Johns Hopkins University

2011

# Physics and Astronomy

***Cover:*** *Close-up photo of single crystals of geometrically frustrated antiferromagnets, such as strontium holmium oxide. The crystals pictured here were grown in the crystal-growth facility of the Department of Physics and Astronomy's Institute for Quantum Matter by research scientist Seyed Koohpayeh. Conflicting magnetic interactions in these materials produce a rich variety of emergent phenomena, including the exotic spin-liquid state of matter.*

***This page:*** *The crystals at approximately 2.5 times their actual size. See related article on page 6.*

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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
UNIVERSITY

## Letter from the Chair

*Dear alumni, colleagues, and friends,*

October 4 was a banner day for Johns Hopkins and especially for our Department of Physics and Astronomy. That was the day Adam Riess, who holds a Krieger-Eisenhower Professorship in our department, was named a Nobel Prize winner for his leadership in the High-z Team's 1998 co-discovery that the expansion rate of the universe is accelerating, a phenomenon widely attributed to an unexplained "dark energy" filling the universe.

This level of achievement on the part of one of our faculty members is an affirmation of the intense quest for knowledge that is under way in our department every day. I believe that every physics and astronomy graduate has played some part in advancing the scholarship of this field. Each of you has a connection—be it past or present—to our department, and I know you share our pride in Adam's great accomplishment.

Even as we take time to celebrate this achievement (and celebrate we did!), the Department of Physics and Astronomy continues to move forward—sowing the seeds for the next round of discoveries in our disciplines. The department has recently embarked on a variety of new ventures, from a partnership with the National Laboratory of Solid State Microstructures at Nanjing University, to forefront work at the Large Hadron Collider at CERN, to building a state-of-the-art telescope in the Atacama Desert in Chile, and to numerous projects on the Homewood campus here in Baltimore.

No matter where they work, our diverse faculty and students share a commitment to deepening our understanding of the most basic, irreducible foundations of nature. I am fortunate to keep the company of so many scholars dedicated to forging new frontiers for our discipline.

In a similar vein, you hold in your hands another new venture for the department: an annual publication. Though it contains just a sampling of the work we have conducted over the past year, it will inform you of some of the department's endeavors, and I hope it inspires you to remain in contact. Enjoy this inaugural issue.

Best,

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

# Chasing the Origins of the Universe…

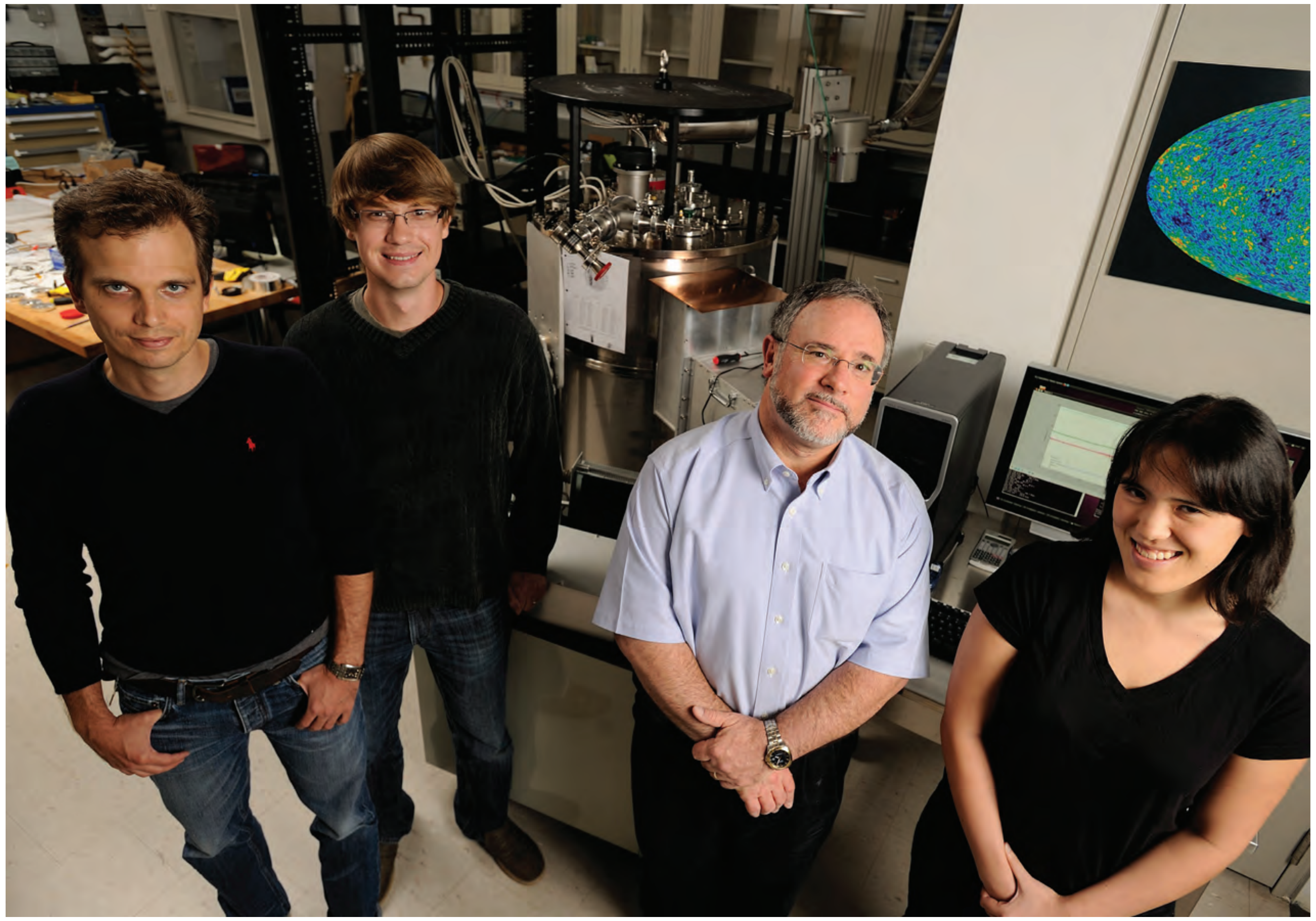
## Right down to the first trillionth of a trillionth of a second

BY KAREN BLUM

Astrophysicist Charles "Chuck" Bennett has spent more than 25 years studying faint afterglow radiation from the earliest moments of the universe.

Bennett, the Alumni Centennial Professor of Physics and Astronomy who came to Johns Hopkins in 2005 from the National Aeronautics and Space Administration (NASA), says there are many unanswered questions about the universe. His is, "What happened at the very beginning?"

"You might think that this is not answerable by humans," he says, "and it may not be, but we're going to try."



*Facing page: Several members of the CLASS team. From left: Assistant Professor Tobias Marriage, Graduate Research Assistant Joseph Eimer, Professor Charles Bennett, and Undergraduate Research Assistant Tiffany Wei. Between Eimer and Bennett rests a helium refrigerator system and dewar, which are used in conjunction to cool CLASS detectors to 100 millikelvin—just one-tenth of a degree above absolute zero.*

With a $5 million grant from the National Science Foundation, Bennett is leading a team developing a ground-based telescope to study the origin of the universe. The instrument will probe the cosmic microwave background radiation—faint traces of the universe's very beginning, 13.7 billion years ago.

Called the Cosmology Large-Angular Scale Surveyor (CLASS), the telescope will search large regions of the sky for a specific polarization pattern generated by gravitational waves formed during the first moments of the universe. Bennett hopes it will help provide a definitive test of the theory of inflation, which suggests that tiny quantum mechanical energy fluctuations suddenly grew at an enormous rate to an astronomical size to start the universe.

