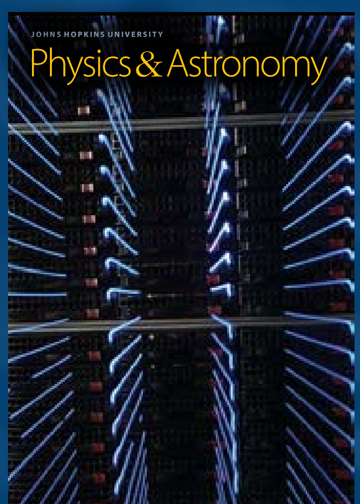
JOHNS HOPKINS UNIVERSITY

2013

Physics & Astronomy



***On the cover:** The Bloomberg Center is home to a new data center that is quickly becoming a hub for the university s data-intensive computing efforts. For the cover, our photographer shot a server cluster using a zoom lens and a slow shutter speed, to create the illusion of the computer lights moving.*

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JOHNS HOPKINS
KRIEGER SCHOOL
of ARTS & SCIENCES

Letter from the Chair

Dear alumni, colleagues, and friends,

I am pleased to be writing to you at the end of another exciting year here in the Department of Physics and Astronomy at Johns Hopkins. Many impressive developments have been taking place across the full spectrum of our activities.

For starters, I want to draw your attention to a once-in-a-lifetime event: the upcoming release of our faculty member David Kaplan's movie *Particle Fever*, which tells the story of the Large Hadron Collider (LHC) and the discovery of the Higgs boson. I saw *Particle Fever* at the New York Film Festival, and I can tell you that it is a winner! It opens nationwide in March 2014.

We continue to make great strides in research in the department, from Oleg Tchernyshyov's beautiful and elegant work on quantum spin systems, to Alex Szalay's leadership in the science of big data, to the critical role played by Andrei Gritsan and his team in elucidating the properties of the Higgs boson at the LHC. We are also pleased that our researchers continue to garner significant awards and recognition—from Holland Ford receiving NASA's Distinguished Service Medal for his key contributions to the Hubble Space Telescope, to graduate students Schuyler Wolff and Alex Greenbaum, who were awarded NSF fellowships, and first-year graduate student Guy Marcus winning the APS's Apker Award.

I also want to draw your attention to the new version of our General Physics course that takes place in a beautifully renovated Bloomberg 478 (see pages 12-13). Nearly 60 percent of Hopkins students take General Physics—that's almost 700 students per semester—and we are working across the board to improve our teaching in these classes that are so critical to our mission. After a set of visits by department members to assess teaching practices at other universities, we have also developed a new active-learning-based curriculum for our discussion sections that are led by our teaching assistants.

Finally, be sure to check out our brand new physics and astronomy website at physics-astronomy.jhu.edu. The new site allows for much easier navigation and offers an overview of all that is happening in the department.

Enjoy this issue, and 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

Associate Professor Andrei Gritsan holds a model that represents a portion of the Compact Muon Solenoid (shown on screen in background). Gritsan's team worked on the CMS, which is a large particle detector built at the Large Hadron Collider and used in the search for the Higgs boson.

Tracking Down the Centerpiece of Particle Physics

JHU Physicist Plays Key Role in Finding Elusive Particle

BY GABRIEL POPKIN

On June 14, 2012, Associate Professor Andrei Gritsan, postdoctoral fellow Sara Bolognesi, and graduate student Andrew Whitbeck—all from Johns Hopkins—gathered with several colleagues for a secret night-time meeting in a conference room at the CERN laboratory in Geneva, Switzerland. The occasion was their first look at a statistical analysis of data from proton collisions in the Large Hadron Collider (LHC), the world's largest particle accelerator. So important were the data that the researchers had analyzed them without actually looking at the results, to avoid any chance of biasing their conclusions.

At this point, the researchers knew a graph with a bump in it would indicate strong evidence the collider had produced the elusive Higgs boson. The Higgs, first proposed in the 1960s, was needed to fill in the largest gap in the Standard Model, the leading theory in fundamental particle physics. Its existence would signify the existence of a field that permeates all space and imbues the matter in the universe with mass.

A flat graph, by contrast, would mean…nobody was quite sure what.

