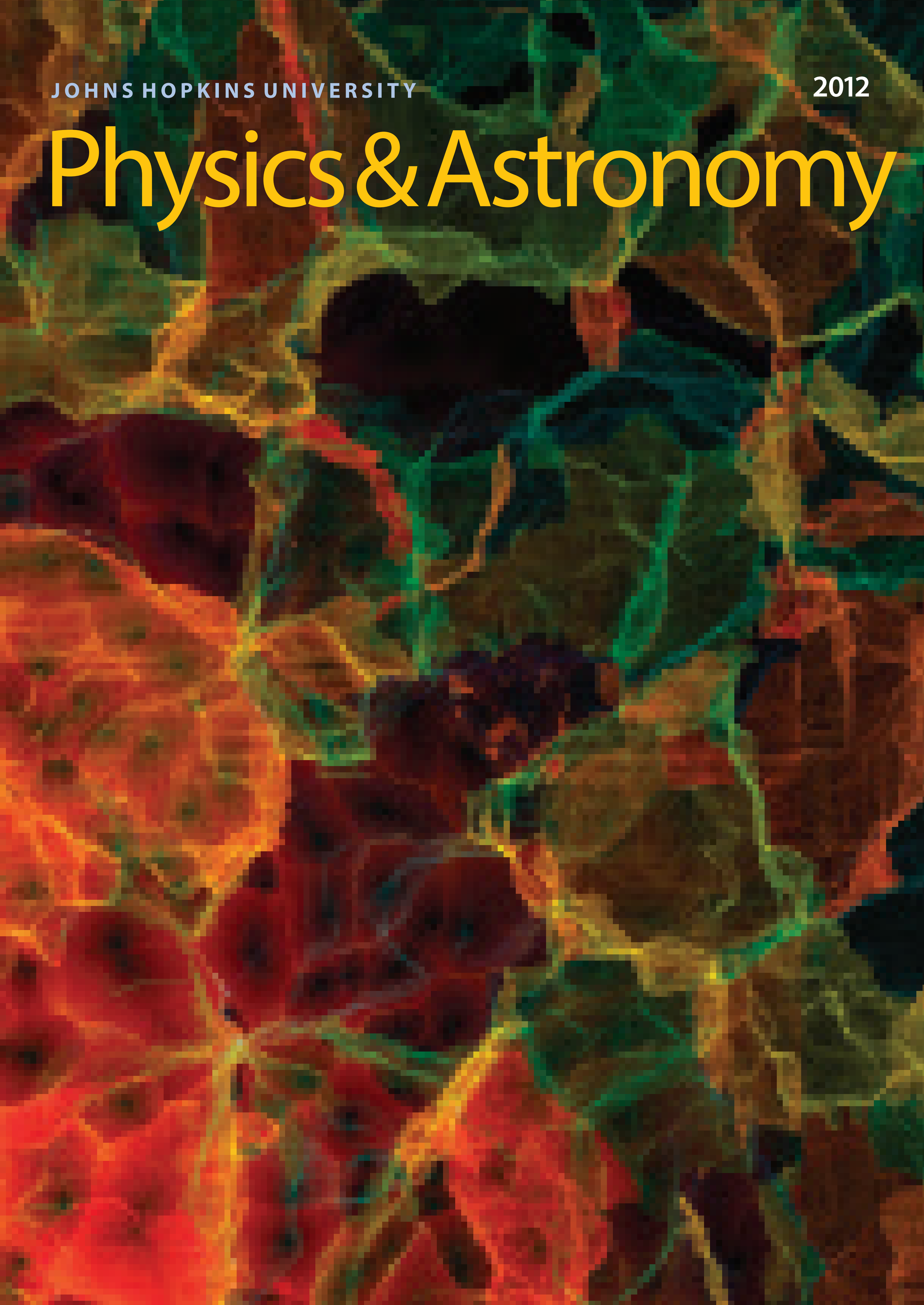
JOHNS HOPKINS UNIVERSITY

2012

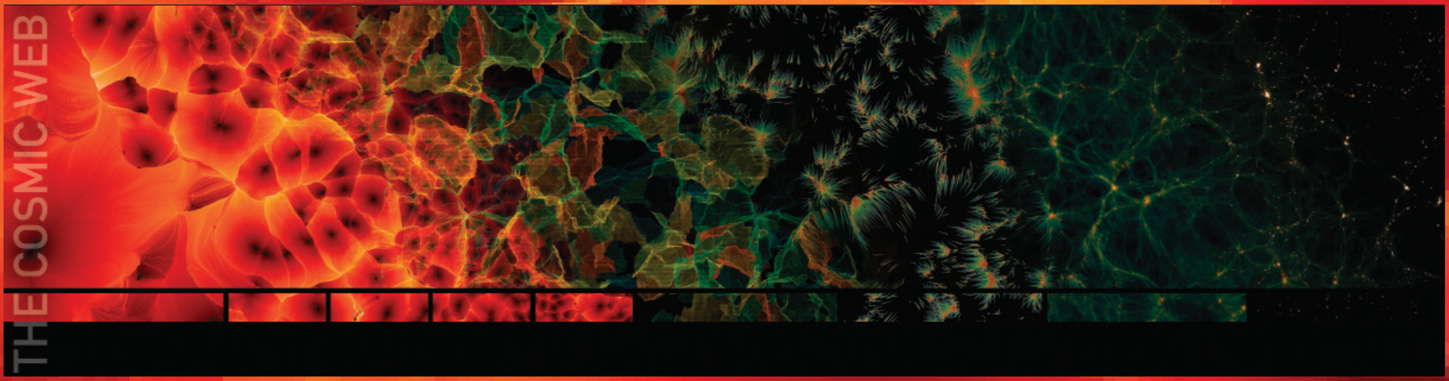
Physics & Astronomy



On the cover: *Created by Johns Hopkins research scientist Miguel Aragón-Calvo, the image is part of a larger computer-generated illustration that depicts streams of matter delineating a network of cosmic voids, each tens of millions of light years across. This particular section shows how most matter in the universe is located in a complex network of walls, filaments, and clusters. We see the individual voids as membranes, each designated with a different color.*

This page: *The streams in this figure illustrate the close relation between the geometry and the dynamics of the cosmic web as matter moves from under-dense voids onto increasingly dense walls, filaments, and clusters.*

Aragón-Calvo's poster, made in conjunction with Julieta Aguilera and Mark SubbaRao PhD '97 from the Adler Planetarium, was awarded first place in the informational graphics category in the 2011 NSF International Science & Engineering Visualization Challenge. Aragón-Calvo is part of Johns Hopkins Institute for Data Intensive Engineering and Science, aimed at developing new ways of building and analyzing huge data sets.



See a detailed view of this poster on the web at zoom.it/Boj2

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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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Letter from the Chair

Dear alumni, colleagues, and friends,

One of the striking things about physics and astronomy at Johns Hopkins is the broad range of scholarship and research pursued by the members of our department. We have condensed matter physicists examining quantum phenomena in solids and pursuing microscopic understanding of familiar phenomena, such as friction; we have theorists researching large-scale structures and the early history of the universe; we have particle physicists leading the charge to analyze the exciting findings from the Large Hadron Collider; we have astronomers locating what could be the most distant galaxy ever seen; we have a team of astrophysicists and engineers developing instrumentation that will enable unprecedented new studies of cosmology and galactic evolution; and we have faculty leading a space mission science team, which produced the three most highly cited scientific papers in the world.