"This inflation theory, in my mind, is like a theory that adds on to the beginning of the Big Bang theory," he says. "Inflation theory actually *is* the theory of how things got started." While most cosmologists agree that the universe started very hot and dense and has been expanding and cooling ever since, the Big Bang theory many use to explain the universe's origin has become misconstrued, Bennett says. According to him, the Big Bang theory clarifies how the universe has evolved, but it doesn't tell us how it began.

Looking at the cosmic microwave background is looking straight into the past, due to the finite speed of light, Bennett explains. "We are directly looking at what the universe looked like 13.7 billion years ago. It isn't an idea, or a concept, we are looking at the light from 13.7 billion years ago, and that's what's so cool about it…it's incredibly exciting to try to use this data to figure out what happened in the first trillionth of a trillionth of a second of the universe." (It's worth noting that Bennett was the principal investigator for the 2001 Wilkinson Microwave Anisotropy Probe space mission, which improved cosmic parameters by a factor of 30,000, fixing the age of the universe to within 1 percent accuracy.)

The instrument will work somewhat like a satellite television dish. A reflector and circuitry within the instrument will intercept microwaves coming from space and direct the signal onto an array of tiny devices (superconducting transition edge sensors or bolometers), where that energy will be absorbed. The device heats up slightly due to this absorbed energy, allowing the team to record the energy coming from different directions of the sky. For this to be possible, the team has to cool the detectors within the instrument to a tenth of a degree above absolute zero. A position-cycled grid of wires located in front of the instrument will rapidly modulate the polarization state input to the detectors so the instrument's effects can be separated from sky polarization.

CLASS will be built at Johns Hopkins and transported to the Atacama Desert of northern Chile—one of the highest, driest places on earth. Bennett has been working with the Chilean government for permission to situate the instrument 17,000 feet above sea level in an evolving astronomical park scattered with other telescopes and observatories. Last year, he visited the area to select a specific location for the telescope, in view of the town of San Pedro de Atacama, some 9,000 feet below. Because the desert's extreme temperatures and little oxygen make for an inhospitable work environment, he plans to have an antenna transmit the data from the telescope to town so team members can access the information on computers at a more moderate altitude, limiting the amount of time spent on-site each day.

Now a year into the five-year grant, the team is well on its way to constructing the telescope. A lab (pictured left) across from Bennett's office houses part of the instrument's core circuitry, as well as cryogenic cooling equipment. An adjacent room holds their polarization filter, consisting of hundreds of thin gold wires, stretched taut.

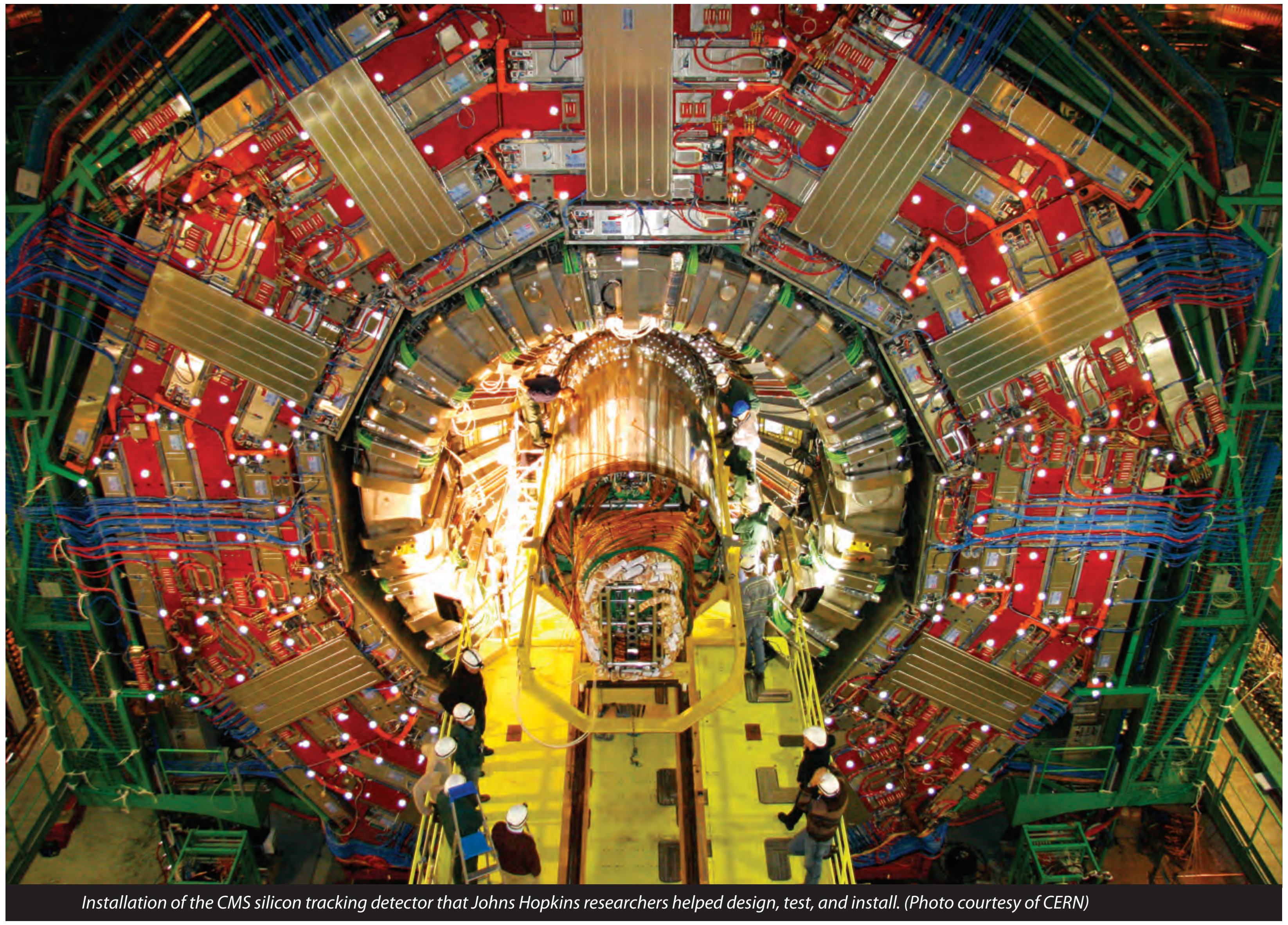
A key member of the team is Assistant Professor Tobias Marriage, who came to Johns Hopkins last year from Princeton University. Marriage has also been studying the cosmic microwave background, and at Princeton he worked on the Atacama Cosmology Telescope (ACT), located on the same Chilean plateau where CLASS will reside. Marriage studies clusters of galaxies that were found by their effect on the cosmic microwave background, and uses this information to deduce additional properties of the universe.

> "One of the most rewarding things is seeing undergraduate and graduate students really dig into the project. It's a great combination of enthusiasm and transfer of expertise."
>
> — TOBIAS MARRIAGE, ASSISTANT PROFESSOR

Marriage has been working closely with Johns Hopkins physics and astronomy students designing state-of-the-art technology for CLASS, including the optical instrumentation and a shield to protect the detectors from the Earth's magnetic field.

"One of the most rewarding things is seeing undergraduate and graduate students really dig into the project," Marriage says. "It's a great combination of enthusiasm and transfer of expertise."

"This is a real watershed moment," he adds. "This project hopefully will be the gateway to many, many more cosmological experiments over the next decades." If CLASS detects the anticipated signal, it would be the first-ever detection of the gravitational waves that signify the origin of the universe.



