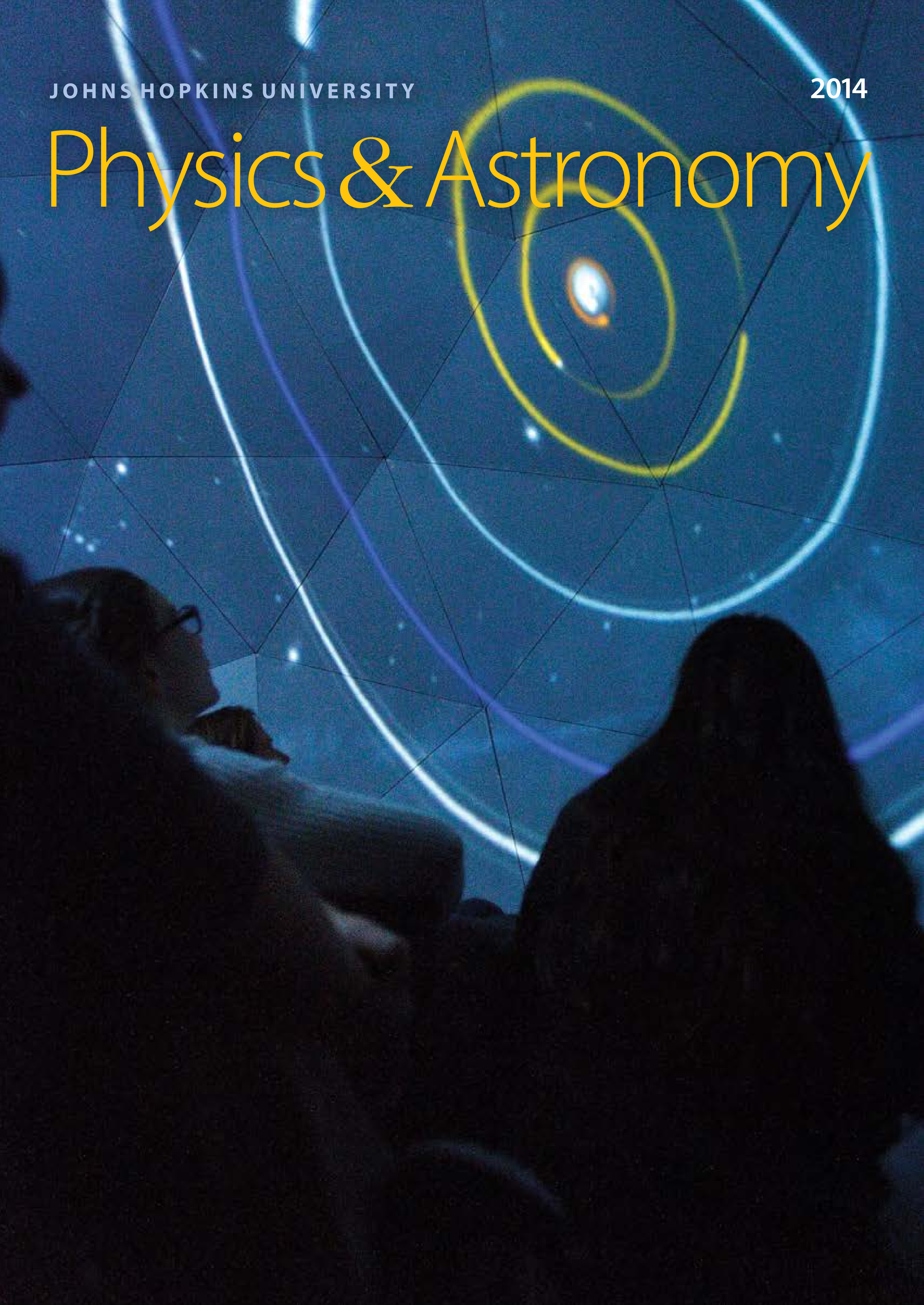
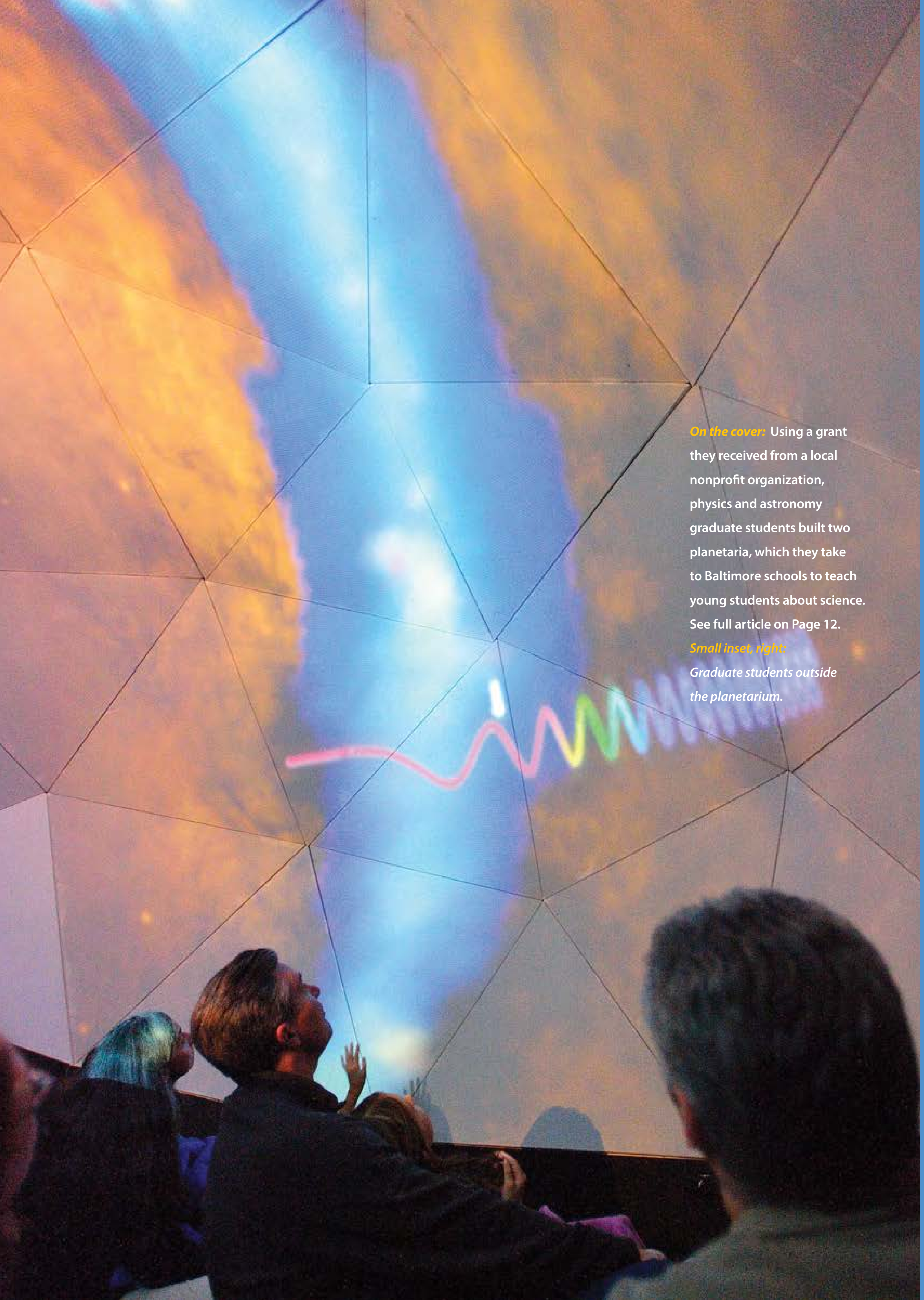
JOHNS HOPKINS UNIVERSITY

2014

Physics & Astronomy





On the cover: Using a grant they received from a local nonprofit organization, physics and astronomy graduate students built two planetaria, which they take to Baltimore schools to teach young students about science. See full article on Page 12. *Small inset, right: Graduate students outside the planetarium.*

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Physics and Astronomy is an annual publication of the Johns Hopkins University Zanvyl Krieger School of Arts and Sciences Department of Physics and Astronomy. Send correspondence to: Kate Pipkin, 3400 N. Charles Street, Wyman 500W, Baltimore, MD 21218 or kpipkin@jhu.edu.

