an empty room in January 2013 and progressing toward the development of a fully-assembled system eight months later (although it took another ten months before he had a fully-functional system). Currently, Dennis uses spectroscopic STM imaging of defect-induced quasiparticle interference in FeSe/SrTiO3 in order to uncover its electronic structure and superconducting pairing mechanism. He is also performing ab initio simulations of atomic defects in FeSe under the guidance of Prof. Efthimios Kaxiras in order to complement the STM data.

Bo Liu

2015 GOLDHABER PRIZE WINNER

Bo Liu finished his PhD in January 2015, with a PhD secondary field in Computational Science and Engineering, and was the winner of the IACS scholarship for computational research. Bo finished his undergraduate study at the University of Science and Technology of China in June 2010, majoring in Applied Physics (condensed-matter physics), where he was twice awarded the National Scholarship for academic excellence.

Bo entered Harvard’s PhD program in the fall of 2010 and joined Prof. Eric Heller’s group to pursue theoretical and computational research. Bo’s PhD research focused on scattering theory in two-dimensional electron systems and plasmonic systems. He worked on explaining an experimentally observed stability of electron transport in two dimensions with classical chaotic dynamics. He also solved an inverse scattering problem in which a prespecified light-scattering wave pattern can be achieved by manipulating the positions of a collection of metallic nanoparticles.
Goldhaber Prize

Siyuan Sun

Siyuan Sun wanted to be a physicist ever since he heard about special relativity in high school. As a freshman at Duke University, he began working for Prof. Ashutosh Kotwal on the Tevatron, which was then the most powerful particle collider at Fermilab.

Now in Harvard’s PhD program, Sun works at the Large Hadron Collider with Prof. Melissa Franklin. Last year, Sun was part of the team that measured the width of the Higgs mass distribution at ATLAS. In his current project, he is working to improve reconstructions of physical processes in which large numbers of particles are undetectable by the detector. He is also involved in monitoring and maintaining the ATLAS detector itself.

Shu-Heng Shao

Shao was an undergraduate student at National Taiwan University in Taipei, Taiwan, where he studied theoretical physics. Shao’s general research interests include quantum field theory, string theory, supersymmetry, and mathematical physics. At Harvard, Shao works with Prof. Xi Yin on various aspects of holographic dualities, and, in particular, the AdS/CFT correspondence, which includes supersymmetric matrix quantum mechanics and little string theory. Shao has also had the opportunity to work with Mboyo Esole and Prof. Shing-Tung Yau in the Math and Physics Departments on the relation between geometric singularities and phase transitions in quantum field theory. In another collaboration with Junior Fellow Clay Córdova, he studied the problem of counting ground states in supersymmetric quantum mechanics, which has broad applications on the counting of BPS states in four-dimensional supersymmetric quantum field theories.

GSAS Merit Fellowship

Ruffin Evans

Ruffin Evans is a fourth-year PhD candidate in the research group of Prof. Mikhail Lukin. A native of Charlottesville, Virginia, Ruffin graduated from the University of Virginia with degrees in both Physics and Chemistry. As an undergraduate, Ruffin was recognized as the top student in his graduating class and also received awards for best undergraduate research in both chemistry and physics. Ruffin obtained support for this research through a Goldwater Scholarship, a prestigious national award for STEM undergraduates.

At Harvard, Ruffin’s research focuses on integrating color centers in diamond with nanophotonic optical cavities. These nanostructures increase the interaction between light and individual color centers, allowing the light to be efficiently controlled on the single-photon level. This work has applications in classical and quantum information technology, where the realization of low-power optical nanomachines remains an outstanding challenge. Ruffin’s research was previously supported by the National Science Foundation through the Graduate Research Fellowship Program.

Tomo Lazovich

Tomo Lazovich did his undergraduate work at Harvard. He first worked with Prof. Melissa Franklin on the CDF experiment at the Tevatron collider at Fermilab, where he developed new online tools for monitoring the detector. Later, he worked with Prof. Franklin and Prof. Joao Guimaraes da Costa on the ATLAS experiment at the Tevatron collider at Fermilab, and he helped to commission the operations of the muon system with cosmic rays and write a senior thesis on the identification and rejection of the cosmic-ray muon background in ATLAS. His thesis won Harvard’s Hoopes Prize.