*Installation of the CMS silicon tracking detector that Johns Hopkins researchers helped design, test, and install. (Photo courtesy of CERN)*

# Discovery on a Grand Scale

## Hopkins physicists play important role with Large Hadron Collider

BY JIM SCHNABEL

Hundreds of feet beneath the countryside west of Geneva, Switzerland, the Large Hadron Collider (LHC) has captured the attention of particle physicists worldwide. The 17-mile circular synchrotron is the newest and largest particle-collider on the planet—capable of boosting clusters of protons to 99.9999991 percent of the speed of light, and steering them against protons that come at the same speed from the opposite direction. Its proton-on-proton collision energies reach 7 TeV, and are expected to attain energies as high as 14 TeV by 2014, seven times higher than the collision energies achieved at Fermilab's Tevatron in Batavia, Illinois—the world's largest collider before the LHC.

"The LHC is essentially a machine for detecting new physics," says Department of Physics and Astronomy Professor Bruce Barnett.

Run by the European physics consortium CERN, with some U.S. funding and plenty of U.S. participation, the LHC has been moving into normal working mode over the past few months. More than 6,000 particle physicists around the world are now trying to map its huge flow of data onto the Standard Model of particles and forces, which has held up well until now, but still contains terra incognita that only multi-TeV energies can illuminate.

"You can think about it as almost like a voyage to discover the Americas," says Associate Professor Kirill Melnikov. "We're still in the middle of the journey; we don't know that we're going to discover anything, but if we do, it will be a discovery on a grand scale."

Johns Hopkins has been a part of this journey from its beginning. Even before the LHC's construction was completed in 2008, Johns Hopkins experimental particle physicists—Professors Bruce Barnett, Barry Blumenfeld, Andrei Gritsan, Petar Maksimovic, Morris Swartz, and their postdocs and students—helped assemble one of LHC's two main detectors, the Compact Muon Solenoid (CMS). The 14,000-ton device enables physicists to detect and analyze the collision-products that explode outward from these proton-on-proton impacts.

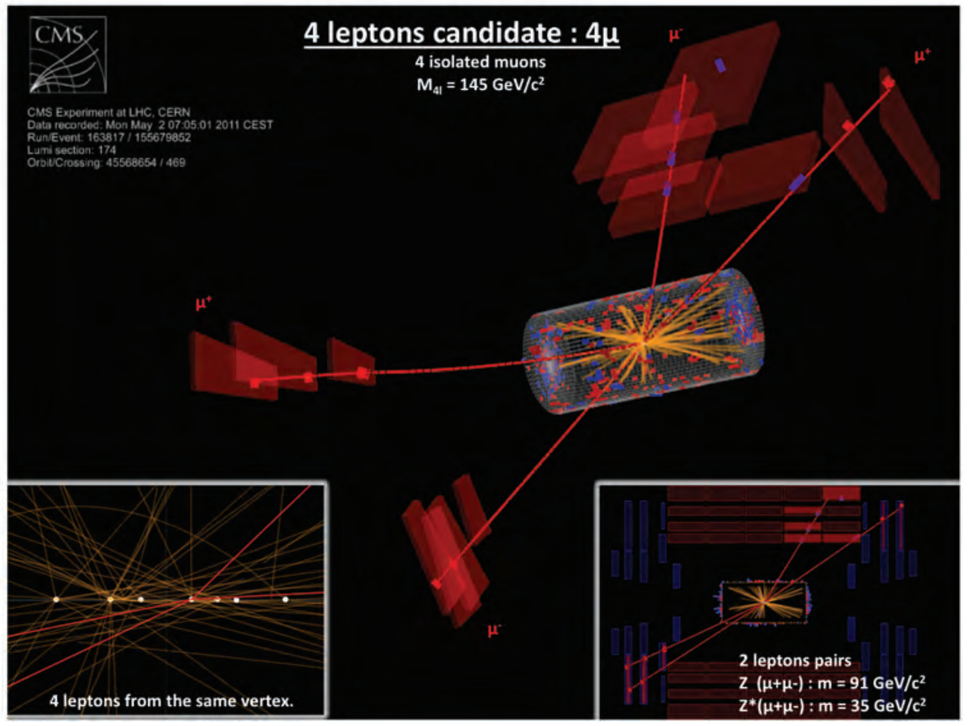
"We took our experience working with detectors at the Tevatron and brought that to the CMS," says Barnett. "We collaborated with other institutions to design the silicon detectors inside the CMS, carefully assembled them, tested them, shipped them off to CERN, and played a part in the delicate process of installing them."

"We've also developed some advanced software for these detectors, and have been designing some next-generation tracking instruments," says Swartz, the principal investigator for the NSF grant that funds most of Johns Hopkins' research at the LHC.

> "A huge mystery is why the top quark weighs 175 times the mass of a proton—about as much as an atom of gold."
>
> — JONATHAN BAGGER, PROFESSOR

The work has been challenging. Useful collision-product-detection requires hardware and software that is sensitive enough to distinguish the fleeting tracks of infinitesimally spaced subatomic particles; sophisticated enough to flag the noteworthy events amid the billions of proton-proton collisions that take place in a typical day of operation; and robust enough to stay useful even after months and years within a maelstrom of radiation. "To continue to get value out of the detectors as they're being degraded by radiation is tricky," says Jonathan Bagger, a Krieger-Eisenhower Professor and theoretical physicist at Johns Hopkins.

But now the CMS detectors are in place and yielding vast amounts of data—with which physicists hope to soon discern the answers to some important questions. Atop their list is the question of whether the hypothetical Higgs boson exists. Discovery of the Higgs boson would explain why the W and Z bosons—which mediate the weak nuclear force—have mass, while the photon—which mediates the electromagnetic force—does not.



*An event with the production of four muons in the proton-proton collisions at the LHC, observed in the CMS detector. Such events are important in the search for the Higgs boson, as the production of four muons is a potential decay mode of the Higgs. (Courtesy of CERN)*

"The Higgs mechanism is the simplest hypothetical mechanism that would give masses to these particles without breaking the Standard Model," says Melnikov. "But being the simplest proposed mechanism doesn't mean that it is the correct one."

Particle physicists worldwide are now scrutinizing data from LHC detectors for statistical hints of the Higgs—which theoretically was unlikely to manifest itself at the Tevatron. Gritsan, who has worked to install and align key CMS detectors, designed special software to pick up decay products that could occur if the Higgs emerges briefly into existence. "If you were to create a Higgs boson, it would live so briefly that the only way to see it would be to detect the channels of products from the two photons, or two W bosons, or two Z bosons into which it can disintegrate," he says.

By early August, data from the LHC had ruled out the existence of a Higgs-like particle over much of its allowed mass range. By the end of 2012, says Gritsan, Hopkins researchers expect the Standard Model Higgs boson to be either observed or completely ruled in. While finding the Higgs would shore up the Standard Model, not finding it wouldn't be considered a failure: "If we don't find it, we'll probably find something else that will be even more interesting and exciting," Gritsan says.

There are other, less popularly discussed puzzles that the LHC could help solve. One of these puzzles has to do with the top quark, discovered at Tevatron in 1994.