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JOHNS HOPKINS
KRIEGER SCHOOL
of ARTS & SCIENCES

Letter from the Chair

Dear alumni, colleagues, and friends,

This is my last letter to you as chair of the Department of Physics and Astronomy. As many of you may be aware, the position of chair in our department is a rotating one. I'm pleased to announce that the next chair is going to be Timothy Heckman, the Dr. A. Herman Pfund Professor in Physics and Astronomy. Tim will take the lead as department chair beginning July 1, 2015.

Much of Tim's recent work has prepared him well to be chair. As director of our Center for Astrophysical Sciences, Tim has played a key role in positioning the department as a leader in the field of astronomy. He came to Johns Hopkins in 1989, holding a joint appointment as a professor in our department and a tenured astronomer at the Space Telescope Science Institute. Tim's research has focused on the evolution of galaxies and supermassive black holes. He has authored or co-authored more than 600 scholarly publications, which have been cited more than 28,000 times. He currently chairs the Pan-STARRS1 Science Consortium Board and is a member of the Subaru Prime Focus Spectrograph Steering Committee. Tim and I have been working together to ensure that his transition to chair is a smooth one.

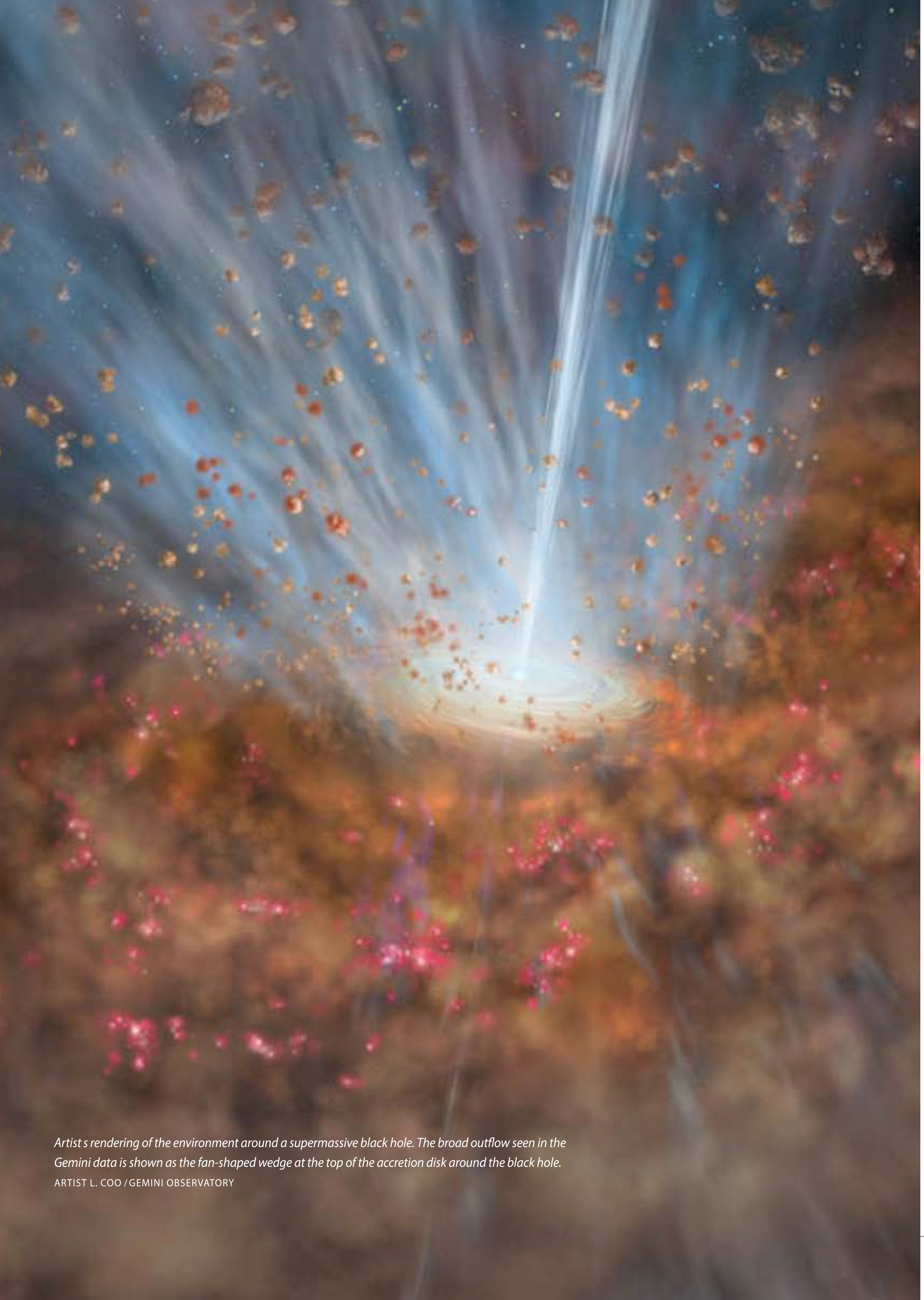
I can truly say that I feel honored to have been chair of this great department for the past six years. We have a tremendous group of faculty, students, and staff, and it is always amazing each year at this time to stop and take stock of what they have accomplished. I hope that you will take a few minutes to peruse this issue to see some of what has been going on.

Most importantly, however, I look forward with excitement to what lies ahead for the department as we continue to advance the cause of physics and astronomy education at all levels, and as we continue our leading impact in many of the key areas of physics and astronomy: the Large Hadron Collider, the quest to define dark matter, exploring the frontiers of big data, probing the origins of the universe, and investigating the mysteries of condensed matter systems, to name a few. The future looks bright!

Thank you once again for your interest in and support of physics and astronomy at Johns Hopkins.

Best,

Daniel Reich, Chair
The Henry A. Rowland Department of Physics and Astronomy



Artist’s rendering of the environment around a supermassive black hole. The broad outflow seen in the Gemini data is shown as the fan-shaped wedge at the top of the accretion disk around the black hole.

ARTIST L. COO / GEMINI OBSERVATORY

Of Quasar Winds and Other Galactic Challenges

BY JOE SUGARMAN

The evening was not going well for astrophysicist Nadia Zakamska. On the cold December night in 2010, she was scheduled for observation time on the Gemini telescope on Mauna Kea in Hawaii. Her proposal was to use the telescope’s new integral field unit spectrometer to collect data on quasar winds, a fresh approach that allows for simultaneous collection of about a thousand spectra of the different parts of an astronomical object; standard fiber spectroscopy, by contrast, gives astrophysicists only one spectrum for an entire astronomical object. But there was an ice storm on the mountain—bad news for good observations—as well as technical issues with the equipment. To make matters worse, once she began collecting data, she was forced to stop. “Another team interrupted our program with something called a target of opportunity observation,” recalls Zakamska, who was a research associate at Stanford University at the time. “Somewhere a supernova went off, and because this was a time-sensitive event, the other team had priority. I was heartbroken. Here’s my precious observing time and all this stuff was happening!”

But when she finally did get her time on the telescope, the results were spectacular. “Immediately, I could tell that something interesting was going on,” says Zakamska, who arrived at Johns Hopkins in 2011 as an assistant professor. “We finally saw those wind signatures that we had been looking for.”