Continuing in the graduate program, Tomo stayed on the ATLAS experiment with Prof. Guimaraes da Costa. He analyzed data taken in 2011 and 2012 from the LHC to search for the signature related to the production of the Higgs boson, the last missing piece of the Standard Model—the theory describing all of the known fundamental particles and their interactions. In July 2012, the ATLAS and CMS experiments jointly announced the discovery of the Higgs. Tomo went on to analyze that particle’s properties in the two-W boson decay channel with the full dataset from Run 1 of the LHC. Now that “Run 2” at the LHC is underway, Tomo has been using the newly discovered Higgs to search for unknown physics beyond the Standard Model. In particular, he is searching for heavy particles that decay into two Higgs bosons, which subsequently decay into two bottom quarks each. This research holds the potential to shed light on some of the unanswered questions in particle physics and will also help us learn more about the nature of the Higgs particle itself.
Recent Graduates

David Isaiah Benjamin
Thesis: Impurity Physics in Resonant X-Ray Scattering and Ultracold Atomic Gases
Advisor: Eugene Demler

Glad Ben-Shach
Thesis: Theoretical Considerations for Experiments to Create and Detect Localised Majorana Modes in Electronic Systems
Advisors: Bertrand Halperin (chair); Amir Yacoby (co-chair)

Willy Chang
Thesis: Superconducting Proximity Effect in Anka Nanowires
Advisors: Charles Marcus (Univ. of Copenhagen chair); Robert Westervelt (Harvard chair)

Andrew Higginbotham
Thesis: Quantum Dots
Advisor: Amir Yacoby

Sofia Magkiriadou
Thesis: Structural Color
Advisor: Gerald Gabrielse

Michael Dean Shulman
Thesis: Entanglement and for Conventional and Topological Qubits
Advisor: Vinny Manoharan

Chia Wei Hsu
Thesis: Novel Trapping and Scattering of Light in Resonant Nanophotonic Structures
Advisors: Marin Soljačić (MIT chair); Adam Cohen (Harvard chair)

Marsela Jorgolli
Thesis: Cooling, Collisions and Non-Sticking of Polyatomic Molecules in a Cryogenic Buffer Gas Cell
Advisor: John Doyle

William R. Spearman
Thesis: Measurement of the Mass and Width of the Higgs Boson in the H → ZZ to 4l Decay Channel Using Per-event Response Information
Advisor: Joao Guimaraes da Costa

Jeffrey Douglas Thompson
Thesis: Small Diatomic Alkali Molecules at Ultracold Temperatures
Advisor: Wolfgang Ketterle

Gyeyoun Chung
Thesis: Exploring Black Hole Dynamics
Advisor: Lisa Randall

Hyeysun Jang
Thesis: Nanoscience Magnetic Materials for Energy Efficient Spin Based Transistors
Advisors: Marc Baldo (MIT chair); Robert Westervelt (Harvard chair)

Ilya Eric Alexander Feige
Thesis: Factorization and Precision Calculations in Scattering Theory: From Chaos to Resonance
Advisor: Eric Heller

Andrew Higginbotham
Thesis: Quantum Dots for Conventional and Topological Qubits
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Chia Wei Hsu
Thesis: Novel Trapping and Scattering of Light in Resonant Nanophotonic Structures
Advisors: Marin Soljačić (MIT chair); Adam Cohen (Harvard chair)

Marsela Jorgolli
Advisor: Hongkun Park

Krzysztof Nowojewski
Thesis: Pathogen Avoidance by Caenorhabditis elegans is a Pheromone-Mediated Collective Behavior
Advisor: Erez Levine

Julia Hege Piskorski
Thesis: Phase Transitions in Range Expansions and Evolution
Advisor: David Nelson

Kevin Michael Mercurio
Thesis: A Quantum Interface for Optical Metafluids
Advisor: Vinny Manoharan

Andraž Kazimierz Nowojewski
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Advisor: Erez Levine

Krzysztof Nowojewski
Thesis: Phase Transitions in Range Expansions and Evolution
Advisor: David Nelson