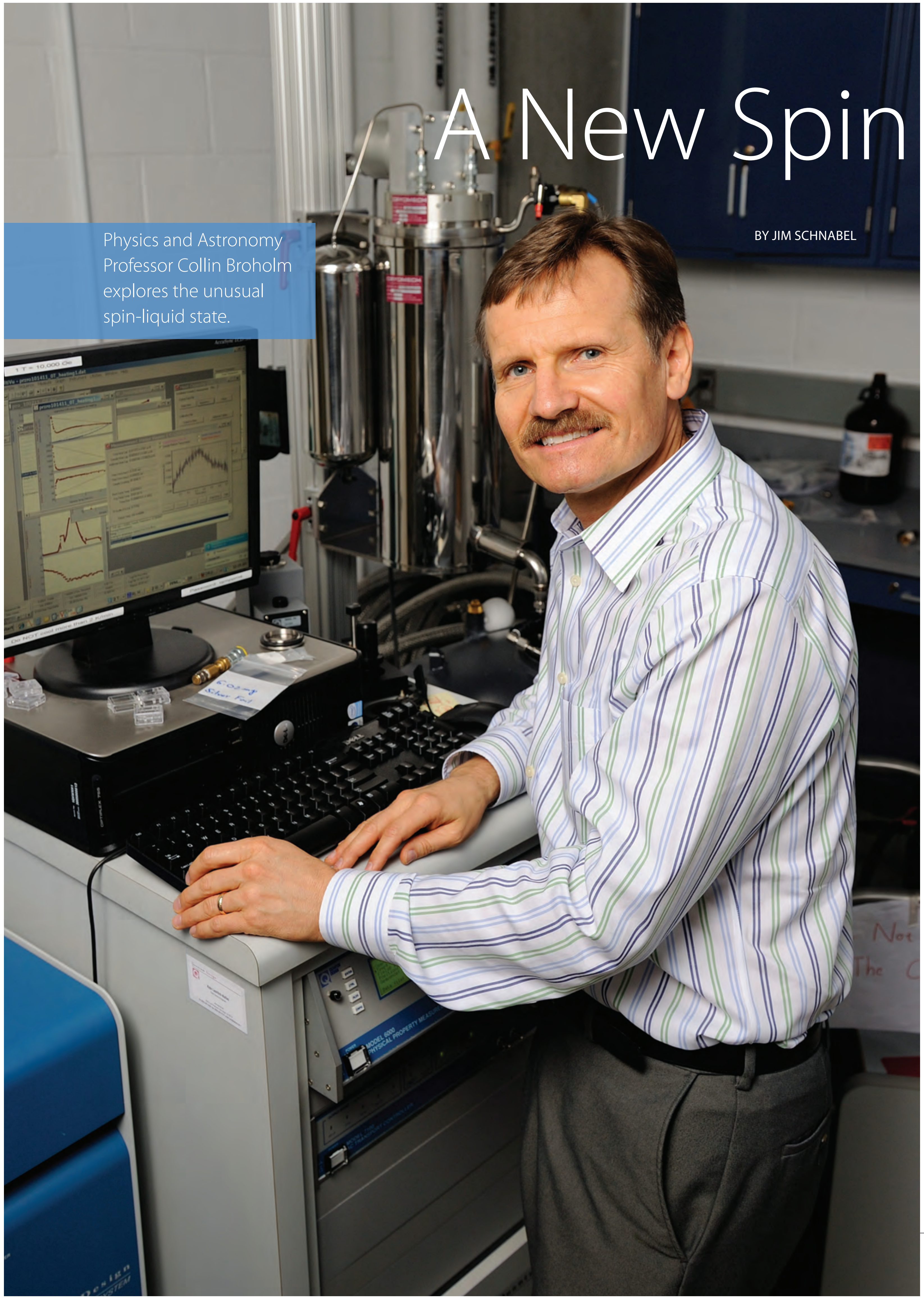
"A huge mystery is why the top quark weighs 175 times the mass of a proton—about as much as an atom of gold," says Bagger. "Since top quarks have so much mass, they must be intimately involved with whatever gives quarks and leptons their mass; what you really want to do is to study them every way you can."

Johns Hopkins professors (theorist David Kaplan and experimentalist Maksimovic) have been busy determining how top quarks should appear in LHC collisions and integrating their techniques into CMS detector software algorithms.

JHU physicists are also hoping the LHC might help solve some of the questions surrounding dark matter, whose existence astronomers infer from their observation that the visible matter in the universe cannot account for all of the universe's gravity. "If dark matter reacts even weakly to the usual collision-measuring instruments, then there's a reasonable chance that it can be detected at LHC," says Melnikov. "Should that happen, it would be a totally different game for physics."

# A New Spin on Quantum Matter

BY JIM SCHNABEL



Physics and Astronomy Professor Collin Broholm explores the unusual spin-liquid state.

*Facing page: Collin Broholm, the Gerhard H. Dieke Professor of Physics and Astronomy*

Collin Broholm, the Gerhard H. Dieke Professor of Physics and Astronomy, is on the trail of a new and exotic state of matter known as a "spin-liquid" state.

"Our motivation is almost entirely to learn new, fundamental physics, but we also have an eye out for applications," says Broholm. "In condensed-matter physics there can be a beautiful confluence of basic phenomena and practical application." In the case of spin-liquids, the exotic quasi-particles they host could one day become the Q-bits of a super-fast quantum computer.

The spin-liquid state is closely related to the superfluid state of helium near the absolute zero temperature, because like in liquid helium, quantum fluctuations preclude a periodic ordered state. "A material in the spin-liquid state is one that should be magnetically ordered from a classical viewpoint but remains a fluid," says Broholm. "It's the magnetic equivalent of superfluid $^4$He."

Like superfluid $^4$He, which has unique roton excitations, electrons in spin-liquids can fractionalize into spinons and holons–quasi-particles that separately carry the electrons' spin and charge. Broholm and his colleagues are on a quest to expose new forms of collective quasi-particles within crystalline solids to understand their interactions, impact on materials properties, and potential for technical applications.

A quantum computer would replace the usual binary 1-or-0 bits by the magnetic states of so-called qubits, which exist in an unresolved, maybe-1-maybe-0 state during calculations. As a result, a continuum of calculations is conducted, from which the result of interest can be projected upon completion. For certain types of computation, this makes a qubit-driven computer dramatically faster than an ordinary binary computer. The challenge is to realize a qubit that operates coherently long enough to complete a calculation. "A spin-liquid might do the job because the collective nature of spinons can protect them from defects and noise," says Broholm.

Originally from Copenhagen, Denmark, Broholm leads a team of scientists with similar interests and complementary expertise in the Johns Hopkins-Princeton Institute for Quantum Matter (IQM). Johns Hopkins professors Zlatko Tesanovic and Oleg Tchernyshyov focus on the theory of quantum-correlated materials; Tyrel McQueen and Robert Cava of the Johns Hopkins and Princeton departments of chemistry, respectively, synthesize spin-liquid-prone materials; and Broholm and Hopkins physicist N. Peter Armitage probe the collective properties of new materials. Specifically, they use neutrons or photons to detect novel quasi-particles and determine whether the new materials match the theory.

Some of this work requires large and expensive equipment that universities cannot afford to operate, so Broholm uses facilities run by the federal government. The National Institute of Standards and Technology (NIST) Center for Neutron Research is conveniently located in Gaithersburg, Md, and Broholm was the principal investigator for a novel instrument that has just been completed there. The Multi-Axis Crystal Spectrometer (MACS) was jointly funded by NIST, the National Science Foundation, and Johns Hopkins, and 20 percent of the beam time on it is available for IQM research.

> "THE SPALLATION NEUTRON SOURCE IS ON A DIFFERENT SCALE. THE NEUTRON-DETECTING SYSTEMS ON THE OUTPUT SIDE ARE THE SIZE OF HOUSES." — COLLIN BROHOLM, PROFESSOR

By probing the distribution of neutrons scattered from the materials of interest, MACS provides an atomic scale view of structure and motion in materials. "Neutrons are perfect for what we're trying to do," says Broholm. "They don't have charge, so they enter materials without disturbing things too much. Yet they do carry a magnetic dipole moment and can deliver energy and momentum to spinons through quantum collisions, witnessed by the pattern of neutron scattering."