That's just a snapshot of the research being conducted in the department, but it illustrates the diverse expertise of our faculty and researchers. This issue of *Physics & Astronomy* provides an overview of some of the impressive endeavors our faculty and students have engaged in during the past year.

On a sadder note, the department continues to mourn the loss of Professor Zlatko Tesanovic, who died suddenly in July of an apparent heart attack. Many of his colleagues, friends, students, and former students gathered in the Bloomberg Center in November for a touching tribute to this extraordinary man. In March 2013, we will host some of Zlatko's colleagues from around the world for the Zlatko Tesanovic Memorial Symposium. A number of distinguished speakers will give presentations, and we will highlight Zlatko's scientific accomplishments. A confident, esteemed academic; a gifted teacher; and a brilliant physicist, Zlatko will be deeply missed. You can read more about his work and life on page 12.

I hope these pages reflect the energy and enthusiasm that is so inherent in our department. Every day I witness in our faculty and students a drive to question and learn, to teach and experience, and to explore and discover.

Thank you 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

The world's largest, most powerful spectrograph could yield a revolution in astrophysics.

Exploring Galaxies,

BY IAN MATHIAS

What is the shape of the universe? How do galaxies form and evolve? What is the nature of dark energy and dark matter? Many complex, multi-year experiments attempt to answer just a fraction of one such query, yet every so often an opportunity arises to answer several of these fundamental human questions all at once. Such an opportunity has arrived, in the form of an instrument called the Prime Focus Spectrograph (PFS). The PFS is currently being built in part by the Johns Hopkins Department of Physics and Astronomy, and once constructed, JHU will be one of just three institutions in the U.S. that will have access to it.

Though construction of the PFS began this year, the spectroscopic study of the universe has been happening since at least 1929. That was the year Edwin Hubble discovered that distant galaxies are moving away from the Milky Way, and hence, that the universe is expanding. As objects in space move away from our galaxy, their emission spectra are displaced toward longer wavelengths. The faster the galaxy is receding, the redder its spectral lines shift. Thus the recession speed is measured by the "redshift."

Hubble's discovery enabled astronomers to correlate galactic distance and redshift by analyzing the shifting spectra of the hundreds of billions of galaxies in the universe. These spectra are collected using telescopes equipped with spectrographs. However, spectral lines from very distant objects are faint and difficult to measure; it takes a very large telescope equipped with a sophisticated spectrograph to garner useful data quickly. To advance this study—to better answer our fundamental questions about the universe—as Roy Scheider famously uttered in *Jaws*, "you're gonna need a bigger boat."

> "We will be able to observe about a million galaxies."
>
> —Brice Ménard, Assistant Professor

Enter the PFS and the team of Johns Hopkins astrophysicists and engineers who are helping to design, construct, and ultimately employ it. In January 2012, Johns Hopkins was named one of the U.S. universities—along with Princeton University and the California Institute of Technology—that will build and use the PFS. The task of designing and building the PFS lies partly in the hands of Stephen Smee, engineering manager, and his team in the JHU Instrument Development Group. "They are one of the preeminent groups in the country in terms of building precision astronomical instruments," says Timothy Heckman, the A. Hermann Pfund Professor of Physics and Astronomy. "The Japanese government's decision to grant us such a large role in the PFS project is, in part, a testament to the excellence of our Instrument Development Group."

The instrument will reside within the Subaru telescope, a facility operated by the National Astronomical Observatory of Japan at the Mauna Kea Observatories in Hawaii. Hitoshi Murayama, of the Kavli Institute for the Physics and Mathematics of the Universe, spearheaded the proposal to build the PFS and is the project's principal investigator. (A truly international affair, the PFS will be used by astronomers at Japanese, U.S., French, and Brazilian institutions.)

The seventh largest optical telescope in the world, the Subaru has an aperture of 8.2 meters. Such a powerful telescope, when combined with the PFS, will enable an unprecedented survey of cosmological spectra—as many as 2,400 galaxies simultaneously. "It is an extremely powerful instrument," says Assistant Professor Brice Ménard, one of five JHU faculty members who will conduct research using PFS. "We will be able to observe about a million galaxies." To a certain extent, the PFS is all about sheer volume—taking in as much data as possible from as many galaxies as possible. "We are now in an era of data-driven science,

Millions at a Time

PHOTO COURTESY OF SUBARU TELESCOPE, NAOJ

and the PFS will contribute to it," continues Ménard. "This is the emergence of a field we could call 'astrostatistics.'"

Ménard will work on the PFS cosmology team—one of three teams (the other two will focus on galactic evolution and galactic archaeology). Cosmologists will use the PFS to take a census of galaxies, utilizing their redshifts to identify trends in their movement in relation to one another over time, thus gaining further insight into the nature of the dark energy that pushes them apart. A more advanced understanding of the geometry of the universe is also expected to be a key outcome of this study, furthering Hopkins researchers' drive to provide more accurate measurements of the universe's curvature, whether it continues to appear Euclidean or if small deviations begin to appear.

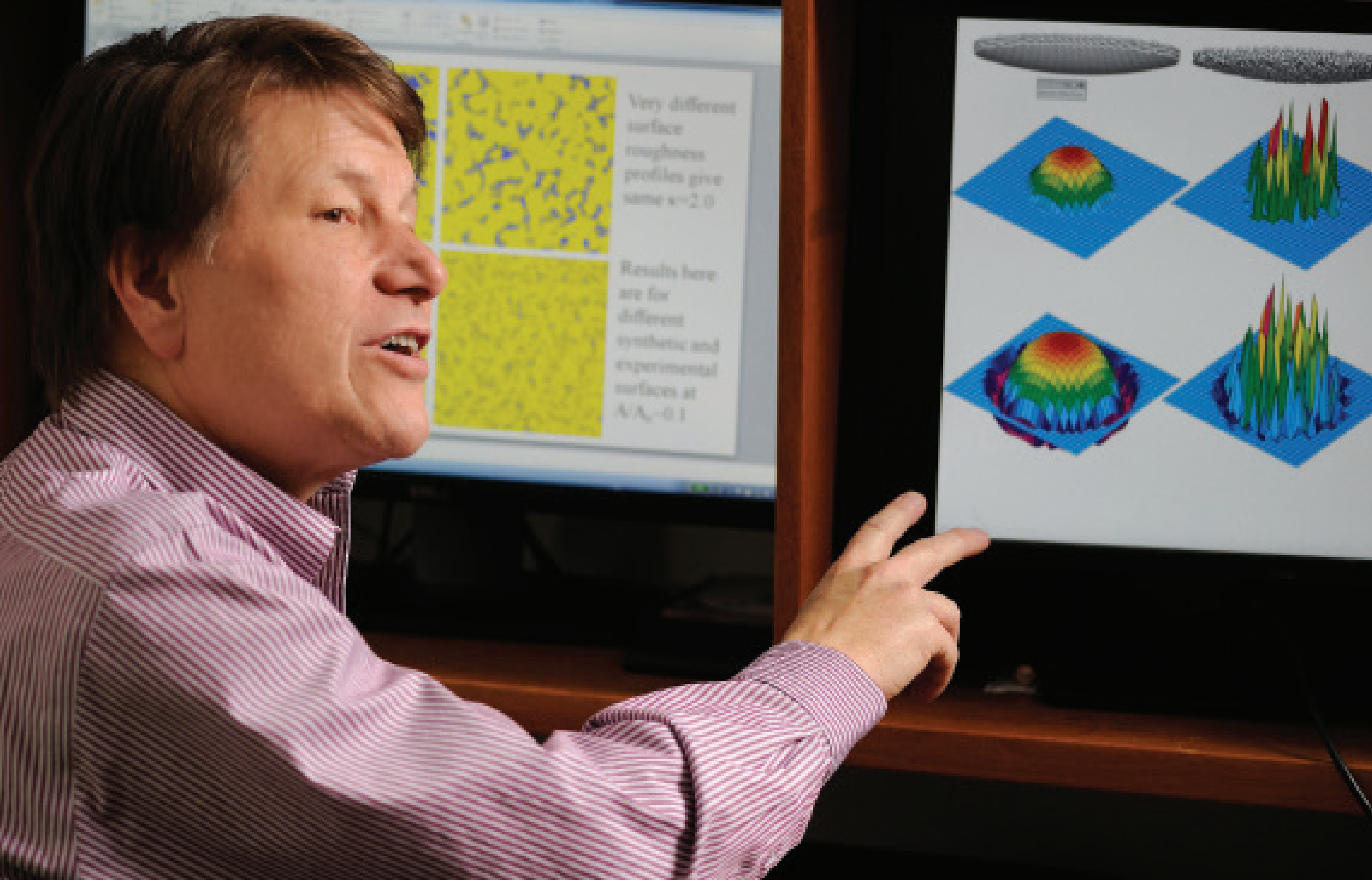
> *"This is the most exciting thing happening in astronomy. It's one of those 'holy grail' studies of our cosmic origins."*
>
> —Timothy Heckman, Professor