Gritsan, the leader of the team working at CERN, projected the graph on a screen, and the scientists knew their long wait was over.

"It all changed in an instant," says Gritsan. "It was an emotional moment, and it left no doubt that we had something big."

On the strength of the two bumps (another one revealed in another channel) and similar evidence from another research group, CERN's leaders called a press conference for July 4, 2012. At the conference, they announced to the world that they had found a new particle with a mass of around 125 billion electronvolts, or GeVs (the electronvolt is particle physicists' preferred way to express mass; 1 eV indicates a mass of about $1.8\ 10^{-33}$ grams). Whitbeck was delegated to sit near the front of the room, armed with a battery of PowerPoint slides to explain the scientists' analysis techniques, should any reporter ask. (None did.)

Left unanswered at the conference, however, was whether the new particle was actually "the" Higgs boson. At the time, LHC researchers were even reluctant to call the particle "a" Higgs boson, preferring instead the cautious "Higgs-like particle." Now, a year and a half later, LHC physicists are much more comfortable saying they have found "a" Higgs, if not yet "the" Higgs. And much of that progress has been due to efforts of the Gritsan lab at Johns Hopkins.

Gritsan and his team are part of the more than 2,000-person collaboration that manages the Compact Muon Solenoid, or CMS, one of two enormous detectors nestled into the LHC's 17-mile-long tunnel. Using arrays of sensors similar to those in a digital camera, the detector takes precision snapshots of the debris spewed out when near-light-speed protons collide and turn their energy into new matter. The CMS was already under construction when Gritsan joined the collaboration in 2005, but he quickly made his mark on the team, finding ways to precisely align the instrument's sensors so researchers could compute the exact paths particles would take through the detector.

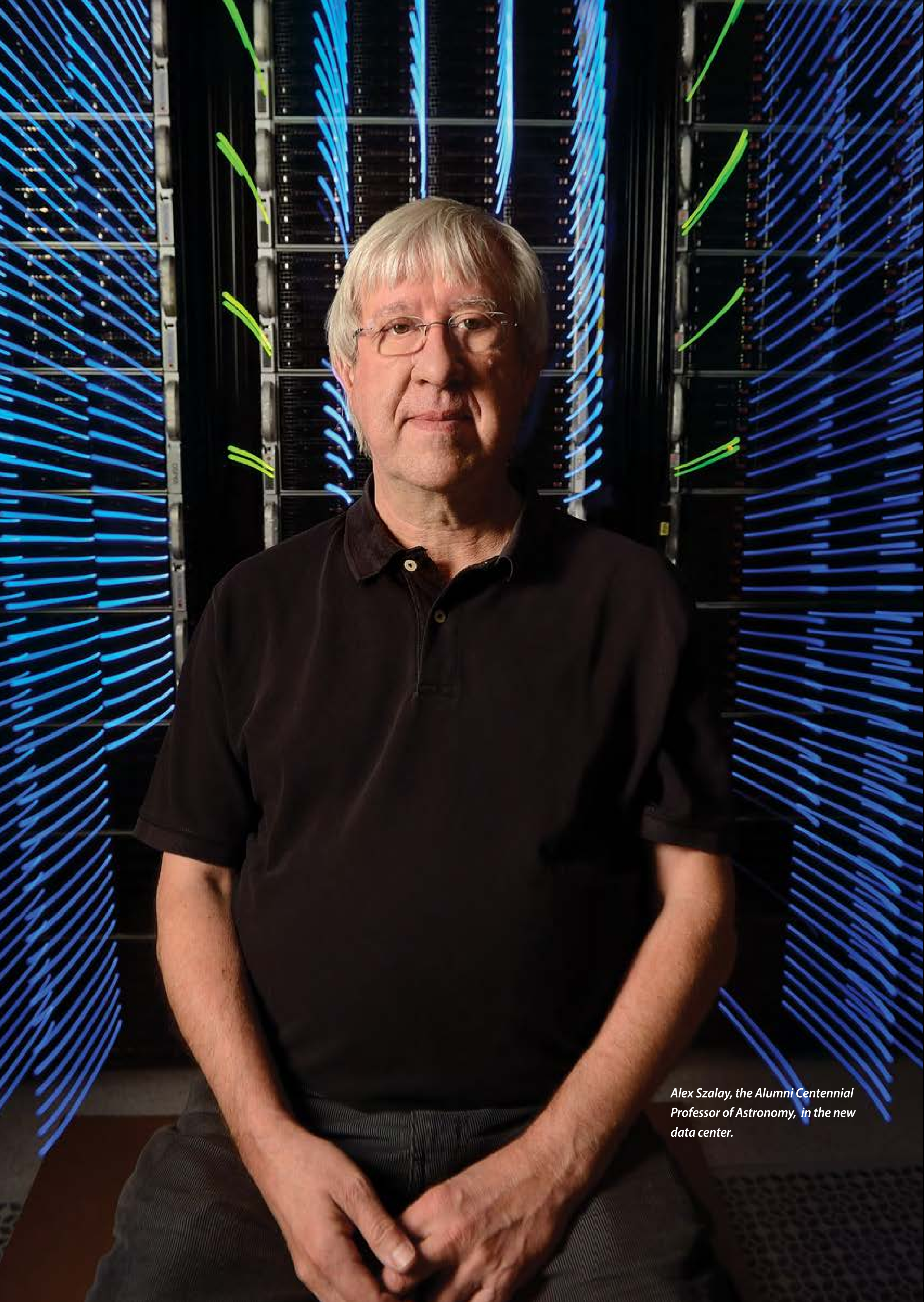
Gritsan simultaneously developed methods to extract useful results from the masses of data the CMS would soon be collecting. The CMS, along with its sister detector ATLAS, was designed to capture not the Higgs boson itself but its decay products, because theorists had shown that the Higgs boson, if it exists, will decay into other particles before it can leave any physical record of its presence. Gritsan and his team looked for signatures of one of the Higgs boson's possible decay "channels," known as "H→ZZ." In this channel, the Higgs decays to two Z bosons; these in turn quickly decay to four leptons—a class of particle that includes electrons and their heavier cousins, muons. As the leptons speed away at close to the speed of light, they leave traces in the layers of sensors that make up the CMS. The sensors then dump their data to a worldwide network of computers.