Because of the complexity of the integral field approach, it would be nearly three years before Zakamska and her team crunched all the data and published a series of papers on their observations. Her efforts were rewarded by the American Astronomical Society with the 2014 Newton Lacy Pierce Prize for outstanding astronomical observation achievements by a young astrophysicist over the past five years. The award committee cited her work in observing quasar winds as well as her in-depth observations of Type 2 quasars, the subject of her graduate thesis.

“The active black hole becomes a bomb which sends blast waves through the galaxy.”

—ASSISTANT PROFESSOR NADIA ZAKAMSKA

“It never occurred to me that the [Pierce Prize] was a likely thing to happen,” says Zakamska, who was pregnant with her third child when the first quasar wind papers were published, making her unable to present her research at international conferences. “I knew we were doing really exciting stuff, but it was poorly publicized. … I received this email from David Helfand, the previous president of the AAS and I just didn’t believe it. For a moment, I thought somebody was impersonating him.”

Zakamska and her team now have more than a dozen programs on Gemini and other telescopes and continue to publish papers on quasar winds, a phenomenon occurring in galaxies with active central black holes. As matter gets sucked into a black hole, it produces vast amounts of radiation, which exerts pressure on material around it, resulting in an outflowing wind of surrounding material. “The active black hole becomes a bomb which sends blast waves through the galaxy,” says Zakamska, who studies the effect quasar winds have on the galaxy as a whole, as the winds push matter farther and farther away from the nucleus.

There are still many questions to answer about the nature of quasar winds, from trying to figure out at what point during the evolution of the galaxy the wind starts to how long it lasts to how it affects various processes like star formation—“all very important questions for understanding galaxy evolution,” she says. “In particular, we think this process limits the maximal possible mass of galaxies in the universe.”

Before she started investigating quasar winds, the bulk of Zakamska’s research focused on Type 2 quasars, a certain type of quasar obscured by gas and dust close to the nucleus. As a graduate student at Princeton, using data from the first Sloan Digital Sky Survey, she discovered a large population of Type 2 quasars, objects theorized to exist but of which only a handful were known. “[At the time], they were rare enough that people weren’t taking them seriously,” says Zakamska, who used data from Sloan to look for specific spectral signatures, proving the existence of the new type of quasar. “It’s one thing to discover that something happens rarely in the universe, it’s another thing to discover that it commonly happens. We found that these objects are quite common.”

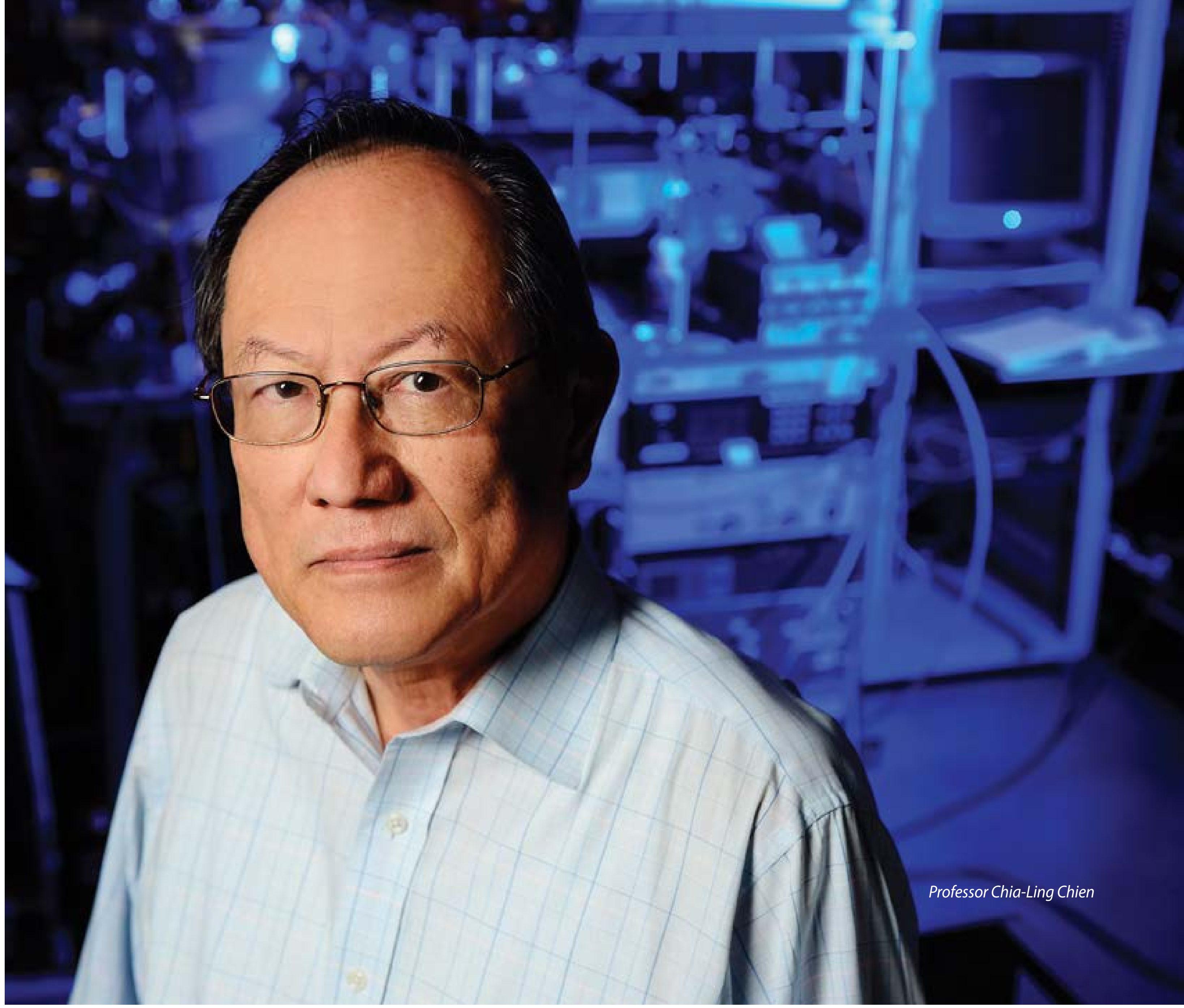
In addition to her research on quasars, Zakamska and a team of Johns Hopkins undergraduates have begun using data from the third generation of the Sloan Survey to investigate the structure of our own galaxy—measuring its spiral structure and the amount of dark matter mass in its halo. If this line of research seems completely unrelated to her past work on quasars, it’s because it is.

“I like to hedge my bets,” she admits, with a laugh. “I like to do things that are completely new. I wonder if anybody has done X. If nobody has, then that’s what I want to do. The data on galactic structure is so new and so different from what anyone has done before; it seems like a very ripe space for discovery.”

Harnessing the Potential of Spin

Chia-Ling Chien makes new discoveries in magnetic physics

BY GABRIEL POPKIN


Professor Chia-Ling Chien

> *"Spin so far is ignored in manipulation of data."*
>
> —PROFESSOR CHIA-LING CHIEN

The information technology revolution of the last quarter century has been built almost entirely on one property of the fundamental electron: its electric charge. But thanks to quantum mechanics, the electron also has a tiny magnetic moment, or spin, that can point "up" or "down," and that could serve as an information carrier. "Spin so far is ignored in manipulation of data," laments Chia-Ling Chien, the Jacob L. Hain Professor.

Chien's research is helping to tap spin's long-neglected promise. His work could lead to advances that dramatically reduce the heat generated by modern electronics and that speed up computer memory. For Chien, however, harnessing spin's potential is just the latest effort in a 30-year career that has touched on almost every branch of magnetism, from superconductivity to giant magnetoresistance to exotic new magnetic materials.

Quantum spin invokes magnetism at its most basic. It gives fundamental particles tiny amounts of rotational or angular momentum, even if the particles themselves are point particles, meaning they cannot "spin" in the conventional sense.