Heckman and Assistant Professor Nadia Zakamska will lead the department's study of galactic evolution with the PFS. "We know a lot about the contemporary universe, but we need to understand more about how we got to this point," Heckman says. Heckman and Zakamska will use the PFS to deepen the understanding of how galaxies and black holes have changed over the history of the universe. "I think this will be revolutionary," Heckman predicts. "We're looking to surpass our ground-breaking SLOAN Digital Sky Survey in slices of time, and in each redshift slice, look at hundreds of thousands of galaxies at once. We'll essentially be making a movie of how galaxies have evolved using the Subaru telescope as a time machine to see the progenitors of the Milky Way."

The PFS will enable an examination of the earliest development of our Milky Way Galaxy by conducting large surveys of its oldest stars—a study called "galactic archaeology." "We're going to look at as many stars in our own galaxy as we can," explains Professor Rosemary Wyse, who will lead Hopkins' study of galactic archaeology at the PFS. "This spectrograph will give us a much better understanding of the chemical abundances of the old stars, how they are moving, and provide insight into the merging history that led our galaxy to be what it is today." Wyse believes the PFS's significant multi-object capacity will yield the best data set ever recorded of the motions and positions of the old stars in the Milky Way, which can help answer some of the fundamental questions of our galactic origin.

"And the more we understand about the formation and merging history of the Milky Way Galaxy," says Wyse, "the more we will understand about the nature of dark matter," which provides the gravity that holds stars and gas together in galaxies while giving off no light at all. "There are increasing tensions between the outcomes of cold dark matter simulations on the scales of individual galaxies and the actual observations we've made from smaller data sets in the past." The PFS at Subaru, Wyse says, will likely provide the definitive data set that will compel the astronomy community to embrace or abandon existing theories on the nature of dark matter.

PFS could likely revolutionize the understanding of a variety of fundamental astronomical studies, and it will take roughly a decade of work to get there. Hopkins' role in the project was approved in early 2012, the PFS will be in service by 2017, and data collection will be complete by 2022—with members of the department closely involved from start to finish. "This is the most exciting thing happening in astronomy," says Heckman. "It's one of those 'holy grail' studies of our cosmic origins."



Above: Mark Robbins explains that the blue regions in the figure on the left screen show the fractal geometry of contacts between rough surfaces. The screen on the right shows how subtle changes in the atomic structure of surfaces lead to qualitative changes in local forces, including friction.

The Slippery Physics of Friction

Professor Mark Robbins uses high-tech modeling and data-intensive computing to explore friction's complex origins.

BY MICHAEL PURDY

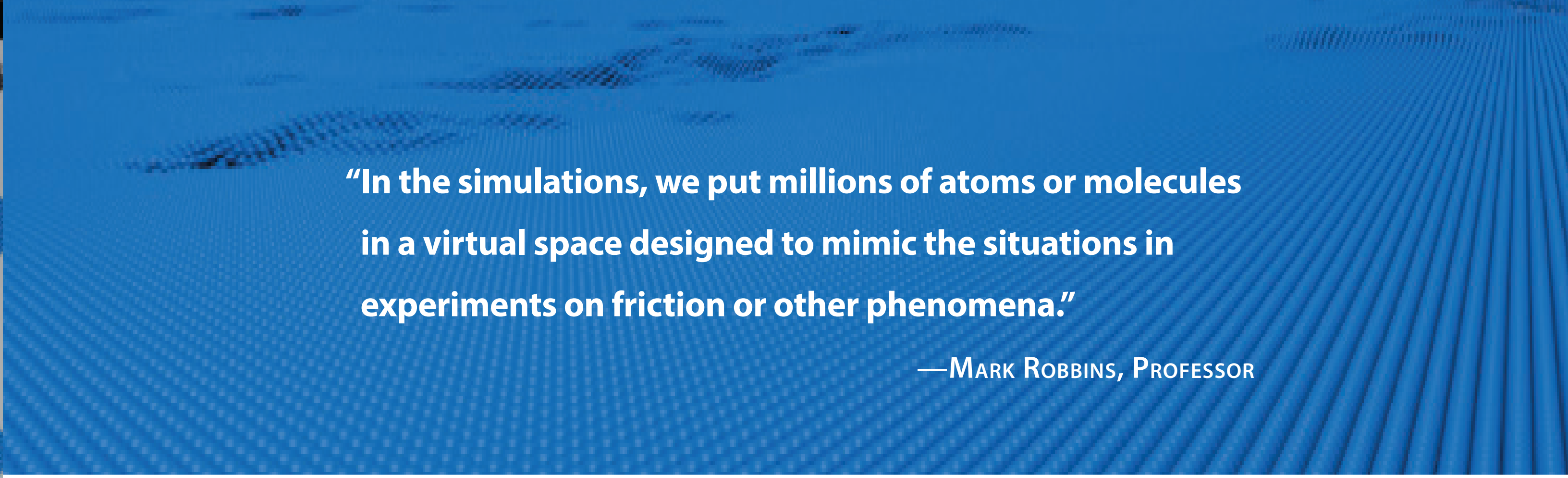
Friction pervades every aspect of daily life from brushing one's teeth to walking to controlling a computer with a mouse. It wears out our shoes and wastes energy in our car engines, but we rely on it when we apply the brakes. One would think that such a familiar phenomenon would be well understood, but the origins of friction have puzzled researchers for centuries.

Introductory physics classes teach what Leonardo da Vinci and Guillaume Amontons determined in their early investigations of friction: that the amount of friction is independent of surface area and proportional to the force pushing the surfaces together, which is called the load. These deceptively simple "laws" work in many cases, but familiar "lawbreakers" include tape, putty, insects, and the geckos featured in TV ads. All rely on friction without any load to stay on vertical walls.

"Many of the challenges of describing friction between two surfaces stem from the fact the surfaces are rough on scales that range from atomic-level features to irregularities that are millimeters in size," says Professor Mark Robbins. "They are fractal in nature, with bumps on top of bumps on top of bumps, and when we study friction, we press two of these bumpy surfaces together, like bringing the Alps down on top of the Himalayas."