That's when the analysis started. The amount of data to be sifted through was truly daunting—20 billion collisions recorded, each yielding roughly 1 megabyte—and the researchers' only hope was to write clever computer programs to extract signals of the particles they sought from this vast, noisy background. Gritsan, Bolognesi, Whitbeck, and several former students in the lab spent years developing a sophisticated analysis method called the Matrix Element Likelihood Approach, or MELA ("mela" means "gathering" in Sanskrit and "apple" in Italian; Bolognesi says she and her colleagues hope their technique is as successful as Apple Computers). MELA, which extracts information on the angles at which decay particles fly away from a collision, is instrumental in amplifying the signal to the so-called "five-sigma" certainty level that gave LHC leaders the confidence to call the famous 2012 press conference. In early 2013, MELA results gave physicists the confidence to call it a Higgs boson, and in October, the two researchers (Peter Higgs and Francois Englert) who first predicted its existence received the Nobel Prize.

With such blockbuster success, LHC scientists now find themselves in a peculiar position. On the one hand, they have made the biggest discovery in particle physics in decades. On the other hand, it is a discovery many people expected; and not finding the Higgs boson would have in some ways been more tantalizing. Meanwhile, the LHC is shut down until 2015 for repairs and upgrades, so any new revolutionary discoveries are at best several years down the road.

But Gritsan and his Hopkins colleagues aren't just biding time until the LHC comes back to life. For one thing, they still have piles of data to analyze as they seek to further understand the new particle.

The Higgs boson mass was found to be consistent with the predictions of the Standard Model, but it is inconsistent with expected quantum effects—so-called "loop corrections"— that can increase the mass enormously, unless there is incredible fine-tuning of the theory to keep the mass relatively small. This suggests that further surprises may be lurking. Moreover, the LHC has thus far operated only at energies up to around 8 TeV, just over half of what it was designed for, meaning researchers have another large energy space to explore once the collider fires up again. New particles could be lurking there, as could clues to the nature of dark matter, dark energy, and the unexplained dominance of matter over antimatter in the universe. In short, says Gritsan, "this is just the beginning; we have found a completely new state of matter-energy, and we do not even know where it will take us."