In today's computer technology, waste heat from electric currents in microcircuits is now the main barrier to faster computer processors, Chien says, so finding a more efficient way to transmit digital information is a major industry goal. For example, in a pure spin current, two electrons with opposite spin travel in opposite directions down a wire. The net result is that two units—or "quanta"—of angular momentum flow in the same direction, in the same way that if a positive charge moves in one direction while a negative charge moves in the other, there is a net transfer of two units of positive charge, but in the case of the spin current no net electrical current flows, thereby reducing heat generation.

But spin current is fickle and not easily controlled. Send an electron down a 10-mile wire and its electric charge will be the same on the other end. Its spin, by contrast, will have flipped within less than a hundred microns in the best known materials, due to random interactions with the environment. Chien is working to design new materials that can carry spin currents longer distances without loss of the spin orientation. He is also improving methods for transferring spin information to and from conventional electric circuits.

Chien is also excited about an exotic new magnetic structure, the skyrmion. Predicted in the 1960s and finally discovered a few years ago, the skyrmion breaks all the rules of traditional ferromagnets: In its low-energy state, for example, its magnetic spins point in a spiral instead of aligning linearly. Chien's research group was the first to create a thin-film skyrmion, a necessary step toward any future device application. He is now trying to determine if skyrmions can sustain long-lasting spin currents, as some theorists have predicted.

In addition to helping manipulate data, spin current could open up new ways to store information. Chien studies magnetic tunnel junctions, which take advantage of a property called quantum tunneling, whereby electrons can bridge a tiny energy gap between two materials. Tunnel junctions have the potential to be used as "magnetoresistive random access memory," or MRAM, which, unlike the RAM in your computer, would be stable even when the computer is off. (Commercial hard drives already use magnetic tunnel junctions, but they operate too slowly to be used as RAM).

Development of MRAM has been hampered, however, because the electric currents needed to operate today's junctions are so large that they can damage or destroy the stored information. Chien discovered that a much smaller spin current, in concert with a small voltage, can do the job while preserving the stored data. His insight could aid companies that are racing to introduce the long-sought "universal memory."

Chien emphasizes that as a research physicist, his goal is not to create commercial products. His job is to explore. If one of his results hints at a practical application, he passes the idea to engineers who look for a way to mass-produce it. For many years Chien collaborated with engineers through a National Science Foundation-funded Materials Research Science and Engineering Center at Johns Hopkins. "We can explore things; the worst thing is we fail," Chien says. Industry scientists "don't take such risks."

Chien's ideas have ranged widely within magnetic physics. In 1992, inspired by the 1988 discovery of giant magnetoresistance in layered structures (which set off a revolution in hard drive technology and was recognized with the 2007 Nobel Prize in Physics), Chien showed that the effect also occurs in granular systems, debunking theories that the multi-layered structure was responsible for the effect.

Chien has also studied superconductivity, the property that allows some materials, when cooled to low temperatures, to conduct electricity without resistance. When a new class of iron-based superconductors was fortuitously discovered in 2008 in Japan, Chien was among the first U.S.-based scientists to obtain samples, and showed that the materials displayed an important symmetry property.

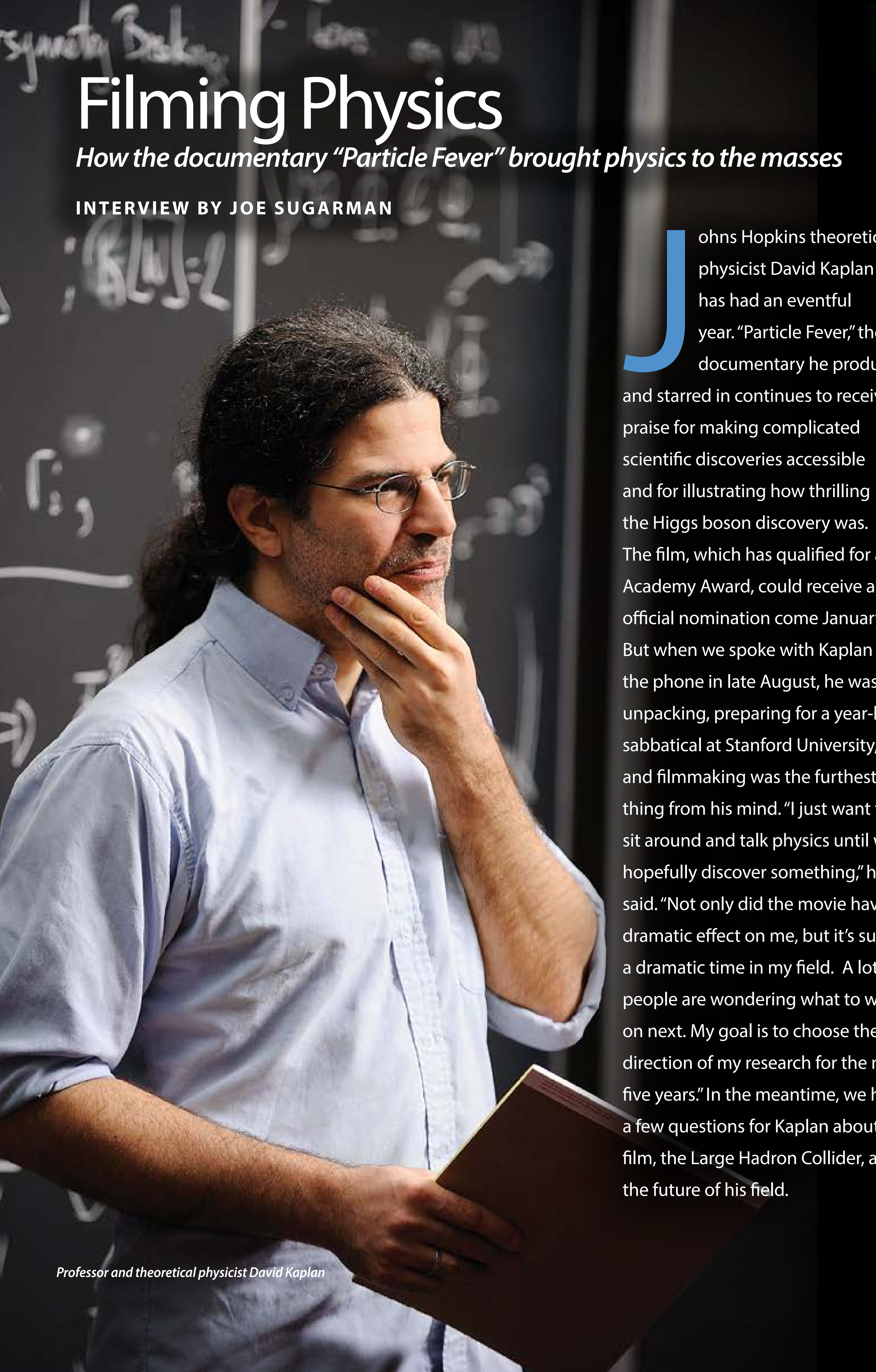
Chien has published more than 400 journal articles, and he is a Fellow of the American Physical Society. He is also a Fellow of the American Association for the Advancement of Science and a 2004 recipient of the David Adler Award of the American Physical Society. But Chien says he is proudest not of the papers that have come out of his lab, but of his students. "Two thirds of them are now university faculty. The rest are in government labs or industrial labs, and they're all doing very well. That gives me a great deal of pride."

That his students have done so well is no accident, though. Chien drills them in how to present their research at conferences and seminars. "The same material, if you give it to different people, the delivery will be totally different. One will knock your socks off; another one could bore you to death," he says. When coaching a student on a presentation, he says, "I may want to hear it three, five, seven, or even more times, until they get it right."