Nadine M. Romdāl
Thesis: High Luminosity Faraday Cups
Advisor: John Huth

Tina Tauso Wang
Thesis: A Quantum Interface between Single Atoms and Nanophotonic Structures
Advisor: Mikhail Lukin

Goldhaber Prize
Dennis Huang
Bo Liu
Shu Hong Shao
Siyuan Sun

RSAS Merit Fellowship
Ruffin Evans
Tomo Lazovich
Hertz Foundation Fellowship
Sabrina Pasterski
National Science and Engineering Graduate (NSF) Fellowship
Laurel Anderson
Aaron Kabcanell

Natural Sciences and Engineering Research Council (NSERC) of Canada Fellowship
Solomon Barkley
Scott Collier
Alexandra Thomson

National Science Foundation Graduate Research Fellowship Program (NSF GRFP)
Ellen Klein
Sabrina Pasterski
Abigail Plummer
Emma Rosenfeld
Julia Steinberg
Elena Urbach

Smith Family Graduate Science and Engineering Fellowship
Sam Dilanou
TUSA Fellowship
Yu-Ting Chen

Graduate Student Awards and Fellowships

Comprendre la physique
David Cassidy, Gerald Holton, and James Rutherford, 2014
Presses polytechniques et universitaires romandes

A History in Sum: 150 Years of Mathematics at Harvard (1825-1975)
Steve Nadis and Shing-Tung Yau
Harvard University Press, 2013

This book—the first French translation of Comprendre la physique—provides a thorough grounding in contemporary physics, placing the subject into its social and historical context. Based largely on the highly respected Project Physics Course developed by two of the authors, it incorporates the results of recent pedagogical research. The text introduces some basic phenomena in the physical world and the concepts developed to explain them. It shows that science is a rational human endeavor with a long and continuing development. The heady mathematical concepts that emerged, and the men and women who shaped them, are described here in lively, accessible prose. “There is perhaps no better book for immersion into the curious and compelling history of mathematical thought,” wrote Brian Greene, a Professor of Physics and Mathematics at Columbia University.

The Art of Electronics
Third Edition
Paul Horowitz and Winfield Hill
Cambridge University Press, 2015

At last, here is the thoroughly revised and updated third edition of the 26th Art of Electronics—widely accepted as the single most authoritative book on electronic circuit design. In addition to enhanced, up-to-date coverage of many topics, the latest edition contains much new material, including 90 oscilloscope screenshots illustrating the behavior of working circuits, 1,100 figures, and 80 tables. The current version of this book retains the feeling of informality and easy access that helped make earlier editions so popular. It is an indispensable reference for anyone, student or researcher, professional or amateur, who works with electronic circuits.

In the twentieth century, American mathematicians began to make critical advances in a field previously dominated by Europeans. Harvard’s mathematics department was at the center of these developments. A History in Sum is an inviting account of the pioneers who trailblazed a distinctly American tradition of mathematics. The heady mathematical concepts that emerged, and the men and women who shaped them, are described here in lively, accessible prose. “There is perhaps no better book for immersion into the curious and compelling history of mathematical thought,” wrote Brian Greene, a Professor of Physics and Mathematics at Columbia University.

The HARVARD PHYSICS MENTOR NETWORK

A new initiative within the Physics Department aims to make the task of finding a professional career a better experience for graduate students and research scholars—a category that includes Post-Docs, Research Associates, Junior Fellows, Visiting Scholars, Associates, Affiliates, and Fellows.

Graduate students and scholars can take part in this initiative in at least two ways. First, the department is creating a list of physics alumni who have offered to answer questions about what work is like in particular industries and in different countries, suggesting steps someone might take to prepare for a career in a given field. To contact any of these individuals, please get in touch with Bonnie Currier (bcurrier@fas.harvard.edu). Although these people have generously volunteered to help, please be respectful of their (limited) time. And please consider becoming a mentor yourself when you move on to new positions. For those alumni who want to be added to the volunteer list, please provide your current email address, appointment title, institution (university, industry, etc.), research field(s)/subfield(s), and the date of your PhD. That’s all we need. Thank you!