By knowing the energy and momentum of neutrons as they enter a material and measuring how much these changed in the course of interacting with the material, Broholm and his colleagues can infer the amount of energy and momentum delivered to spinons—and thus infer properties of the spinons themselves. With 50 times the number of neutrons per time unit hitting the sample and 20 detectors to collect scattered neutrons, MACS is much more efficient than conventional instrumentation and is providing a whole new view of magnetism and electronic correlations at the atomic scale.

Broholm and his colleagues say they are also excited about the capabilities of the completely new Spallation Neutron Source (SNS) at the Department of Energy's facility in Oak Ridge, Tennessee (Broholm has a joint-faculty appointment there). The SNS produces neutrons by "spallation" of nuclei when energetic protons from a ~1 GeV accelerator strike a dense target. The pulsed incident proton beam creates a pulsed neutron beam with peak intensities much greater than is possible at a reactor-based facility. "SNS is on a different scale," says Broholm. "The neutron-detecting systems on the output side are the size of houses." He should know, having served as the chair of the SNS's Experimental Facilities Advisory Committee from 2002 to 2006. For his scientific research and his work to develop neutron scattering instrumentation, the Neutron Scattering Society of America (NSSA) awarded him its 2010 Sustained Research Prize.

Broholm's work on the spin-liquid state most recently led him to Japan, where he spent several months visiting with physicists at the University of Tokyo's Institute for Solid State Physics. "Over the last 20 years or so, they've developed a lot of expertise in the discovery and characterization of novel electronic materials, so I've been visiting there to strengthen our collaboration," he says. "They bring expertise in materials production, and on our side we're helping to disentangle atomic scale properties of strange quantum magnets through neutron scattering."

# RESEARCH BRIEFS

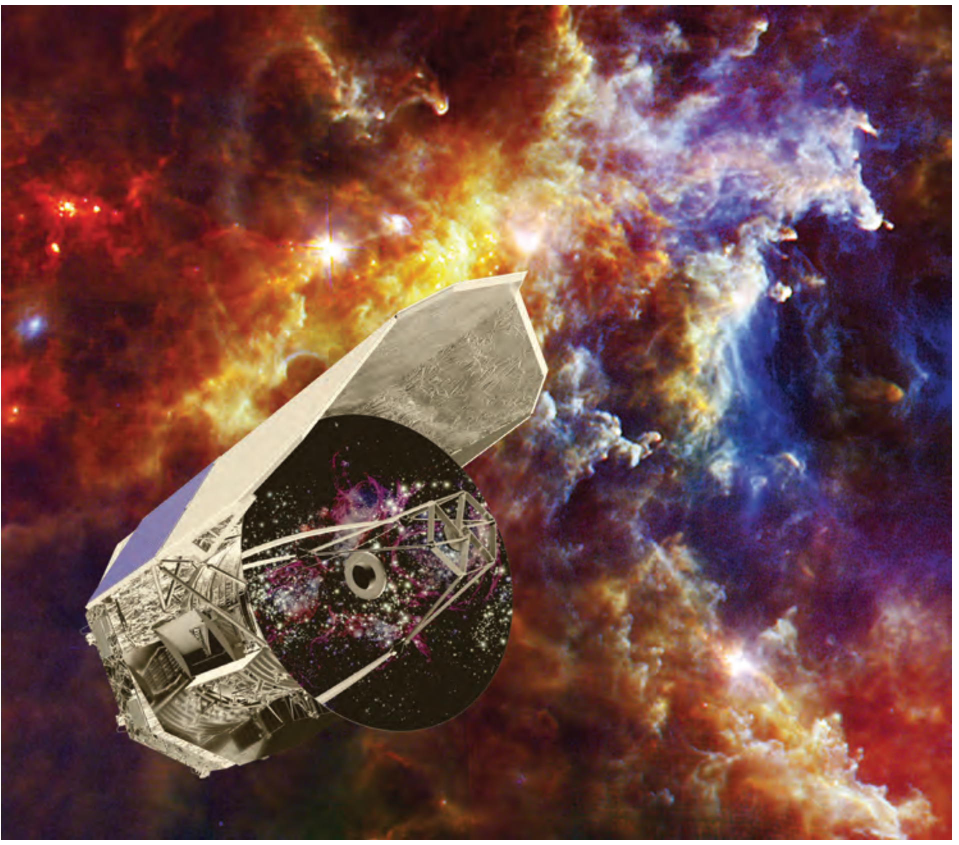


PHOTO COURTESY OF ESA, C. CARREAU.

## Data from Herschel Observatory Unlocks Clues to Star Formation

**P**hysics and Astronomy Professor David Neufeld has been gathering and analyzing data from the Herschel Space Observatory (pictured above), the largest infrared observatory in orbit. Herschel's 3.5 meter diameter reflecting telescope (the largest single mirror ever built for a space telescope) and its Heterodyne Instrument for the Far Infrared (HIFI) allow the observatory to measure frequencies to one part in a million, "which makes it particularly good at observing molecules in space," explains Neufeld. He has been using Herschel's exceptional power to discover and analyze previously undetectable clouds of interstellar gases, most notably those that contain water or hydrogen fluoride. Both gases are commonly present at the beginning and at the end of a star's life cycle, and Neufeld's work may ultimately become essential in tracing star formations in more distant galaxies.

## New Course Combines Space Science and Engineering

**T**he department has launched a new course called Introduction to Space Science and Technology, designed for undergraduate students preparing for a career in space science and engineering. The course addresses topics such as conducting research in the space environment, space mission design, systems engineering, and human operations in space. Last semester the course was team-taught by three faculty members with extensive experience on the subject: Warren Moos, principal investigator for the Far Ultraviolet Spectroscopic Explorer (FUSE); Stephan Murray, principal investigator for the High Resolution Camera for the Chandra X-ray Observatory; and John Grunsfeld, an astronaut on five NASA space flight missions.

"This course has a somewhat hidden agenda as well," says Moos. "Students are going to begin to understand how to design, implement, and accomplish very large scientific enterprises. That skill set will be useful, no matter what they do after Hopkins." Building on this cross-disciplinary approach, Space Science and Technology is co-listed by the physics and astronomy; earth and planetary sciences; materials science and engineering; and mechanical engineering departments.

## Hopkins Astrophysicist Awarded $3.2 Million NASA Grant to Build Sounding Rocket

**S**tephan McCandliss, an astrophysicist at Johns Hopkins since 1988, has been awarded a $3.2 million grant from NASA to build and launch a sounding rocket-borne spectro-telescope called FORTIS, which could ultimately define the origins of the meta-galactic ionizing background that permeates space. The grant is a continuation of a 2004 NASA grant called "Rocket and Laboratory Experiments in Astronomy—FORTIS: Pathfinder to the Lyman Continuum."

According to McCandliss, the 1,123-pound, 24-foot-long rocket payload, scheduled to be launched in early 2012 from New Mexico, will be used to measure the escape of Lyman alpha (the principal spectral line emitted by atomic hydrogen) from nearby star-forming galaxies.

McCandliss, with the assistance of a small crew of graduate students and engineers, has constructed much of the sounding rocket from scratch, within the labs and offices of the Bloomberg Center for Physics and Astronomy. Using this multi-object spectro-telescope, enabled by micro shutters that control the selection of light, he has devised innovative ways to observe galaxies, estimate their origins, and ultimately answer the question, "How did the universe come to be ionized?"