Since the 1950s, scientists have known that the area where rough surfaces touched was a small fraction of the total area where their surfaces overlap. To explain why friction is typically proportional to load, they made two assumptions: That the contact area between surfaces grew linearly as the load on the surfaces increased, and that there was a constant friction force per unit area. Testing these assumptions has remained a challenge.

"Our research group has been able to do the first large numerical calculations of the contact area between fractal surfaces," Robbins says. "Despite the complex geometry, area is proportional to load and



> **“In the simulations, we put millions of atoms or molecules in a virtual space designed to mimic the situations in experiments on friction or other phenomena.”**
>
> **—MARK ROBBINS, PROFESSOR**

SIMULATION IMAGE, ABOVE, COURTESY MARK ROBBINS

a remarkably simple equation allows us to predict the ratio.” The model also predicts a simple linear rise in electrical conductivity, stiffness and other contact properties with load. The latest research asks what makes surfaces sticky. A simple criterion explains why geckos and tape can break friction laws while a book or coffee cup does not.

Understanding the friction per unit area in regions where atoms on opposing surfaces make contact has proved much harder. Robbins has been one of the pioneers in studying how friction operates at nanometer scales. Surprising behavior is observed with solids flowing like fluids and fluids acting like solids. Indeed, friction almost always vanishes between two clean surfaces, in sharp contrast to our experience with macroscopic objects. The resolution to this contradictory behavior may lie in the ultra-thin layer of water molecules and hydrocarbons that cover any surface not kept in a vacuum.

“The water and the hydrocarbons in this monolayer of dirt aren’t strongly bound,” Robbins says. “We found that this gives them the flexibility to move to favorable sites between the two surfaces and lock them together—like sand between two macroscopic surfaces. This simple idea explains a growing number of experiments on atomic to macroscopic scales.”

Robbins loves uncovering baffling mysteries like this that underlie everyday phenomena. He uses computer simulations as virtual experiments to develop and test theories.

“In the simulations, we put millions of atoms or molecules in a virtual space designed to mimic the situations in experiments on friction or other phenomena,” he explains. “We watch them to see what they do, and then we try to construct simple analytical models that explain how atoms determine the behavior of macroscopic objects.” Other research projects have examined how adhesives work, why plastics are hard to break, why raindrops don’t slide down window panes and how it’s possible to drink through a straw, which fluid mechanics says should take infinite energy.

Using Physics to Help Protect the Military

Robbins has brought his experience in bridging the gaps between atomic and macroscopic scales to the new Hopkins Extreme Materials Institute (HEMI). Housed in JHU’s Whiting School of Engineering, HEMI is headed by K. T. Ramesh, the Alonzo G. Decker, Jr. Professor of Science and Engineering. Its first project was launched in April 2012 with up to $90 million in funding over 10 years from the U.S. Army.

Robbins is part of that project, a collaborative endeavor called Materials in Extreme Dynamic Environments, which is a major component of President Obama’s Materials Genome Initiative. He and his colleagues are conducting fundamental research into protective materials, developing new predictive models for how well they will absorb energy in an attack.

“We want to understand and predict how every aspect of material structure from atomic bonds to macroscopic shape affects the behavior of materials at high strain rates,” Robbins says. “The central vision of the Materials Genome Initiative is that this type of capability will revolutionize the development of future materials.”

At Johns Hopkins, Robbins is a key player in high-performance computing for research. He is chair of the committee that runs the Homewood High Performance Computing Cluster, which includes over 400 computer nodes with more than 4,000 processing cores. The cluster is a shared facility used by many JHU researchers and is part of the Institute for Data Intensive Engineering and Science at Hopkins, a center dedicated to bringing together data-intensive research from different departments for cross-disciplinary collaboration.

Robbins, a faculty member since 1986, was also recently awarded a prestigious Simons Fellowship in Physics, which allows him to set aside teaching and administrative duties for a year. He is pursuing research projects developed during a three-month workshop he organized last spring on “The Physical Principles of Multi-Scale Modeling.” The goal of the workshop, held at the Kavli Institute for Theoretical Physics, was to develop models for physical processes that bring together different scales of analysis and different types of physics. “Friction is a great example of this challenge,” Robbins says. “You can’t just look at the properties and behavior of atoms, and you can’t ignore roughness on millimeter scales. A revolution in techniques for bridging these scales promises to transform the way we approach physical systems and the complexity of the problems we can solve.”

Research of

Theorist Marc Kamionkowski Spans Many Fields

BY GABRIEL POPKIN

Is Marc Kamionkowski a particle physicist, an astrophysicist, or a cosmologist?

"I'm a theorist," says Kamionkowski. In the 2011-12 academic year, his first at Johns Hopkins, he has published papers on gravitational waves, cosmic acceleration, dark matter, and particle decay—a remarkable discipline-bridging assortment of research. "When you're a theorist in physics, you can jump around to different areas. You don't have to wait for the satellite to launch, or for the collider or telescope to be built."

That's not to say Kamionkowski is uninterested in what experimentalists learn from their satellite missions, telescope observations, and collider experiments—quite the contrary, in fact. Previously the Robinson Professor of Theoretical Physics and Astrophysics at the California Institute of Technology, Kamionkowski sees his role as tightly linked to experiments in cosmology, astrophysics, and particle physics. "My job is to keep an eye on a bunch of unrelated fields, synthesize and amalgamate results from different areas, and provide feedback in the form of suggestions for new experiments that would answer questions that remain."

Although Kamionkowski's graduate research had been on the nature of dark matter, an area where he is still active, as a postdoc he developed an interest in the cosmic microwave background (CMB) results coming out of the Cosmic Background Explorer satellite, or COBE. COBE established that the CMB radiation released around 380,000 years after the Big Bang—the so-called "time of last scattering"—is anisotropic, or non-uniform, giving us critical information about the evolution of the large-scale structure we see in our universe today.

Kamionkowski and some of his colleagues published a series of papers suggesting further measurements that could map the CMB with enough precision to answer long-standing questions about the geometry of the universe. These papers helped make the case for the Wilkinson Microwave Anisotropy Probe, or WMAP, which was led by JHU physicist Charles Bennett (who had also been a key figure behind COBE) and launched in 2001, sooner than anyone expected. "We thought it would take several decades for this experiment to be carried out," says Kamionkowski.

Beyond confirming that the universe is flat (Euclidean) to an order of magnitude of greater precision than before, WMAP provided strong support for previous observations made of distant supernovae, which had shown that the expansion of the universe is accelerating. More broadly, WMAP is credited with ushering in the era of "precision cosmology," and establishing the field as a core subject within physics and astronomy. "Cosmology used to be the butt of everyone's jokes," says Kamionkowski. "Now it's a paradigm of how quantitative science should be done. I take pride in being one of the people who motivated this transformation."

Pushing precision cosmology even further, Kamionkowski and colleagues have suggested a way to peer beyond the CMB into the very earliest moments of the universe. They proposed that the polarization of radiation coming from the CMB could be used to look for gravitational wave signals from the first tiny fractions of a second after the Big Bang—the period of rapid expansion known as inflation. Previously, these signals had been thought to be too small to be observed, but Kamionkowski's papers stimulated a number of research efforts. "Experimentalists picked up on this faster than I had anticipated," says Kamionkowski, "and the idea of inflation started to seem like it could be a little less crazy."

Alongside his work on the early universe, Kamionkowski continues to probe the nature of dark matter, which accounts for around 23 percent of the energy in the universe. Most cosmologists concur that dark matter must be an as-yet undiscovered particle, and Kamionkowski is in the camp that believes this particle will turn out to be described by the theory supersymmetry, which was developed to answer some of the questions that emerged from the Standard Model of particle physics. Kamionkowski's earlier research showed that quantum mechanics places an upper limit on the mass of a supersymmetric dark matter particle; this limit suggests that the particle's mass should be accessible by the Large Hadron Collider (LHC). His more recent work has helped guide particle collider, cosmic ray, and neutrino experimentalists in looking for the signatures of these thus-far unobserved particles.