The second way to tap into this initiative is through the Official Group for the Harvard Physics Community at LinkedIn (https://www.linkedin.com/groups/4-499923). Be sure to identify yourself as a Physics Graduate Student or Research Scholar in your profile. You can remain in this group as an alumnus. We hope you’ll find these resources and networking opportunities helpful. We world, of course, appreciate any feedback on how the Department of Physics can best support your career development.

Following last year’s highly successful gathering, the Harvard Physics Department’s research scholars came together on September 17, 2015 for the third annual Post-Doc/Research Scholar Retreat. Nearly 60 scholars enjoyed this day-long event at the historic MIT Endicott House in Dedham, MA, a magnificent rural setting for reflection and discussion. The day began with the levy challenge of having to give one-minute introductions about group collaborations. A diverse range of individual and collaborative projects were exhibited in the poster session. Scholars had time for recreation and a fun, science-based trivia game.

Invited speakers were Mr. Dennis Overbye, Deputy Science Editor, The New York Times, and Dr. Simona Roli, Program Manager at the U.S. Department of Energy, Office of Science, and Office of High Energy Physics. Harvard’s very own Roy J. Glauber, Mallinckrodt Research Professor of Physics, was the keynote speaker.

This event was organized by post-docs from our research scholar cohort, who also serve on our research scholar advisory committee, in conjunction with the Department’s Research Scholar Coordinator.

THE HBS MOUNT EVEREST SIMULATION

Last January, thirty of our Research Scholars organized into teams of five to tackle a virtual Mount Everest. Led by Willy Shih, Robert and Jane Clink Professor of Management and Practice at the Harvard Business School, this team-based simulation led the scholars through a “six-day” climb in two hours, during which participants worked together, overcoming many obstacles in order to reach the “summit.” Those who took part in this effort found their leadership, decision making, and team building skills challenged at practically every step of their virtual ascent, but almost all found the experience rewarding.

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The second way to tap into this initiative is through the Official Group for the Harvard Physics Community at LinkedIn (https://www.linkedin.com/groups/4-499923). Be sure to identify yourself as a Physics Graduate Student or Research Scholar in your profile. You can remain in this group as an alumnus. We hope you’ll find these resources and networking opportunities helpful. We world, of course, appreciate any feedback on how the Department of Physics can best support your career development.

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In this fascinating exploration of our cosmic environment, Lisa Randall, a particle physicist and New York Times bestselling author, uses her research into dark matter to illuminate startling connections between the furthest reaches of space and life on Earth. Randall suggests that the comet—which crashed into the Earth 66 million years ago, killing off the dinosaurs—might have been dislodged from its orbit in the Solar System by passing through a disk of dark matter embedded in the Milky Way. Her book thus raises an astonishing (although admittedly speculative) proposition: Dark matter could have played a role in wiping out the dinosaurs.

Jim MacArthur derives great satisfaction from connecting diverse research groups. “I think that one of most important functions of the e-shop is that it is a mechanism of collaboration between research groups, not just in the Department of Physics staff, highlighted in the Lukin, Yacoby, Loncar, and Walsworth groups, as well as in the instructional lab in the Science Center, and labs at Wellesley, Columbia, Howard University, Lincoln Labs, and several local start-ups. They all need variations on the same basic instrument, which advances efficient energy use and a reliance on renewable sources.” And he goes on: “One of the fun parts of this job is finding an instrumentation solution that solves several problems in several different labs, and then using that instrument as a way to foster a certain amount of communication between the groups. An example is the nitrogen-vacancy-center research done in the Lukin, Vavylonis, Loncar, and Walsworth groups, as well as in the instructional lab in the Science Center, and labs at Wellesley, Columbia, Howard University, Lincoln Labs, and several local start-ups. They all need variations on the same basic instrument, an agile synthesizer around 2.8 GHz.”

Jim enjoys his role at Harvard, remarking that, coming after his earlier experiences, “designing things that professionals use to do their job better” is, in some sense, a “captain's job.” Perhaps that explains why those of us in the buildings on weekends often see Jim in his lab, finishing up instruments for his many scientific clients.