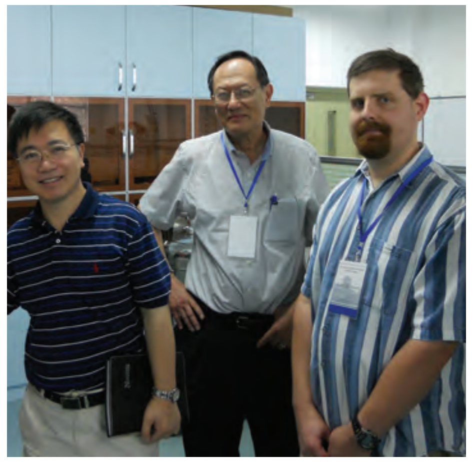
"This is really entrepreneurial science," explains McCandliss. "Programs such as this further the Hopkins tradition of creating new science with innovative instruments, while providing unique opportunities for hands-on training of students."


*Research Professor Stephan McCandliss (left) oversees graduate students Keith Redwine (center) and Brian Fleming as they assemble the FORTIS payload in preparation for a focus test.*

## Grant Funds Collaboration with Nanjing University and Chinese National Laboratory

**T**he Department of Physics and Astronomy was among the first wave of departments to receive funding from the new JHU Benjamin and Rhea Yeung Center for Collaborative China Studies. The center chose 11 proposals to fund this year, its first year of operation, including one from the physics and astronomy department that would forge a partnership with the National Laboratory of Solid State Microstructures (NLSSM) at Nanjing University. The department will receive $150,000 per year to work with the laboratory, initially on joint research in condensed matter physics. It is expected that the Yeung Center will fund this project for up to five years. The project's principal investigators, Professor Chia-Ling Chien from Johns Hopkins and Professor Mu Wang, the director of the NLSSM at Nanjing University, have planned several modes of research, focused on current research problems of mutual interest and involving interactions and reciprocal exchanges by faculty, post-

*Continued on p. 10*


*From left: Professor Hai-Hu Wen, of Nanjing University, and Johns Hopkins professors Chia-Ling Chien and Tyrel McQueen.*


*Physics and Astronomy Professor Rosemary Wyse*

## The Matter of the Universe

**A**s a founding member of the RAVE (Radial Velocity Experiment) collaboration, Physics and Astronomy Professor Rosemary Wyse studies the motions and chemical compositions of 36,561 stars in the Milky Way galaxy. Data acquisition from this international project is slated to conclude in 2012, after nine years of observation, and Wyse hopes that the subsequent final analyses will reveal new theories on how galaxies are formed and the nature of dark matter.

"We want to infer, from looking at the stars now, what conditions were like when they formed," says Wyse. Although there have been other similar spectroscopic surveys in addition to RAVE, "each has its own niche in the sense of what piece of the galaxy you're looking at and what sort of spectra you're getting."

According to Wyse, the RAVE survey, funded by the National Science Foundation, is unique in that it is looking at all types of stars, and encompasses a large enough sample to discover unusual objects to study.

"It's exciting," says Wyse, "because we have a lot of new data right now, and at the same time we're beginning to have the computer power to do the matching detailed simulations of galaxy formation—so we can compare them with the great observations that we're getting."

Describing this part of her work as "galactic archaeology," Wyse has focused much of her research on the stars in the Milky Way galaxy, the object of the RAVE effort. " The stars in our galaxy cover the whole history of the universe, from the oldest stars to the youngest," she says, making it a perfect mix of star evolution to observe. One of Wyse's pivotal research achievements was in characterizing the stellar population of the thick disk in the Milky Way and to point out its importance in constraining or defining the dark matter.

In all of Wyse's research, dark matter plays a critical role. "The merger history of the Milky Way is driven by this mysterious dark matter. If we can figure out the merging history—and therefore galaxy evolution—then we can place constraints on the nature of dark matter."

— *Diana Schulin*

*Grant Funds from p. 9*

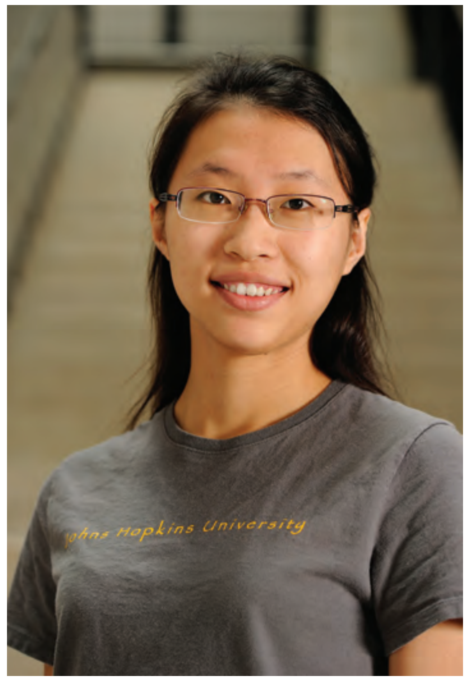
docs, and graduate students. A group of Johns Hopkins faculty traveled to Nanjing in August to kick off the program. "This looks like a highly promising partnership," says Department Chair Daniel Reich, who was part of the delegation. "We were able to establish links and connections with faculty at Nanjing University in this first visit that we will be able to build on in the coming years." This initiative will likely lay the groundwork for future Johns Hopkins–Nanjing partnerships within the department and in other physical science disciplines, such as materials research. Just as important, the new affiliation offers students and faculty not only a chance to collaborate with their peers in Nanjing, but also a tremendous opportunity to broaden their social and cultural horizons.

## Undergraduate Publishes Research on Spin Ice; Garners Awards

Physics major Yichen Shen '11 was recognized this year for his impressive study of artificial spin ice, a class of nanostructured materials harboring magnetic monopoles. In his junior year, Shen started working under the supervision of Oleg Tchernyshyov, a professor and condensed matter theorist in the department, on a research project funded by a Hopkins Provost Undergraduate Research Award. Shen utilized his analytical training (he received a BS in physics and an MA in mathematics during his four years at Johns Hopkins) to conduct numerical simulations of the Tchernyshyov group's research, uncovering a deficiency in their original model and helping the group build a reliable description of the system that agrees with experiments. He went on to analytically derive a statistical distribution of magnetic avalanches and perform numerical simulations that confirmed his predictions.

Shen's research was published this year in a co-authored article in *Physical Review Letters*. His work on artificial spin ice also caught the attention of the American Physical Society, which named him a finalist in their annual LeRoy Apker Award, a distinction the society awards to "young physicists who have demonstrated great potential for future scientific accomplishment." The Department of Physics and Astronomy lauded his work as well, awarding Shen the 2011 Donald E. Kerr Memorial Award, given annually to an outstanding physics major. Shen shared the honor with Justin Silverman and Xinlu Huang.

Now a graduate student at MIT, Shen continues to work with the Tchernyshyov group, whose members are preparing a full-length article on their research for the *New Journal of Physics*, in which Shen will be the lead author.



*2011 Gardner Fellow Danru Qu*

## 2011 Gardner Fellow Works at Crossroads of Biology and Condensed Matter Physics

Danru Qu has been named the 2011 William Gardner Fellow. This award, given to first- or second-year physics and astronomy graduate students, relieves promising young scholars like Qu of their teaching duties for one semester so they can get a head start on doctoral research.

Qu, now a second-year graduate student, has already demonstrated a talent and zeal for her area of interest—using the tools and principles of condensed matter physics to attempt to differentiate species of bacteria. "Various species of bacteria have different numbers and arrangements of flagella," she explained in her fellowship proposal. "Despite their importance in the mobility of bacteria, flagella are hollow tubes only 20 nm in diameter, too small to be seen by optical microscopy."