Unsurprisingly, the searches for dark matter and supersymmetry are among the hottest topics in particle physics today, and many believe the LHC has a shot at providing us the answer—especially now that it may have delivered the long sought Higgs boson. "We used to say that if the Higgs is discovered, that proves supersymmetry exists; and if supersymmetry exists, the lightest supersymmetric particle should be the dark matter," says Kamionkowski. "[We now have reason to believe] the Higgs exists, but it's still a pretty tenuous argument. We would like to see the lightest supersymmetric particle observed at the LHC." Whether the LHC will reveal dark matter and supersymmetry remains to be seen. "You never know. If we did, we wouldn't need to do the experiment." While the LHC experiment continues, Kamionkowski forges ahead in his own "lab"—which mostly consists of a desk, paper, and pencils.

"I'm actually one of the last of my generation to still make a living with paper and pencil," he says. "Sometimes I work on projects involving simulations, but I'm not a simulator. I like to think of myself as an idea-oriented pencil-and-paper theorist."

For someone with the wide-ranging curiosity and talents of Marc Kamionkowski, the diverse and high-powered Department of Physics and Astronomy at the Krieger School is an ideal place to work. "There are a lot of exciting things going on in physics and astrophysics at Johns Hopkins," he says. "There are really smart people, creative people, people who know how to get things done. This department is smaller than some of the places it competes with, but it looms large. When you put it together with the Space Telescope Science Institute, it's a great place to be. The trajectory is extremely positive."

RESEARCH BRIEFS

Assistant Professor N. Peter Armitage makes adjustments to the new helium reliquefier system.

Department Responds to Global Helium Shortage

Early in the fall semester, researchers and faculty members installed a helium recovery system and liquefier in the Bloomberg Center. Condensed matter physicists and astronomers in the department use liquefied helium to create extremely cold research conditions (often just a few degrees above absolute zero). When helium gas is released into the air, whether from a party balloon or from liquid helium vaporized in a research cryostat, it dissipates into the atmosphere, never to be utilized again. The new system, which captures used helium from labs throughout the department and then purifies and re-cools it back to the liquid state, serves as a much-needed recycler of this non-renewable resource. It can store 500 liters of liquid helium.

"The liquefier delivers helium to researchers at a greatly reduced cost," explains Assistant Professor N. Peter Armitage, who spearheaded the liquefier's acquisition and installation. "The price of helium had increased about 30 percent in the five years or so leading up to when we decided to buy a liquefier last year, and the price has gone up about another 40 percent just in this year alone. And we can't even get it reliably. Helium is becoming more expensive and less available."

The current scarcity of helium could have significant implications for the space, high-tech, and medical industries.

"It's just wasteful not to have a liquefier," says Armitage. The liquefier creates a nearly closed loop of helium usage within Bloomberg, and by enabling a stable and affordable supply of liquid helium for the department, it will provide critical infrastructure for research from superconductivity and nanoscience to cosmology for years to come.

WMAP Team Scores Big with Gruber Cosmology Prize and World's Most Cited Papers

Professor Charles Bennett and the Wilkinson Microwave Anisotropy Probe (WMAP) space mission science team were awarded this year's Gruber Cosmology Prize.

Bennett and the 26-member WMAP team were recognized for their unprecedented study of ancient light dating back to the infant universe. The WMAP team, led by Bennett, was able to determine a much more precise age, shape, composition, and history of the universe. The WMAP team also discovered that the first stars formed when the universe was only about 400 million years old.

The annual Gruber Cosmology Prize recognizes "fundamental advances in our understanding of the universe." It is co-sponsored by the Gruber Foundation and the International Astronomical Union and aims to acknowledge and encourage further exploration.

"It is tremendously exciting to be recognized with the Gruber Cosmology Prize," says Bennett, the Alumni Centennial Professor of Physics and Astronomy. "I have been very fortunate to work with the talented and fine people of the WMAP team, and I am particularly delighted that our entire science team has been honored with this prestigious award."

Bennett and the team shared the $500,000 prize, and Bennett was given a gold medal in August at the International Astronomical Union meeting in Beijing.

In addition to winning the Gruber Cosmology Prize, the research conducted by Bennett and the WMAP team resulted in production of the three most highly cited scientific papers in the world in 2011, according to Thomson Reuters' Science Watch. Papers from the WMAP mission have made it to the top of the list in previous years (2003, 2007, 2009), but this is the first time they have taken the top three spots.

Milestone: The Judd-Ofelt Theory Turns 50

No one would have guessed that in 1962, rare earth metals would become a staple of modern living in less than 50 years time. Likewise, few would have guessed that 31-year-old physicist Brian Judd was on the verge of publishing seminal research on rare earth metals that his colleagues would cite well into the 21st century—becoming more popular and relied upon as decades came and went.

Brian Judd became fascinated by the rare earth ions in crystalline materials or liquids while studying at Oxford in the 1950s. He was particularly interested in the paramagnetic resonance of these 15 elements' electrons, an effect akin to the nuclear magnetic resonance used in medical imaging devices.

The study of rare earth metals was advancing thanks in part to interest in crystals stimulated by radar and microwave research. But these metals and their ions were still puzzling researchers because, despite their similarities, they produced strikingly different signatures when analyzed with a spectrograph.

"They were just a big mystery," says Judd, the Gerhard H. Dieke Professor Emeritus in the Department of Physics and Astronomy. And few researchers have done more to try to unravel that mystery than he has.

As late as the early 1960s, physicists struggled to find a mathematical language to describe the behavior of these elements at the sub-atomic level, where classical physics breaks down and quantum theory takes over.

What no one knew 50 years ago was that one day rare earth doped materials would play a crucial role in fiber optic communications, and make it possible to produce miniaturized electronic components for everything from laptop computers and mobile phones to hybrid cars and lasers.

Judd's key scientific contribution to the field came in 1962, when he published a paper titled "Optical Absorption Intensities of Rare-Earth Ions," that proposed a mathematical method for predicting how the f electrons in rare earths behave when they jump from one energy level to another while orbiting the atom's nucleus.

Brian R. Judd, Gerhard H. Dieke Professor Emeritus

Judd, then at the University of California at Berkeley, used the mathematical theory of Lie groups to simplify the calculations needed to describe the behavior of rare earth electrons, without sacrificing accuracy.

His paper was published the same day as a structurally similar work on f electrons by George Ofelt, a graduate student of Brian Wybourne at Johns Hopkins University, which did not include Judd's detailed numerical comparisons between theory and experiment for the radiation intensities of the electrons. The approach came to be known as the Judd-Ofelt Theory.

"The reason that the article I wrote was so successful was that it dealt directly with experiment," Judd, now 81, said in an interview. "I remember that the British physicist Maurice Pryce told me never to get seduced by the mathematics. It's very easy to be first of all amazed by how the mathematics is beautiful in a funny kind of way, by the surprises you get when you work out the mathematics.

"But Pryce said, 'Never be seduced.' And in fact when I wrote the article it was strictly calculations with the idea of describing only what an experimentalist would find useful."

The Judd-Ofelt Theory quickly became a standard work, frequently cited in papers by other researchers. Its citation rate accelerated sharply in the early 1990s, after the invention of erbium-doped optical fiber amplifiers, critical for long-range optical fiber communications, and is now being referenced over 200 times per year.