Alex Szalay, the Alumni Centennial Professor of Astronomy, in the new data center.

The Next Scientific Revolution: Big Data

Astrophysicists are harnessing a profusion of information that will lead to new discoveries.

BY GABRIEL POPKIN

Throughout history, astronomers have struggled to coax even the smallest bits of information about our universe from the night sky. Their task is rapidly becoming easier, however, thanks to powerful modern telescopes and computers that are expanding the astronomical data stream from a trickle to a torrent. But this shift, while in many ways a researcher's dream come true, also creates new challenges.

"No scientist has ever refused to take more data if they could," says astrophysicist Alex Szalay, the Alumni Centennial Professor of Astronomy. "The question is how do we make sense of it all? And that's becoming hard—very, very hard."

In the past two decades, Szalay and his Johns Hopkins colleagues have become leaders in confronting these challenges. They have developed techniques to collect, store, and analyze vast quantities of astronomical data. Now they are applying what they've learned to fields as far-flung as genomics, linguistics, engineering, neuroscience, and ecology. "Big data" is fundamentally changing how science is done, says Szalay. "We are really undergoing a major scientific revolution right now."

Szalay became involved in big data a little over two decades ago, when Johns Hopkins joined the Sloan Digital Sky Survey (SDSS), an ambitious effort to map around a quarter of the night sky in unprecedented detail. At the time, SDSS researchers were concerned about how to handle the 10 terabytes of data they planned to collect. Szalay started building databases to organize the information and allow scientists to analyze it, even though he admits "[he] didn't know anything about databases" at the time.

Collaborating with legendary Microsoft computer scientist Jim Gray, Szalay created a new kind of system with the tools needed for analysis sitting on the same server as the data. SDSS then made both the data and the tools available to the astronomy community. Suddenly, scientific discovery was no longer limited to a small group of scientists who collected or had access to a data set—now anybody with an internet connection could get involved. As a result, SDSS has become one of the most productive scientific projects in history: it has already generated more than 5,000 publications from groups around the world, and researchers continue to mine both new and old SDSS data for additional discoveries. "The result is a lot of people are coming in with very clever ideas that even the collaboration could never think of," says Szalay.

Some of the most innovative ideas have come from Assistant Professor Brice Ménard, an astrophysicist who joined the Johns Hopkins faculty in 2010. Using sophisticated statistical techniques, Ménard was able to map intergalactic dust, which is so faint that astronomers had not previously been able to detect it. Ménard showed that intergalactic space held far more of this dust than anyone had thought. He has more recently extended his techniques to map intergalactic gas and dark matter. Szalay says Ménard is an "example of the next generation of scientists who are playing these instruments like a master."