Thus, Qu will use the research time afforded by the fellowship to experiment with recently invented electric tweezers, which can rotate minuscule objects, including bacteria. Since rotation characteristics depend on the geometrical details of the object, bacteria with different flagella would display different rotation characteristics. "It could be possible to differentiate bacteria in liquid by their response to an external electric field," says Qu. "In this manner, we can identify bacterial species without actually 'seeing' the flagella."

Such an achievement "would be a scientific first," says Chia-Ling Chien, the Jacob L. Hain Professor of Physics and one of Qu's mentors in the department. "I am impressed by Danru's academic record, drive, and determination."

Qu is the third 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.

> *"It could be possible to differentiate bacteria in liquid by their response to an external electric field. In this manner, we can identify bacterial species without actually 'seeing' the flagella."*
>
> *—Danru Qu*

# PEOPLE

## Four New Named Professorships Awarded

The Department of Physics and Astronomy honored four faculty members with named professorships in 2011. Timothy Heckman was named the inaugural Dr. A. Hermann Pfund Professor in early May, while Charles Bennett, Adam Riess, and Joseph Silk were granted named professorships in late September in a celebration of their accomplishments.

**Timothy Heckman**, the inaugural Dr. A. Hermann Pfund Professor, has played a major role in defining the understanding of black holes and star formation. Aside from his numerous awards and achievements, Heckman is also the director of the Johns Hopkins Center for Astrophysical Sciences, which is a focal point for the activities of the more than 100 astrophysicists in the department. His professorship is named in honor of Dr. A. Hermann Pfund, who in many ways set the foundation for modern astronomy during his tenure at Johns Hopkins from 1903 to 1947.

*Professor Timothy Heckman*

**Charles Bennett**, the Alumni Centennial Professor in Physics and Astronomy, is one of the world's leaders in the study of the cosmic microwave background radiation. Bennett has garnered many awards and accolades for his research, including election to the National Academy of Sciences, the Henry Draper Medal, the Gruber Prize in Cosmology, the Harvey Prize, the Comstock Prize in Physics, and the Shaw Prize in Astronomy. His professorship was named in honor of the alumni on the occasion of the university's 100th birthday, celebrated in 1976 with a year of events and a symposium that brought scholars from all over the world to Johns Hopkins.

**Adam Riess**, the Krieger-Eisenhower Professor in Physics and Astronomy (and recent Nobel Prize recipient—see back cover), has played a critical role in discovering the nature of dark energy. In addition to his named professorship, Riess has garnered many other honors, such as the Sackler Prize, the Shaw Prize in Astronomy, the Gruber Prize in Cosmology, a MacArthur Fellowship, and the Einstein Medal. The Krieger-Eisenhower Professorship is a tribute to one of the university's greatest benefactors, Zanvyl Krieger, and his close friendship with former Johns Hopkins University President Milton Eisenhower.

**Joseph Silk**, the Homewood Professor in Physics and Astronomy and one of the department's most recent hires, has established himself as one of the world's leading theoretical astrophysicists over his 40-year career, having published more than 500 scholarly papers. Among his many awards and honors, he most recently received the 2011 Balzan Prize for his inspired work on the early universe. His professorship, named in honor of the School of Arts and Sciences' north Baltimore campus, was established by the school's Academic Council.

"Appointment to an endowed chair has been a coveted honor for distinguished faculty ever since the first professorships were created five centuries ago at the universities of Oxford and Cambridge," Dean Katherine Newman noted at the September event that celebrated Bennett, Riess, and Silk. "Those who hold endowed chairs are leaders in their fields. They are the pioneers who will chart new courses of discovery and attract the brightest and most promising students. These faculty members bring added luster to the name of Johns Hopkins."

*From left: Department Chair Daniel Reich, School of Arts and Sciences Dean Katherine Newman, and Professors Adam Riess, Charles Bennett, and Joseph Silk.*

## New Appointments

**Marc Kamionkowski** joined the department in the 2011–12 academic year after serving as an endowed professor of theoretical physics and astrophysics at the California Institute of Technology. Kamionkowski, who earned his PhD in physics from the University of Chicago, is a world leader in the study of dynamics, large scale structure, and early history of the universe. His current research interests include dark matter, inflation and the cosmic microwave background, and cosmic acceleration.

The department welcomed **Tobias Marriage** in 2010–11 as an assistant professor after postdoctoral study at Princeton University. Marriage is an experimental cosmologist who is playing a leading role in experiments to observe the cosmic microwave background and answer important questions about the origins and evolution of the early universe and the nature of dark energy. His research activities include millimeter-wave instrumentation, fieldwork, and analysis. Current projects include the Atacama Cosmology Telescope, the Atacama B-mode Search, and the Cosmology Large Angular Scale Surveyor. He earned his PhD from Princeton in 2006.

After completing graduate studies at Princeton and a postdoc at MIT, **Tyrel McQueen** came to Johns Hopkins in 2010–11 as an assistant professor in the physics and astronomy department and the chemistry department. McQueen's study of materials straddles the line between inorganic chemistry and condensed matter physics. "My primary appointment in the chemistry department allows me to design and synthesize new materials containing electrons displaying emergent behaviors," he says. "But my lab's location—in the Department of Physics and Astronomy—encourages me to explore the physical properties of the materials I'm researching on a level usually studied by condensed matter physicists."

**Brice Ménard** joined the Department of Physics and Astronomy in 2010–11, after working as a senior research associate at the Canadian Institute for Theoretical Astrophysics. An assistant professor, Ménard is a theorist who is interested in extragalactic astrophysics and cosmology.

By mining large data sets to gain insight into the universe, he has made major discoveries about the relationship between stars, dark matter, and the presence of tiny grains of dust around galaxies. Ménard earned his PhD from the Max Planck Institute for Astrophysics and concluded postdoctoral research at the Institute for Advanced Study in Princeton, N.J.

**Nadia L. Zakamska** is a theorist and observational astronomer who joined the department in 2010–11 as an assistant professor. She was previously a research associate at the Kavli Institute for Particle Astrophysics and Cosmology at Stanford University. Before that, she was a five-year member at the Institute for Advanced Study. Zakamska, who earned her PhD in astrophysics from Princeton University, focuses her research on observational astronomy, including active galactic nuclei and ultraluminous infrared galaxies, and theoretical astrophysics, including outflows from compact objects and dynamics of stellar and planetary systems.