Honoring More Than 125 Years in Physics

Carol Drenn, Jan Ragusa, Darley Maynard, and Barbara Drauschke

It was another banner year for the Department of Physics staff, highlighted by a combined celebration of four milestone birthdays, as shown. Seasoned veterans Barbara Drauschke, Carol Davis, Darley Maynard, and Jan Ragusa all turned 65 in 2015, hosting a fun-filled party, complete with historic photos and a generous feast, that only they could muster. These women have served the Department with distinction for a collective total of 126 years and 135 years for the University at large. We are so grateful for their service and excited about the next chapter in their careers. The historic knowledge they carry is remarkable, from first-hand reflections of dictating correspondence for Professor Norman Ramsey and Professor Francis Pipkin to the early days of mathematical physics, when Professor Jaffe was delighted to learn that Ms. Drauschke knew how to type mathematical equations, and Professor Gabrielse had yet to have three children. We owe an incredible debt to these dedicated women, and the Department has been forever transformed by their diligence and longstanding commitment.

World-Class Circuit Designer

Jim MacArthur

Following some 15 years of circuit design experience at high-end manufacturers like HP, Data General, and Lexicon, Jim MacArthur founded our Electronic Instrument Design Lab (EIDL), which is now in its 15th year. He educates graduate students in all aspects of circuit design, as well as devising state-of-the-art instruments for laboratory research. MacArthur’s devices have populated laboratories both at Harvard and at more than 25 institutions in the US and abroad (including MIT, Princeton, Stanford, and Yale, and universities in Australia, Canada, Denmark, Germany, Israel, Japan, Netherlands, Switzerland, and the UK).

Jim’s output is prodigious—more than a thousand laboratory instruments (many of which seriously push the limits of performance achievable with contemporary technology), spread over some thirty research groups in Physics and SEAS. In the words of several of his professional clients, “The electronics shop has enabled precision measurements that were previously beyond our reach.” On so many occasions we have collaborated with Jim to build custom-made instrumentation that has made our work possible. There really isn’t anything that Jim can’t do.” In my opinion, Jim MacArthur ranks among the very best things at Harvard. He brings to our group unique capabilities and is simply implacable. He is profoundly important, both in terms of research and education of my students. The electronics shop remains one of my FAVORITE things at Harvard. Jim is excellent, knowledgeable, fan friendly, accessible. A perfect 10. And (somewhat more succinctly): “We are fortunate to have this world-class circuit designer as our academic collaborator.”

Circuit-design education is a major part of EIDL’s charter, and the graduate students fairly gush with enthusiasm: “My experience with EIDL has been nothing short of awesome. Jim is fantastic, and has served extraordinarily well in the dual roles of teacher and engineer...” What is particularly remarkable is not only that he can answer any question I have with an expert answer, nuanced with subtleties about particular parts, but that he is so willing to be helpful and put up with my own incompetence.”

Flanking the ladies, two seasoned veterans look back on their collective 126 years. Seasoned veterans Barbara Drauschke, Carol Davis, Darley Maynard, and Jan Ragusa all turned 65 in 2015, hosting a fun-filled party, complete with historic photos and a generous feast, that only they could muster. These women have served the Department with distinction for a collective total of 126 years and 135 years for the University at large. We are so grateful for their service and excited about the next chapter in their careers. The historic knowledge they carry is remarkable, from first-hand reflections of dictating correspondence for Professor Norman Ramsey and Professor Francis Pipkin to the early days of mathematical physics, when Professor Jaffe was delighted to learn that Ms. Drauschke knew how to type mathematical equations, and Professor Gabrielse had yet to have three children. We owe an incredible debt to these dedicated women, and the Department has been forever transformed by their diligence and longstanding commitment.

From The Great Wall To The Great Collider: China and the Quest to Uncover the Inner Workings of the Universe

Steve Nadis and Shing-Tung Yau

International Press, 2015

The 2012 discovery of the Higgs boson was a sensational triumph—capping off a 48-year-long search that completed the so-called “Standard Model” of particle physics. While the celebrations were still underway, researchers in China were laying the groundwork for a giant accelerator—up to 100 kilometers in circumference—that would transport physics into a previously inaccessible, high-energy realm where a host of new particles, and perhaps a sweeping new symmetry, might be found. This book describes the ambitious, international effort to build a “Great Collider,” which could provide a fuller understanding of our universe’s origins and its most basic constituents.