One of Chien's colleagues at Hopkins, theorist Oleg Tchernyshyov, recalls an anecdote: "Every time Chia-Ling comes in in the morning, he goes into the lab and asks what's new. They have to be prepared to tell him something interesting that has happened in their research project. His students are trying hard to surprise him with something interesting."

With characteristic modesty, Chien also attributes his success to picking the right field at the right time. "I'll tell you a true story," he says. "In 1984, when I was a much younger man, a famous physicist visited the department. He asked, 'What do you do?' I said 'I work on magnetism,' and he said, 'That field is dead.' I said 'I also work on superconductivity;' he said, 'That field is also dead.' What he didn't know is that in 1986, the first [high-temperature] superconductor would be discovered. In 1988 [giant magnetoresistance] was discovered…Since 1988 there has been a flurry of activity [in magnetism that has lasted] to this day."

"In that sense I was very lucky," he says. "This thing has been going on for 25 years, my whole career."



Professor and theoretical physicist David Kaplan

Filming Physics

How the documentary "Particle Fever" brought physics to the masses

INTERVIEW BY JOE SUGARMAN

Johns Hopkins theoretical physicist David Kaplan has had an eventful year. "Particle Fever," the documentary he produced and starred in continues to receive praise for making complicated scientific discoveries accessible and for illustrating how thrilling the Higgs boson discovery was. The film, which has qualified for an Academy Award, could receive an official nomination come January. But when we spoke with Kaplan over the phone in late August, he was unpacking, preparing for a year-long sabbatical at Stanford University, and filmmaking was the furthest thing from his mind. "I just want to sit around and talk physics until we hopefully discover something," he said. "Not only did the movie have a dramatic effect on me, but it's such a dramatic time in my field. A lot of people are wondering what to work on next. My goal is to choose the direction of my research for the next five years." In the meantime, we had a few questions for Kaplan about his film, the Large Hadron Collider, and the future of his field.

Q: So how did you go about making particle physics compelling in the movie?

A: The core was that we really wanted to make this a story about a group of people [primarily experimental and theoretical physicists] who were doing something at a dramatic time. … The number one goal in terms of structure was to introduce the characters first. You first have to like the people, and then you're interested in what they're doing because you have an attachment to them.

Q: How did you decide how much physics to include in the film?

A: We argued a lot in the beginning about how much to set up and what not to set up. Our attitude about the science in the film was that the only physics that goes in should help propel the story forward and not just for the sake of teaching people anything.

Q: Have you heard any criticisms about how you portrayed the science?

A: There's been some narrow criticism that we didn't explain enough. Some people watch the film and think they're watching a Nova special, and they'd like to learn all these things in detail. But that was never the intention. We wanted people to feel like they didn't have to understand everything, but they got a sense of what was going on, which allowed them to follow characters through events.

Q: Essentially you were making a movie in real time with no idea about how it was going to end. That must have been a little crazy.

A: [Director] Mark Levinson and I had two totally different attitudes that fit together well. His attitude was that at every stage, assuming we'd run out of money or couldn't continue shooting, could he end the film? Could he use the material he already had and make a movie? He was constantly second guessing what the end would be. For me, I demanded that the movie end once the data from the LHC had an emotional impact on the theorists. The experimentalists would be affected just by the machine working, but I wanted all of the characters to go through something. I started making the movie from the perspective of the theorists—that's me—so I wanted to make the film on what was learned, not just that this big machine works.

Q: You sound as much a filmmaker as theorist now.

A: I'm trying to recover from that!

Q: Do you think a physicist was the only one who could have made this movie?

A: Yes, for sure. If you come from the outside, you feel like you have to explain the physics, that that's the important part. Mark has a PhD in physics and I'm in the thick of it, so we knew what the human story was. It's really hard to see through this complicated vernacular and see the human condition inside of it. The physicist can see what makes it such an interesting time for the field—and focus on the people themselves.

Q: There's a scene in the film where you confide to the camera that the theory of supersymmetry—your life's work—might not be true. You comment that that's "pretty cool." Do you still feel that way?

A: Oh, yeah. I sort of want nature to scare me. I'd like to figure things out, but supersymmetry is not something I'm attached to. It would be convenient if it were discovered, because I'm an expert on it, and I can give lots of big talks and explain it to people, but I like to learn new things.

Q: What's the best case scenario when the LHC goes back online?

A: If the LHC sees any new particle or even sees something that is a deviation from what the Standard Model predicts and does so significantly, it's another transformation. But if nothing new is seen, we really don't know where the next big discovery or theory will show up. What we do know is that there are deep issues with the Standard Model. It can't be the complete theory and the most compelling experimental reason for that is dark matter. That already is an indicator that the universe is made of things beyond the Standard Model. The question is, are we going to be able to get information about it?

Q: If nothing new is discovered, is that bad news for particle physics?

A: There is stress in the community that if the LHC doesn't see anything else and if we don't build a bigger collider, people are afraid that the field is dead. The motivation to fund it will disappear and people just won't go into it and progress will be incredibly slow. I'm not quite of that mind. It's hard for me to believe that in a modern society, there at least won't be some support for this type of research.

Q: What direction do you see your research taking during the next five years?

A: I have some crazy ideas about what dark matter could be. I don't want to tell you much because it's not well-formed. Instead of individual particles, it could be chunky objects made out of a new particle beyond the Standard Model. There are also a lot of people trying to understand black holes again. It's something I never dove into deeply, so maybe that little slice of the field could use people who think differently and try to figure something out.

Q: Do you foresee more films in your future?

A: Ha! I'm a much happier person when I'm doing physics than making movies. My goal for the next year is to do as much physics as humanly possible.

NEWS BRIEFS

Adam Riess Shares $3 Million Breakthrough Prize

Adam Riess

Nobel laureate **Adam Riess**, the department's Thomas J. Barber Professor, was named a recipient of the Breakthrough Prize in Fundamental Physics for the discovery of the acceleration of the universe.

Riess received the award, the most lucrative academic prize in the world, at a ceremony in November. He shares the $3 million award with Saul Perlmutter, an astrophysicist at the University of California, Berkeley, and Brian P. Schmidt, of the Australian National University, along with their teams. The three scientists' years of research found that the universe is expanding quickly rather than slowing down as had been assumed for years.

"I am deeply honored and grateful to have worked with outstanding colleagues and world-class facilities," said Riess, who is also a research scientist at the Space Telescope Science Institute.

The Breakthrough Prize is sponsored by Yuri Milner, a Russian entrepreneur and philanthropist; Sergey Brin, co-founder of Google; Anne Wojcicki, the founder of the genetics company 23andMe; and Mark Zuckerberg, the founder of Facebook. The four innovators established the prize to celebrate the world's great science and math minds and to generate excitement about the pursuit of the two fields as a career.

Riess was joined at the ceremony by Ronald J. Daniels, president of Johns Hopkins University, who congratulated the scientist's achievement.

The Breakthrough Prize is one of several prestigious awards that Riess has received in recent years. In 2011, he won the Nobel Prize in Physics for his leadership in the High-z Supernova Search Team's 1998 discovery that the expansion rate of the universe is accelerating, a phenomenon widely attributed to a mysterious, unexplained "dark energy" filling the universe. He shared the prize with Perlmutter and Schmidt. Both teams also shared the Peter Gruber Foundation's 2007 Cosmology Prize for the discovery of dark energy, and the 2006 Shaw Prize in astronomy for the same discovery. Overall, 50 astronomers will share a piece of the $3 million prize with each of the two teams splitting $1.5 million.

Brice Ménard Awarded 2014 Packard Fellowship in Science and Engineering

Astrophysicist **Brice Ménard**, an assistant professor in the department, is the recipient of one of this year's Packard Fellowships for Science and Engineering.