In August, Judd and Ofelt were honored at a chemistry and physics conference in Udine, Italy, where a series of speakers celebrated the 50th anniversary of the publication of their work.

"It's really defined the whole field for the people who study the spectroscopy of these rare earth elements," says Daniel Reich, chair of the department.

The late physicist Brian Wybourne, who studied rare earth elements at Hopkins in the early 1960s, wrote in 2004 that the Judd-Ofelt papers "represent a paradigm that has dominated all further work on the intensities of rare earth transitions in solutions and solids up to the present time."

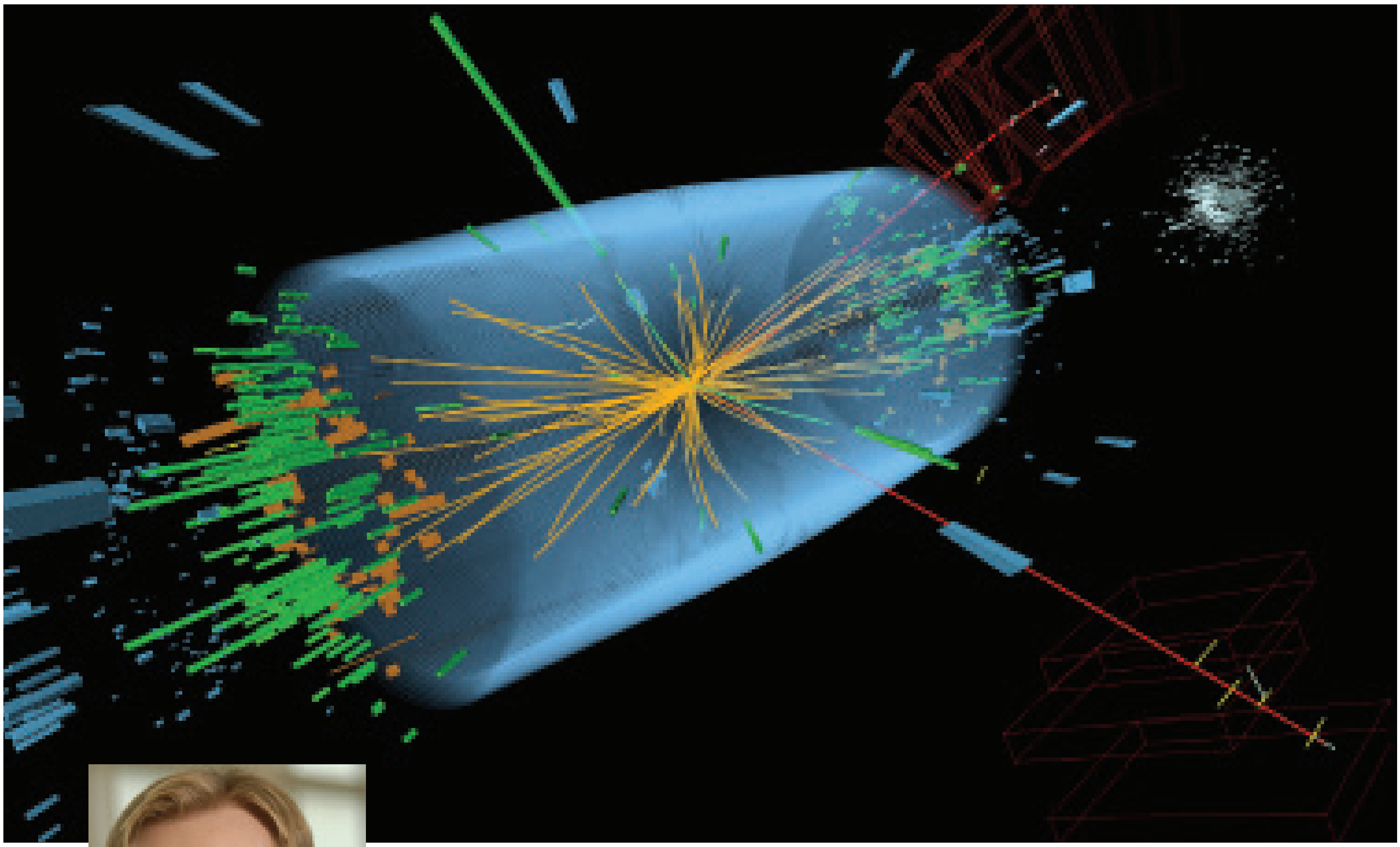
Judd came to Hopkins in 1966, not long after authoring his groundbreaking research paper, and he would remain on the Homewood campus for the rest of his career. Today he is retired and living in Baltimore with his wife, Josephine Gridley, but keeps in touch with his former graduate students and maintains an office at the Homewood campus.

Even in retirement, Judd remains fascinated by the mathematical challenges posed by elements 57 through 71 of the periodic table. "There's a whole pile of mysteries, to my mind, in the mathematics of rare earths," he said.

"Everything can be calculated according to quantum mechanics. And everything works out well." But certain complicated electron configurations produce results that still puzzle him, and he is still trying to understand them.

"If you get too interested in the mathematics, you can spend a lifetime working it out," he says. "And in fact that's what happened to me. I've become seduced by the mathematics."

—Doug Birch



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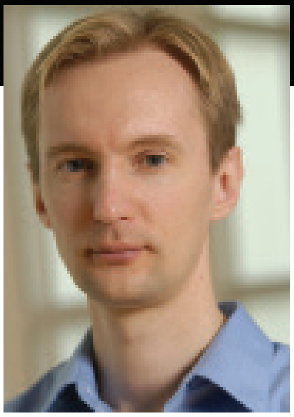


“We do not yet know where it will lead us. But it may have profound implications.”

—ANDREI GRITSAN, ASSOCIATE PROFESSOR

Faculty and Students Instrumental in LHC Breakthrough

Members of the department played important roles in this summer’s discovery of a new particle that contains qualities consistent with the Higgs boson—arguably the most important particle physics breakthrough in decades.

For most of 2012, Associate Professor Andrei Gritsan, post-doctoral fellow Sara Bolognesi, and graduate student Andrew Whitbeck traveled back and forth from Baltimore to the Large Hadron Collider (LHC) in Geneva, Switzerland. The trio was part of a large, world-wide team of physicists working on the Compact Muon Solenoid (CMS), one of two massive particle detectors used to analyze the LHC’s proton-proton collisions in the search for the long-predicted Higgs boson.

Gritsan and his team focused their search for the Higgs boson on a specific form of decay of the Higgs into two Z bosons. They developed an array of very specific variables designed to indicate the presence of a new particle over the course of billions of individual collisions. And the presence of a new particle is precisely what they and their colleagues found.

But what particle? Much more research is needed to identify the new particle and confirm if it is, in fact, the Higgs boson. Such a confirmation would help explain how massless particles acquired mass in the very early history of the universe and add more legitimacy to the Standard Model. “We do not yet know where it will lead us,” explains Gritsan, who has been working at the LHC since 2005. “But it may have profound implications.”

Regardless of the particle’s true identity, Gritsan, Bolognesi, and Whitbeck contributed to its discovery and were front-and-center at the LHC during the exciting early days of July, when the revelation was announced. “It was a huge discovery that will influence my research for the rest of my career,” says Whitbeck.