The Energy Revolution: The Physics and the Promise of Efficient Technology

Mara Prentiss

Harvard University Press, 2015

Energy can be neither created nor destroyed—but it can be wasted. The United States wastes two-thirds of its energy, including 80 percent of the energy used in transportation. So the nation has a tremendous opportunity to develop a sensible policy, based on benefits and costs, which advances efficient energy use and a reliance on renewable sources. Energy Revolution presents the science, as well as the political and technical information, needed to support a bold claim: Wind and solar power could generate 100 percent of the “United States” average total energy demand for the foreseeable future, even without waste reduction.

Dark Matter and the Dinosaurs: The Astounding Interconnectedness of the Universe

Lisa Randall

Ecco, 2015

In this fascinating exploration of our cosmic environment, Lisa Randall, a particle physicist and New York Times bestselling author, uses her research into dark matter to illuminate startling connections between the furthest reaches of space and life on Earth. Randall suggests that the comet—which crashed into the Earth 66 million years ago, killing off the dinosaurs—might have been dislodged from its orbit in the Solar System by passing through a disk of dark matter embedded in the Milky Way. Her book thus raises an astonishing (although admittedly speculative) proposition: Dark matter could have played a role in wiping out the dinosaurs.

Celebrating Staff

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Jim’s output is prodigious—more than a thousand laboratory instruments (many of which seriously push the limits of performance achievable with contemporary technology), spread over some thirty research groups in Physics and SEAS. In the words of several of his professional clients, “The electronics shop has enabled precision measurements that were previously beyond our reach.” On so many occasions we have collaborated with Jim to build custom-made instrumentation that has made our work possible. There really isn’t anything that Jim can’t do.” In my opinion, Jim MacArthur ranks among the very best things at Harvard. He brings to our group unique capabilities and is simply implacable. He is profoundly important, both in terms of research and education of my students. The electronics shop remains one of my FAVORITE things at Harvard. Jim is excellent, knowledgeable, fan friendly, accessible. A perfect 10. And (somewhat more succinctly): “We are fortunate to have this world-class circuit designer as our academic collaborator.”

Circuit-design education is a major part of EIDL’s charter, and the graduate students fairly gush with enthusiasm: “My experience with EIDL has been nothing short of awesome. Jim is fantastic, and has served extraordinarily well in the dual roles of teacher and engineer...” What is particularly remarkable is not only that he can answer any question I have with an expert answer, nuanced with subtleties about particular parts, but that he is so willing to be helpful and put up with my own incompetence.”

Jim derives great satisfaction from connecting diverse research groups. “I think that one of most important functions of the e-shop is that it is a mechanism of collaboration between research groups, not just in the department, but throughout Harvard, and for that matter, the world,” he says. “When students ask about the best capacitor for cryogenic applications, I direct them—sometimes I almost have to force them—to the Gabrielse lab, which has filled a notebook of data on cryogenic capacitor performance.” And he goes on: “One of the fun parts of this job is finding an instrumentation solution that solves several problems in several different labs, and then using that instrument as a way to foster a certain amount of communication between the groups. An example is the nitrogen-vacancy-center research done in the Lukin, Vavylonis, Loncar, and Walsworth groups, as well as in the instructional lab in the Science Center, and labs at Wellesley, Columbia, Howard University, Lincoln Labs, and several local start-ups. They all need variations on the same basic instrument, an agile synthesizer around 2.8 GHz.”

Jim enjoys his role at Harvard, remarking that, coming after his earlier experiences, “designing things that professionals use to do their job better” is, in some sense, a “captain’s job.” Perhaps that explains why those of us in the buildings on weekends often see Jim in his lab, finishing up instruments for his many scientific clients.
Departmental Events

Physics Monday Colloquium

Our weekly colloquia with a single invited speaker is held at 4:15PM in Jefferson 250, preceded by an all-community tea at 3:30PM in the Jefferson Research Library. If you are ever in town, we would be delighted for you to join us. Drop in or email us at: colloquium@physics.harvard.edu

To watch past Colloquia, go to the Monday Colloquium Archive at: https://www.physics.harvard.edu/events/colloq_archive

For a listing of upcoming Monday Colloquia and other seminars and events in the department, check out our Calendar webpage: https://www.physics.harvard.edu/events/gencal

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