The fellowships provide the nation's most promising early-career scientists and engineers with funding and the freedom to explore new frontiers in their fields of study. He will receive a grant of $875,000 from the David and Lucile Packard Foundation. Ménard will use the fellowship to advance his work in statistical analyses of large astronomical data sets and the study of galaxy formation and cosmology. His work has led to the detection of gravitational magnification by dark matter around galaxies, the discovery of tiny grains of dust in the intergalactic space, and a better understanding of how light rays propagate throughout the universe.

Chluba Named Royal Society Fellow

Associate Research Scientist **Jens Chluba** is one of 43 new Royal Society University Research Fellows in 2014. He will take the five-year fellowship to the Institute of Astronomy at Cambridge University beginning in January 2015. The fellowship recognizes Chluba's studies of physical phenomena that can be probed with the cosmic microwave background.

Kamionkowski Wins Simons Award

Marc Kamionkowski

Professor **Marc Kamionkowski**, who is developing theories to explain how the universe was formed, is one of six physicists who have been selected to receive a 2014 Simons Foundation Investigator award, which will provide up to $1 million to support his work.

The Simons Investigator program gives each recipient $100,000 annually in research funding for five years. The support may be extended for an additional five years, after an evaluation of the scientific impact of the scholar's work.

This program was launched in 2012 to provide stable support to outstanding scientists, enabling them to conduct long-term studies of fundamental questions. The awards are given to mathematicians, theoretical computer scientists, and to theoretical physicists such as Kamionkowski.

"The intent is to support theoretical physicists to think freely and creatively, and that's a great thing," said Kamionkowski, who joined Johns Hopkins in 2011. "What I do is pure curiosity-driven research. This award is a huge honor for me."

Cosmologists, Kamionkowski said, try to figure out where the universe came from. Other space researchers use powerful telescopes and other instruments to gather data about stars and other distant phenomena. "Our job as theorists," he said, "is to study a lot of these measurements and try to see what they're trying to tell us. We then attempt to come up with a consistent history of the universe that conforms to the laws of physics."

He added, "We spend a lot of time sitting around brainstorming. Sometimes, we come up with brilliant ideas, only to find out a few days later that they were ridiculous. "But sometimes we come up with ideas that are then used to guide observations that may result in important discoveries."

Earlier this year, in fact, a team of observational cosmologists found evidence that appears to support the idea of cosmic inflation—a period of very rapid expansion that is believed to have happened in a fraction of a second after the Big Bang.

Using a telescope located at the South Pole, researchers may have detected a distinctive pattern of light in the sky. This pattern, a lingering "glow" dating back to the birth of the universe, was predicted 18 years ago by Kamionkowski. Tiny fluctuations in this afterglow are believed to provide important clues to conditions in the early universe. Although the South Pole findings are still being reviewed, Kamionkowski said, "the evidence is tantalizing, but not yet fully conclusive. I'm looking forward to seeing some of the remaining questions resolved by several forthcoming experiments, including the CLASS telescope project that is co-led by Chuck Bennett and Toby Marriage, two of my department colleagues at Johns Hopkins."

His theories concerning cosmic microwave background radiation—that faint glow remaining from the Big Bang—also tie in with recent efforts aimed at mapping the universe. "Our job as cosmologists is to figure out what this map is revealing to us," he said. "There's a huge amount of information there, if we can just crack the code. It's helping us to construct a model detailing exactly what happened in that fraction of a second after the Big Bang occurred."

He added, "One of the things that has unified people over so many generations is that they've looked up at the sky and wondered about the nature of the universe."

Silk Elected to National Academy of Sciences

Joseph Silk, the Homewood Professor of Physics and Astronomy, was among the 84 new members and 21 foreign associates elected to the National Academy of Sciences in April, in recognition of their distinguished and continuing achievements in original research.

Silk, who has written or co-authored more than 500 publications, conducted important early work on homogeneities in the cosmic microwave background and how they are influenced by density fluctuations in the matter of the early universe, in particular by a damping effect that bears his name.

Zakamska Wins 2014 Pierce Prize

Assistant Professor **Nadia Zakamska** has been awarded the 2014 Newton Lacy Pierce Prize for outstanding achievement in observational astronomical research.

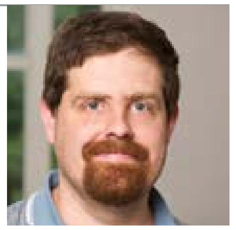
Awarded by the American Astronomical Society, the Pierce Prize is given annually to astronomers for excellence over the past five years in observational astronomical research based on measurements of radiation from an astronomical object. Awardees must be younger than 36 years old to receive the prize.

Most of Zakamska's research interests are in the field of extragalactic astronomy.

NEWS BRIEFS

Kaplan and McQueen Selected for Sloan Research Fellowships

Jared Kaplan



Tyrel McQueen

Jared Kaplan, assistant professor of particle physics, and **Tyrel McQueen**, assistant professor of chemistry in the Department of Chemistry with a joint appointment in the Department of Physics and Astronomy, are 2014 recipients of the Sloan Research Fellowship.

The Alfred P. Sloan Foundation awards fellowships each year to early career scientists whose achievements identify them as the next generation of scientific leaders. The award is $50,000 to further their research for a two-year period.

"I'm grateful for the validation of my research," Kaplan said of the award. "This is particularly encouraging because I've chosen to work on a somewhat unusual range of topics, from quantum gravity to collider physics to the study of materials exhibiting strange new phases of matter."

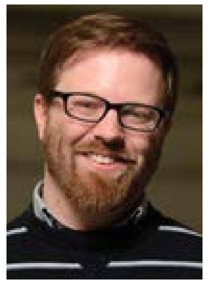
Kaplan came to Johns Hopkins in 2013 from a postdoctoral position at the SLAC National Accelerator Laboratory at Stanford University.

McQueen said he is pleased that the "non-directed nature of the fund gives me the flexibility to follow my instincts and explore the most interesting scientific questions in solid-state materials chemistry."

In addition to receiving the Sloan Research Fellowship, McQueen was also awarded the Cottrell Scholar Award from Research Corporation for Science Advancement in 2014. Cottrell Scholars are selected via proposals that are peer reviewed for excellence in research. McQueen's proposal for the award focused on his research to synthesize and test new high-temperature superconducting materials. "We seek to develop rational design principles for new and improved superconductors, materials that carry a direct electrical current with zero loss," McQueen said.

McQueen was a post-doctoral research associate at the Massachusetts Institute of Technology before coming to Johns Hopkins in 2010.

2014 Gardner Fellow Straddles Theory and Experimentation



Wesley Fuhrman

Wesley Fuhrman, a condensed matter physicist whose research spans both theory and experimentation, is the 2014 recipient of the department's William Gardner Fellowship. The third-year PhD candidate has had the chance to conduct experiments on quantum materials that he has also analyzed theoretically. He hopes to continue the trend of being on "both sides of the ball" as his career progresses.

Fuhrman hails from California and was drawn to Johns Hopkins in part by the Institute of Quantum Matter (IQM) that is led by his adviser, Collin Broholm, the Gerhard H. Dieke Professor. "The IQM has this connectivity [among its members] that allows us to see a project through in a comprehensive way that none of the other schools I saw could accomplish," Fuhrman says. The research conducted by the IQM is funded by the U.S. Department of Energy, and IQM members use instruments at The National Institute of Standards and Technology and Oak Ridge National Laboratory.

The Gardner Fellowship allows Fuhrman to spend more time on his research and on experiments conducted at both of those facilities. "Wes is an excellent example of the power of our new graduate program to engage students at the frontiers of knowledge from an early stage," says Broholm. Gardner Fellows are relieved of teaching obligations for one semester. "The Gardner Fellowship is allowing him to focus 100% on research, and the impact is apparent from an impressive string of high-quality papers published or in review."