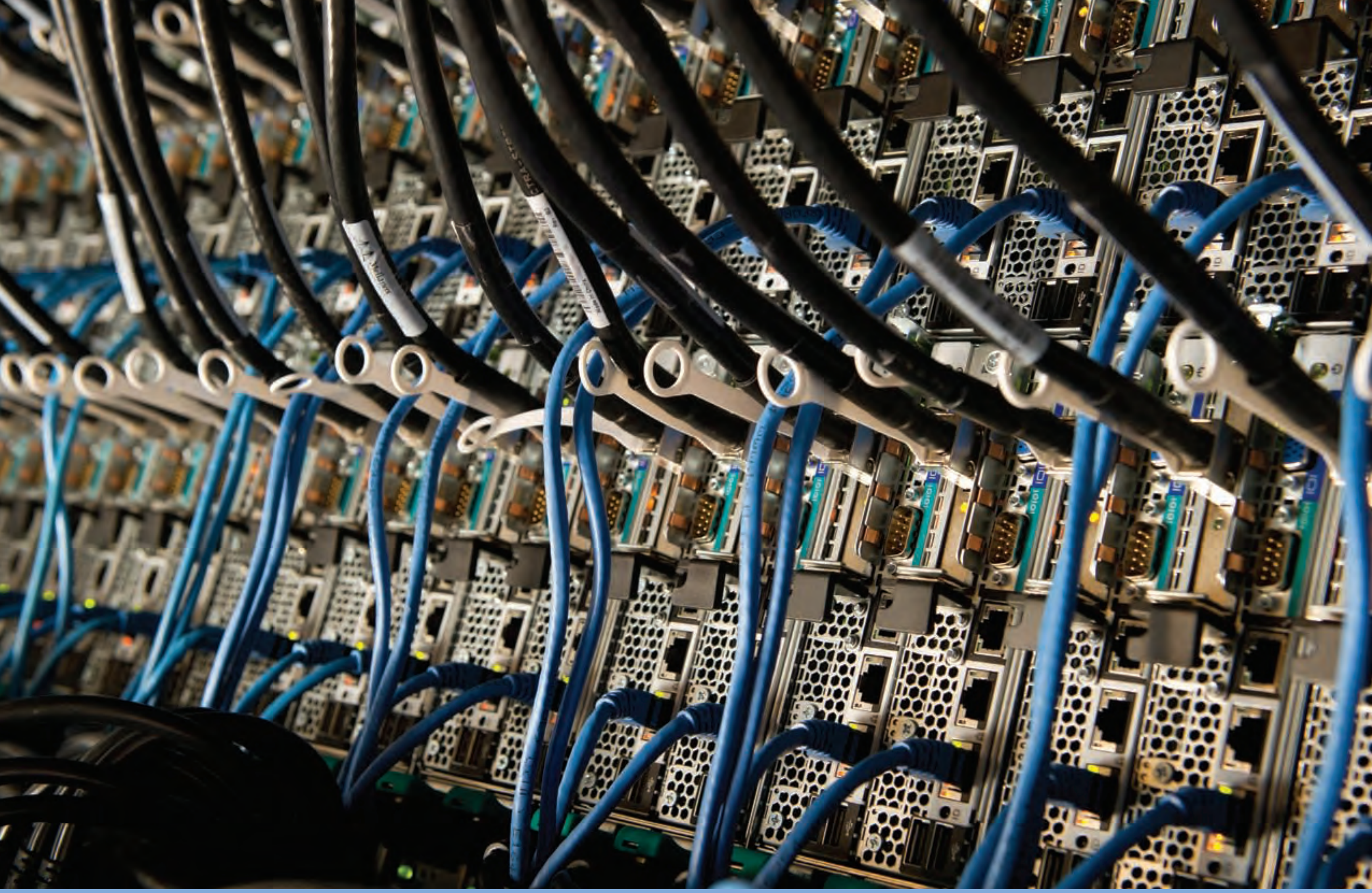
## Johns Hopkins Receives Grant to Upgrade Maryland's Internet Pipeline

Johns Hopkins University and the University of Maryland at College Park received a $1.2 million grant from the National Science Foundation (NSF) to build one of the world's fastest and most advanced scientific networks.

"This bandwidth upgrade will allow enormous scientific data sets to be moved to Johns Hopkins from Google, the Oak Ridge National Laboratory, and the San Diego Supercomputer Center, for example," said Alexander Szalay, Alumni Centennial Professor of Physics and lead researcher on the grant.

The network, supported by NSF's Office of Cyberinfrastructure, will be one of the country's first public 100 Gbps Internet connectivities, allowing Johns Hopkins and its collaborators to stay on the cutting edge of science, moving data sets thousands of times bigger than previously possible. The network will be built at Johns Hopkins University at the Bloomberg Center for Physics and Astronomy and supported by the regional MAX research and engineering network aggregation point at the University of Maryland.

*Professor Alexander Szalay*



# Not Your Average Server Room

*A former mission control center has been transformed into the new home for Johns Hopkins data-intensive computing.*

There's a large—3,100 square feet—brightly lit room on the first floor of the Bloomberg Center that was once a critical base for the Far Ultraviolet Spectroscopic Explorer (FUSE). It was the control center for the FUSE, which was launched into space in 1999 and operated until late 2007. Four years later, the room is now repurposed, dedicated to exploring a realm that is quickly becoming nearly as vast and difficult to navigate as space itself: data.

Funded in part by the National Science Foundation through an American Recovery and Reinvestment Grant, the new data center serves both the Krieger School of Arts and Sciences and the Whiting School of Engineering, and several major computing clusters in the room are dedicated to projects led by physics and astronomy faculty members. By the end of 2011, the data center will house two data-intensive computing clusters, dubbed GrayWulf and Data-Scope; the entire Homewood High-Performance Cluster (HHPC), and several other state-of-the-art computing projects. Each will be used to create, store, organize, and eventually interpret the vast amount of data generated from disciplines such as astrophysics, genetics, condensed matter physics, environmental science, or bioinformatics.

Only partially completed as of this fall, here is a sampling of the computing power already available in the new data center:

- Two towers of graphics processing unit (GPU) powered computers called the 100Teraflop Graphics Processor Laboratory. One teraflop denotes the ability to perform one trillion operations per second.
- 10 gigabyte-per-second connectivity between clusters in the data center and computers elsewhere on the Johns Hopkins network.
- Over 3,500 compute cores in the HHPC (each comparable to those in a fast desktop PC) that can be harnessed to work in parallel on complex problems.
- A direct connection to Internet2—an advanced networking consortium of academic and research clusters like the HHPC from around the U.S. More than 350 member institutions will soon share 100 gigabit-per-second connectivity and 8.8 terabits of capacity, granting research institutions like Johns Hopkins unprecedented shared-computing capability.
- GrayWulf, the largest database in any university, has roughly 1.5 petabyte storage capacity. That's equivalent to 6,000 250 gigabyte hard drives—a typical amount of storage on a consumer laptop. When completed, Data-Scope will have a 10 petabyte capacity.

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# Congratulations, Adam Riess!

*Adam Riess (left) celebrates his Nobel Prize with Department Chair Daniel Reich (right).*

On October 4, 2011, Adam Riess, the Krieger-Eisenhower Professor of Physics and Astronomy, became Johns Hopkins University's 35th Nobel laureate. The Royal Swedish Academy of Sciences' early morning announcement hailed Riess' discovery of the universe's accelerating expansion as one of the most profound and important of our generation.

Riess shares the prize with Brian Schmidt, of the Australian National University, who worked directly with Riess; and Saul Perlmutter, of the University of California, Berkeley and Lawrence Berkeley Laboratory, who worked with a separate team.

By examining supernovae from more than five billion light years away, Riess played a pivotal role in demonstrating that the expansion rate of the universe is increasing. In 1929, astronomer Edwin Hubble showed that the universe is expanding, but this expansion was expected to slow due to the gravitational pull of matter in the universe. In attempting to detect that expected decrease in the expansion rate, the Nobel winners revealed just the opposite: an accelerating expansion. The Nobel committee was careful to award the prize for the discovery of the acceleration, leaving aside the vexing question of what is causing the expansion to accelerate. Theories abound under the catch-all phrase "dark energy," including Einstein's cosmological constant, vacuum energy, an evolving universal scalar field or fields, or a flaw in the theory of general relativity. Whatever the cause, the discovery is a landmark that will change cosmology, and possibly fundamental physics.

"We at the Krieger School of Arts and Sciences are enormously proud of this most significant accomplishment," said Dean Katherine Newman. "This type of internationally recognized achievement illustrates all that Johns Hopkins is about: the quest for knowledge, the drive for discovery, and the passion to make a difference in the world."

The Department of Physics and Astronomy is now home to two Nobel Prize winners: Riess and Professor Riccardo Giacconi, who received the Nobel Prize in physics in 2002 for his pioneering work in the field of X-ray astronomy.