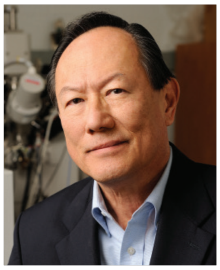
PEOPLE

Faculty Members Receive Prestigious Fellowships and Awards

Tyrel McQueen recently garnered the 2012 David and Lucile Packard Foundation Fellowship for Science and Engineering. Just 16 Packard Fellowships are awarded annually, each honoring young scientists with unusually creative research interests. McQueen, a dual appointment in the Department of Physics and Astronomy and the Department of Chemistry, will use the fellowship's $875,000 stipend to further his unique interdisciplinary research: discovering, designing, and controlling materials with exotic electronic states of matter. Applications for such study are wide-ranging, from fundamental science to solving complex energy problems.

"I'm excited to see generous support for new materials synthesis and solid state chemistry," says McQueen, "and the flexibility offered by these unrestricted funds will be invaluable to my research team as we pursue exotic new quantum phenomena in electronic materials."

"The Krieger School is enormously proud of the accomplishments of Professor McQueen, and we look forward eagerly to the discoveries he will provide in the years to come," adds Dean Katherine Newman. "I have had the personal pleasure of hearing him lecture undergraduates on his work, and he conveys the kind of excitement that we want budding scientists to hear. We are grateful to the Packard Foundation for recognizing this rising star."



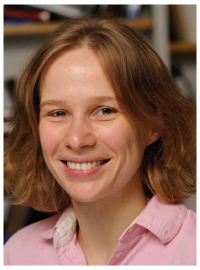
Chia-Ling Chien, the Jacob L. Hain Professor, has won the 2012 Asian Union of Magnetics Societies Award. Given once every two years to researchers from AUMS member countries, the award honors Chien's significant contributions to magnetics research. In particular, the union cited Chien's "seminal contribution to magnetic materials, nanostructures, magnetoelectronic phenomena, and devices."

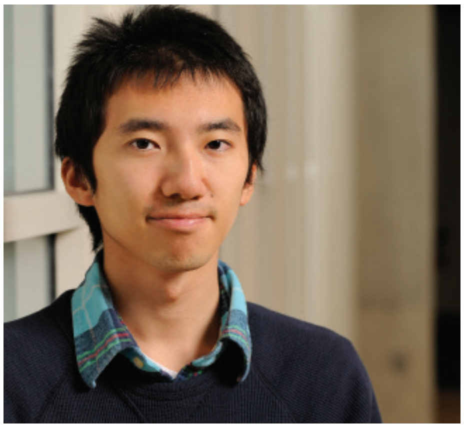
Research scientists **Mark Neyrinck** (left) and **Miguel Aragón-Cavalo** won a New Frontiers in Astronomy & Cosmology award for their work combining origami concepts with measurements of the universe's shape and complexity. Neyrinck and Aragón-Cavalo will use the prize money to construct the first all-inclusive quantitative measurement of the entropy of the cosmic web—the cellular, web-like arrangement of galaxies in the universe that shares concepts and methodologies with origami and paper-folding. The award is funded by the John Templeton Foundation.

Brice Ménard was selected by the Maryland Academy of Sciences as the Outstanding Young Scientist of 2012. The award was established in 1959 to recognize and celebrate the extraordinary contributions of young Maryland researchers across all fields of science. Ménard was recognized for his research in extragalactic astrophysics and cosmology.

Ménard also won the 2012 Sloan Research Fellowship to support his research on extragalactic astrophysics and cosmology. The Sloan Fellowship honors early-career scholars with outstanding promise with two-year $50,000 grants, which Ménard will use to continue developing new techniques of mining large astronomical data sets. His work using such techniques has already 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.

Ménard's fellowship marks back-to-back Sloan awards for the department: **Nadia Zakamska** was awarded the Sloan Fellowship in 2011 for her research with Earth and space-based telescopes and large data sets.





Gardner Fellow Studies Quasar Spectra

When he began graduate studies in 2011, **Ting-Wen Lan** didn't imagine he would win the department's sought-after Gardner Fellowship. In fact, he didn't know he was eligible. Having just arrived from Taiwan, Lan focused on his study of astronomy (and, when there was time, the English language).

But in one of his first courses, Observational Astronomy, Lan caught the attention of Assistant Professor Brice Ménard, who co-taught the course with Assistant Professor Nadia Zakamska. "For the final part of his semester project, Ting-Wen had to estimate how many quasars from the Sloan Digital Sky Survey (SDSS) should be spectroscopically

(cont. from p. 11)

examined to detect intervening Mg II absorbers," explains Ménard, whose research interests also include this spectroscopic study of extremely distant quasars. "We expect most first-year grad students to come up with a rough estimate. Ting-Wen surprised us by performing an entire Monte Carlo simulation using real data to take into account all the parameters of the survey."

"Without a doubt," says Ménard, Lan was ready for a research project. Ménard had been working with post-doctoral student Guangtun Zhu on a new algorithm to automatically detect absorbers in quasar spectra and was ready to begin applying it to the vast data sets from the SDSS, the Baryon Oscillation Spectroscopic Survey (BOSS), and the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS). Lan was in a perfect position to begin assisting. "This was related to my study in Professor Ménard's course," says Lan. "He suggested the fellowship and I applied."

The Gardner Fellowship freed Lan from teaching assistant responsibilities for the first half of 2012—time he spent researching and analyzing the surveys, some of which are available just to Johns Hopkins and a handful of other institutions around the world. "The fellowship provided me with an opportunity to start my research earlier [in my graduate program] and learn more about what I'm interested in."

"Ting-Wen made very good use of this opportunity," says Ménard. "He has demonstrated remarkable problem-solving ability, and one day he could very well surprise us again."

Lan is the fourth Gardner Fellow. The fellowship was founded by William Gardner '68, who received his PhD in physics under Professor Warren Moos. After a successful career in fiber optics and telecommunications, Gardner now supports a high priority of the department—enabling graduate students to start their doctoral research as early as possible.

Johns Hopkins Mourns Death of Professor Zlatko Tesanovic

Professor Zlatko Tesanovic

PHOTO COURTESY OF THE DEPARTMENT OF PHYSICS & ASTRONOMY

The Johns Hopkins Department of Physics and Astronomy lost one of its most distinguished members with the premature death of Professor **Zlatko Tesanovic**. He died of a heart attack July 26 at the George Washington University Hospital in Washington, D.C., after collapsing at Reagan National Airport. He was 55.

Zlatko was born in Sarajevo, in what was then Yugoslavia. He earned his undergraduate degree in physics in 1979 from the University of Sarajevo. A Fulbright Fellowship brought him to the University of Minnesota, where he earned a PhD in physics in 1985. Zlatko then did postdoctoral work at Harvard University and Los Alamos National Labs before arriving on the Johns Hopkins campus as an assistant professor in 1988. He was promoted to associate professor in 1990 and to full professor with tenure in 1994.

A leading theoretical condensed matter physicist, Zlatko's research in recent years primarily concerned high temperature superconductors and related materials. In particular, he worked on the theory and phenomenology of iron- and copper-based high temperature superconductors. He also studied the quantum Hall effect, and other manifestations of "strong correlations" and emergent behavior in quantum many-particle systems. The theme that ran throughout his work was that of strong correlations between electrons. He sought to understand how it is that large ensembles of strongly interacting, but fundamentally simple particles like electrons in solids, can act collectively to exhibit complex emergent quantum phenomena like high temperature superconductivity.

Zlatko published more than 125 papers, and received numerous honors and awards, including a David and Lucile Packard Foundation Fellowship. He mentored 10 graduate students and seven postdocs. He was a leader in the department and worked diligently to attract stellar faculty and students to Johns Hopkins.