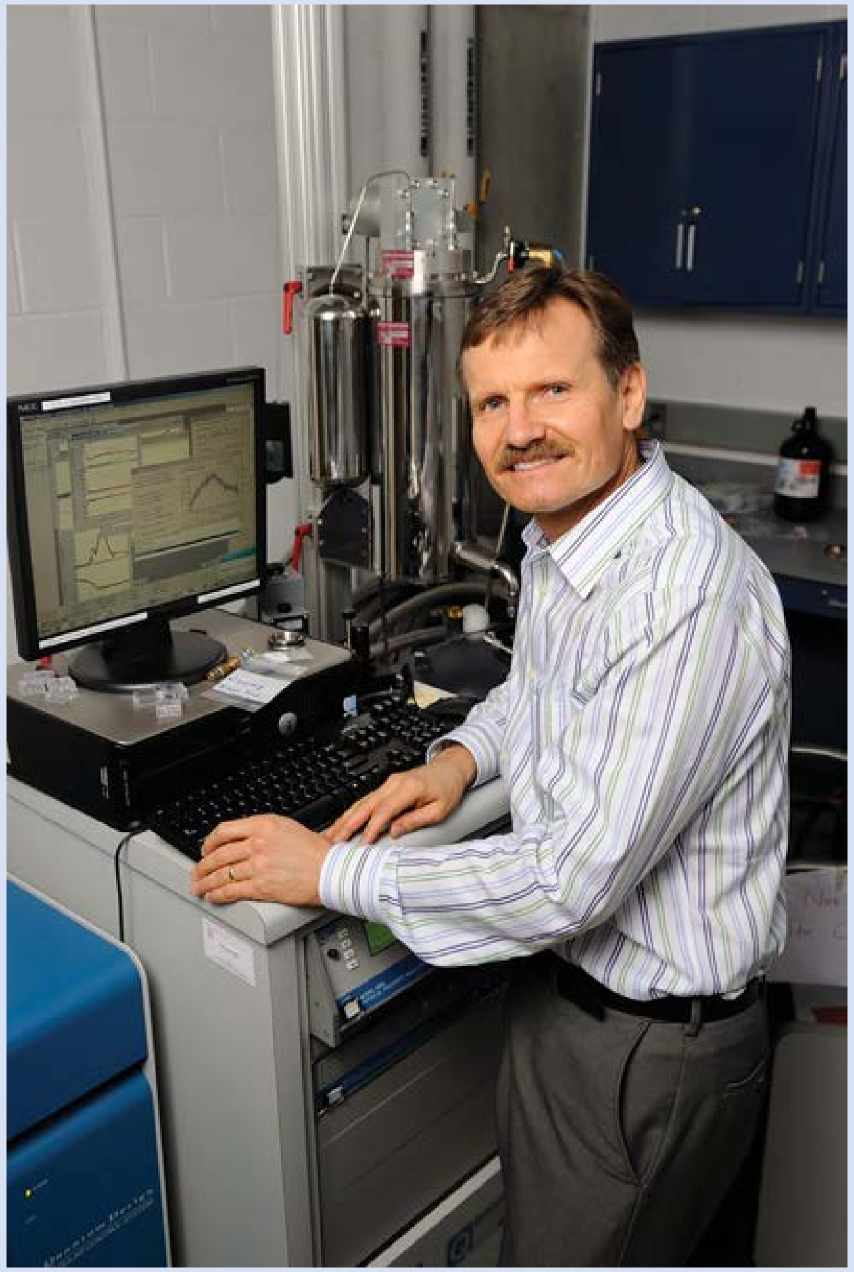
"I've just submitted two articles for review about samarium hexaboride (SmB6), and we were able to do a nice neutron experiment and see some things that no one has seen before and that were quite unexpected," Fuhrman says. At low temperatures, there is a thin electrically conducting shell on every surface of otherwise insulating SmB6. By scattering neutrons from electrons within SmB6, Fuhrman has exposed the electronic structure that leads to this. "On the experimental side, the research would stop right there, but rather than [doing so], I was able to work with another IQM professor to flesh out the theory work to propose a reasonable idea of what we think is going on."

"Wes is diving into the exciting area of topological Kondo insulators where his unique combination of theoretical and experimental talent is particularly effective. From Feynman diagrams to CAD-drawings of intricate sample mounts, Wes is on top of things and it's a real joy to work with him," Broholm says.

Fuhrman plans to continue the pattern of combining experimental and theoretical work in his future research. "One of my favorite things about condensed matter physics is that you can do an experiment and then do a little bit of theory and then maybe you come up with another experiment and push on that way, as opposed to other disciplines where the theory is extremely rigorous before you can make any predictions," he says.

Fuhrman is the sixth Gardner Fellow. The fellowship was founded by William Gardner, who received his PhD in physics in 1968 under Professor Warren Moos and had a successful career in fiber optics and telecommunications at Bell Laboratories. Gardner now supports a high priority of the department—enabling graduate students to begin their doctoral research as early as possible.

—Jon Schroeder

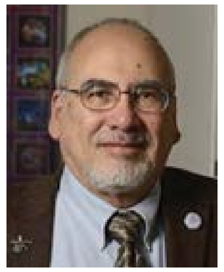


Broholm Named Moore Investigator

Collin Broholm, the Gerhard Dieke Professor of Physics and Astronomy, was named one of 19 new Moore Experimental Investigators in Quantum Materials. The five-year program from the Gordon and Betty Moore Foundation seeks to help physicists who experiments could help transform our understanding of quantum materials. Broholm will be awarded $1.8 million to fund his research on neutron scattering.

The director of the Johns Hopkins Institute for Quantum Matter, Broholm received the Sustained Research Award of the Neutron Scattering Society of America in 2010. His research focuses on anomalous forms of magnetism, superconductivity, and their interplay. He has built two spectrometers at the NIST Center for Neutron Research and is affiliated as a joint faculty with Oak Ridge National Laboratory.

Murray Elected to AAAS



Research Professor **Stephen Murray** was among the 338 new 2014 fellows elected to the American Association for the Advancement of Science.

Murray, who conducts research in high-energy astrophysics and X-ray astronomy, was elected for contributions to high-resolution X-ray imaging spectroscopy, and for founding the NASA Astrophysics Data System that has transformed the way we access information. The data system, used by virtually all astronomers and astrophysicists worldwide, has provided free access to the published literature in the field.

Postdoc Ross Wins Neutron Scattering Society Award

Kate A. Ross, a post-doctoral fellow in the department, was awarded the 2014 Prize for Outstanding Student Research, given by the Neutron Scattering Society of America.

Ross' research focuses on pyrochlore magnets, which have been a playground for the physics of exotic ground states, as many different magnetic ions can be made to decorate the pyrochlore lattice—a network of corner-sharing tetrahedral and one of the defining architectures supporting geometrical frustration in three dimensions. Ross is joining Colorado State University as an assistant professor.

Graduate Students Build Small-Scale Planetaria for Educational Outreach

The Physics and Astronomy Graduate Students (PAGS) Association at Johns Hopkins comprises about 120 graduate students who take their passion for physics and astronomy beyond course work and research. The group supports their fellow graduate students within the department and also has made it their mission to improve physics and astronomy literacy in Baltimore city schools. Over the past 18 months, the educational outreach arm of PAGS, founded by fourth-year graduate student Alexandra Greenbaum and currently led by third-year graduate student Rachael Alexandroff, secured grant funding and constructed two small planetaria that can each accommodate approximately 15 young learners at a time.

After submitting a proposal titled "Bringing the Skies to Baltimore" to Ignite Baltimore, a nonprofit that funds ideas that address the city's social challenges, the PAGS outreach team was awarded a $2,500 "Ignition Grant" to fuel their plan. That funding gave PAGS the ability to purchase two standard digital projectors, two curved mirrors, and enough lumber and cardboard to form two geodesic viewing domes—one that is 9 feet wide and one that is 12.5 feet wide. Katie Harrington, a third-year graduate student, managed construction of the planetaria last summer. "We followed construction plans from WorldWide Telescope; they also make the software that we use to project our presentations," said Alexandroff. Those presentations are entirely crafted by PAGS members; they are written, edited, and even narrated by the department's graduate students. To date, three presentations have been created that play inside the planetaria: "Scales of the Universe," "Colors of the Universe," and "What Is the Universe Made of?" Each presentation lasts about 10 minutes and is designed to blend with a fifth-grade science curriculum.

Last spring, one of the two PAGS-built planetaria became a permanent fixture at Southwest Baltimore Charter School. During a grand opening ceremony, PAGS members ran all three presentations.

"I got to see how small this one big building is compared to everything else in the universe," said Lloyd, a fifth-grade student.

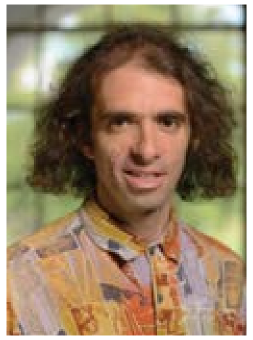
Physics and astronomy graduate students Kevin Fogarty (left) and Alexandra Greenbaum assemble the dome of the planetarium, made of cardboard triangles and attached with binder clips, for easy assembly.

To view a video created by Baltimore City Schools about the grand opening visit http://vimeo.com/89105665.

The remaining planetarium is frequently transported to different schools and events throughout Baltimore, where PAGS members share their latest recorded presentations. In late October, the planetarium was one of the highlights of an educational event open to the public at the nearby Space Telescope Science Institute.

—*Jon Schroeder*

New Faculty Member Explores Quantum Condensed Matter



Ari Turner

What catches **Ari Turner**'s attention is surprising phenomena, peculiarities that are difficult to explain: superfluidity and magnetism in ultracold atoms, topological phases in solids. "When you start thinking about them, you get a lot of ideas," says Turner, the department's newest faculty member. "I like to think imaginatively about these problems. You don't get as inspired about things that are more straightforward."

Turner, an assistant professor, arrived at Johns Hopkins last winter, after earning his PhD from Harvard University and doing his postdoctoral studies at the University of California, Berkeley. He was then a faculty member for two years at the University of Amsterdam in the Netherlands—where he taught statistical mechanics, the same class he taught last spring at Hopkins.

Turner, a theorist in condensed matter physics, is also the newest member of the Institute for Quantum Matter, a collaboration between researchers at Johns Hopkins and Princeton University, where he spent his undergraduate years. Thus far, he's been focusing on collaborating with experimentalists on topological insulators, a newly discovered type of material that can't conduct electricity in its interior but does carry current along its surface. "The neat thing is no matter how much you scratch the surface, they will still conduct electricity at the surface," says Turner.

Topological insulators are currently being studied for controlling magnetic memory logic in computer chips. Turner and Peter Armitage, an associate professor in the department, will be investigating a variety of topological insulators called Weyl semimetals and how they interact with light.

Turner's interests also involve examining how ordinary gases become superfluids and the nature of superfluids themselves. "A lot of stuff in quantum mechanics is abstract but with superfluids, there are analogies to phenomena in daily life like vortices when water goes down the drain." He points out that a vortex can also form in a superfluid, but will last indefinitely because there is no friction in a superfluid state.

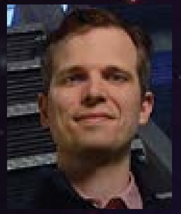
Turner says an underlying aspect of his research is looking at how quantum mechanics relates to classical physics. He has looked at the dynamics of cold atomic gases and electronic surface states, with the end goal of understanding the relationships between quantum fluctuations and thermalization. He is also applying entanglement to find ground state properties of quantum systems.

Turner finds inspiration in analogies between his research subjects and surprising concepts that people have discovered in other areas of physics.

—*Joe Sugarman*

Big Black Holes Can Block New Stars

Massive black holes spewing out radio-frequency emitting particles at near-light speed can block formation of new stars in aging galaxies, a study by Assistant Professor Tobias Marriage has found.

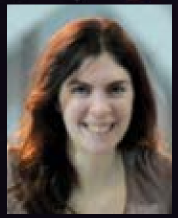


Tobias Marriage

The research provides crucial new evidence that it is these jets of "radio-frequency feedback streaming from mature galaxies central black holes that prevent hot free gas from cooling and collapsing into baby stars.

When you look into the past history of the universe, you see these galaxies building stars, said Marriage, co-lead author of the study. At some point, they stop forming stars and the question is: Why? Basically, these active black holes give a reason for why stars stop forming in the universe.

The findings have been published in the journal *Monthly Notices of the Royal Astronomical Society*. They were made possible by adaptation of a well-known research technique for use in solving a new problem.



Megan Gralla

Johns Hopkins postdoctoral fellow Megan Gralla found that the Sunyaev–Zel dovich effect signature typically used to study large galaxy clusters—can also be used to learn a great deal about smaller formations. The SZ effect occurs when high-energy electrons in hot gas interact with faint light in the cosmic microwave background, light left over from earliest times when the universe was a thousand times hotter and a billion times denser than today.

The SZ is usually used to study clusters of hundreds of galaxies but the galaxies we re looking for are much smaller and have just a companion or two, Gralla said.

What we re doing is asking a different question than what has been previously asked, Gralla said. We re using a technique that s been around for some time and that researchers have been very successful with, and we re using it to answer a totally different question in a totally different subfield of astronomy.

"I was stunned when I saw this paper, because I ve never thought that detecting the SZ effect from active galactic nuclei was possible, said Eiichiro Komatsu, director of the Max Planck Institute for Astrophysics in Germany and an expert in the field who was not involved in the research. "I was wrong. … It makes those of us who work on the SZ effect from galaxy clusters feel old; research on the SZ effect has entered a new era.

In space, hot gas drawn into a galaxy can cool and condense, forming stars. Some gas also funnels down into the galaxy s black hole, which grows together with the stellar population. This cycle can repeat continuously; more gas is pulled in to cool and condense, more stars begin to shine, and the central black hole grows more massive.

But in nearly all mature galaxies —the big galaxies called elliptical because of their shape—that gas doesn t cool any more. "If gas is kept hot, it can t collapse, Marriage said. When that happens: No new stars.

Marriage, Gralla, and their collaborators found that the elliptical galaxies with radio-frequency feedback relativistic radio-frequency emitting particles shooting from the massive central black holes at their center at close to the speed of light—all contain hot gas and a dearth of infant stars. That provides crucial evidence for their hypothesis that this radio-frequency feedback is the off switch for star-making in mature galaxies.

Marriage said, however, that it is still not known just why black holes in mature elliptical galaxies begin to emit radio-frequency feedback. The exact mechanism behind this is not fully understood and there are still debates, he said.

—*Dennis O'Shea*

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Assistant Professor Tobias Marriage (standing left) and assistant research scientist Tom Essinger-Hileman (standing right) with the radio telescope they built with undergraduate Nick Lybarger '13 and Steve Wonnell, the department's instructional resource manager. Located on the roof of the Bloomberg Center for Physics and Astronomy at Johns Hopkins, the telescope is used as a teaching tool in advanced lab classes and intersession classes. While a number of measurements can be made with the radio telescope, Marriage focuses on the rotational velocity of our galaxy. Students use the telescope to measure the speed at which neutral hydrogen gas orbits the center of the Milky Way. They show that the gas orbits cannot be sustained by the luminous matter that we see in the galaxy. Students also learn that the orbits are instead consistent with the widely accepted notion that most of the mass in the galaxy is in a large halo of dark matter that we cannot detect except through its gravitational influence on orbits. Students who work with the telescope l to r: Emily Wagner '15, Grace Mumby '15, Manwei Chan '16, Matthew Petroff '15, and Nicholas Mehrle '16.

JAMES T. VANRENSSELAER