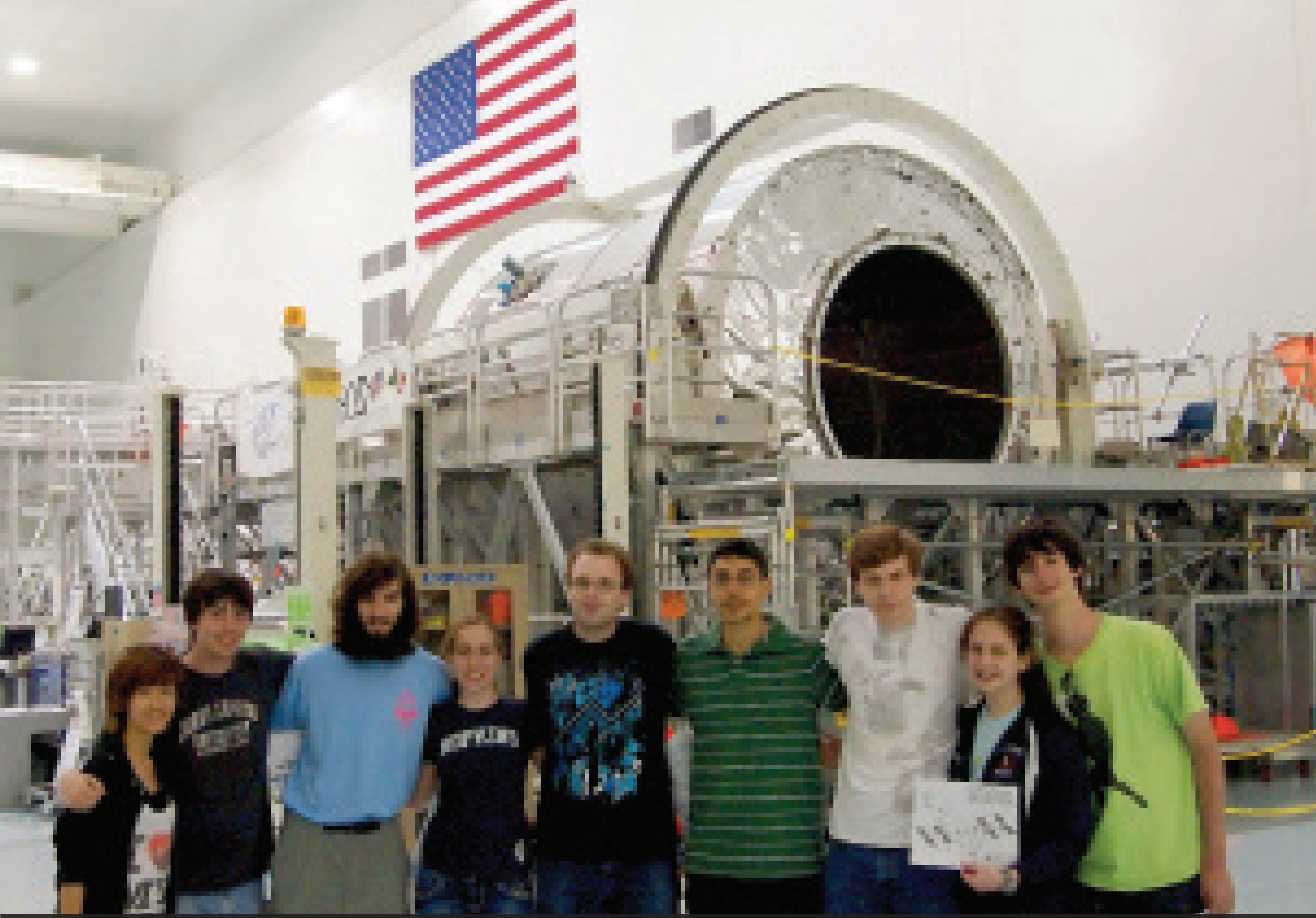
He was also an academic leader at JHU and recently served as secretary of the Homewood Academic Council, the elected faculty body responsible for faculty governance and tenure review. As Krieger School of Arts and Sciences Dean Katherine Newman noted at a memorial service in Tucson, Ariz., "Zlatko was a great citizen of the department and of the community." One may not have agreed with him on everything, but ultimately one could be sure that he was motivated by a deep desire for what was best for the department and university.

In addition to his academic successes, Zlatko was a man of many talents. He was a master classical guitarist, an aficionado of Baltimore's gastronomical delights, and had a hysterical and occasionally biting wit. Among many things, he was known for his brightly colored Hawaiian print shirts and being able to get a table at any restaurant in town with no more than a phone call. "It's taken care of," he would whisper to the nervous host of a distinguished colloquium speaker in search of last-minute dinner reservations.

Zlatko was a man of passionate beliefs and deep convictions. He was an exceptional scientist and teacher, a loyal friend, a trusted colleague, and devoted to his family. He will be greatly missed.

Zlatko is survived by his wife, Ina Sarcevic, a professor of physics at the University of Arizona; his daughter, Rachel Sarcevic-Tesanovic, who will graduate from the Krieger School in May; and his sister, Mirjana Tesanovic.

—N. Peter Armitage, Assistant Professor



Members from the Johns Hopkins chapter of the Society for Physics Students visited NASA's Kennedy Space Center earlier this year. Here they visit an area used for assembling and testing parts of the International Space Station. (l-r): JiYeong Kim '13, David Coren '12, Paul O'Neil '13, Marie Hepfer '13, Eddie Brooks '13, Georges Obied '15, Ben Hartman '14, Jessica Noviello '14, Kevin Mather '13.

PHOTO COURTESY OF MARIE HEPFER '13

For Students in Physics Society, It's all About the Teamwork

Eddie Brooks '13 and Marie Hepfer '13 remember what it was like to be freshman physics and astronomy majors. "I felt dwarfed by all of these older, intelligent students," says Brooks. "But now that's me."

As president and vice president (respectively) of the Johns Hopkins chapter of the Society of Physics Students (SPS), Brooks and Hepfer say membership is an ideal way to become integrated into the professional community.

Members of the SPS meet every Friday afternoon to talk physics and exchange ideas in a relaxed setting. "While our focus is on majors, the group is open to any undergraduate who's interested in physics," says Hepfer. After graduation in spring, Hepfer plans to pursue a career in aerospace engineering.

Brooks, a double major in physics and earth and planetary science, says it's important for physics majors to spend time together because so much of their academic study and research requires them to work in teams.

One of this year's highlights for the group was a trip to the Kennedy Space Center and the Cape Canaveral Air Force Station. Thanks to a few faculty connections, the group was given exceptionally close access, and they were able to engage in a mission control simulation.

With the guidance of Professor Petar Maksimovic, members of the group also hold tutoring sessions and bring in outside speakers, including department alumni. Maksimovic says that past SPS members have also organized trips to major laboratories such as Fermilab in Illinois, the SLAC National Accelerator Laboratory in California, and even CERN in Switzerland.

"Our professors encourage us to work together, and the SPS helps to foster that environment," says Brooks. "We help physics majors see what their future will hold."

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Physics Fair
2012

In April, more than 600 young people, ranging from elementary through high school age, visited the Bloomberg Center for the department's ninth annual Physics Fair. Each year during the day-long fair, about 100 physics and astronomy faculty members, post-docs, and graduate and undergraduate students engage children in individual and team competitions, a physics-themed scavenger hunt, observatory viewings, and hands-on demonstrations, such as the classic hair-raising experiment (left inset) using the Van de Graaff generator. In addition, visitors could tour research laboratories and attend a "Professor Extraordinaire" show featuring lively demonstrations.