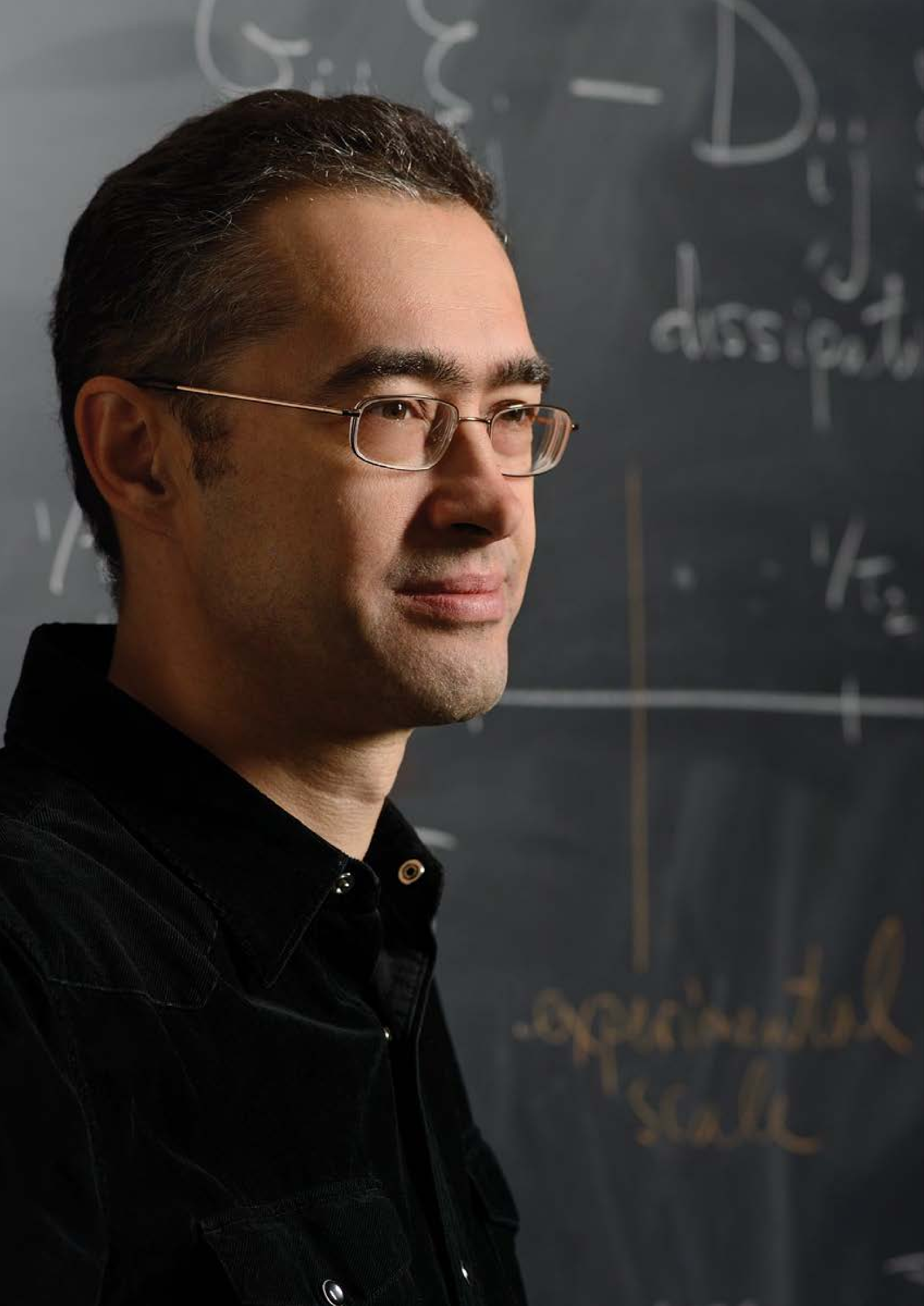
> *"We are really undergoing a major scientific revolution right now."*
>
> —Professor Alex Szalay

Of course, the amount of data that seemed big when SDSS began now seems modest. Ten terabytes can fit onto a few palm-sized hard drives, and even the 400 terabytes the survey ended up collecting are hardly tremendous by today's standards. But Johns Hopkins is also a member of the Large Synoptic Survey Telescope (LSST), a next-generation instrument that will begin operating in 2022. LSST will photograph the sky every few nights, collecting as much data in one night as SDSS gathers in a year. With so much data available, says Ménard, "You are limited by your own imagination."

Faculty have also pushed big data science into new territory by creating an initiative that cuts across the traditional Johns Hopkins divisional boundaries. The Institute for Data Intensive Engineering and Science, or IDIES, is set to transform a host of disciplines. In ecology, for example, scientists from the university's Department of Earth and Planetary Sciences are installing a global network of wireless sensors to collect data on soil temperature, moisture, and carbon flux. Because soil microbes release far more carbon dioxide than all human activities, the data from this network could answer questions of fundamental importance to understanding and predicting future climate change. Szalay, the institute's director, says IDIES was the first interdisciplinary big data center of its type when it launched in 2009, and has since inspired similar efforts at other universities.

Johns Hopkins' move into big data has positioned the university as a computing powerhouse. In 2008, Szalay and his colleagues launched Graywulf, a server cluster named in honor of Jim Gray, who had been lost at sea the previous year. Thanks to the team's focus on increasing data throughput rates, Graywulf won a major competition for high-speed data processing, beating out entries from many places better known for computer science. Johns Hopkins faculty then bested themselves with Data-Scope, which came online this summer and reads data 30 times faster than Graywulf, making it the fastest data-processing system at any university in the world. Data-Scope, which is available to selected research groups from Johns Hopkins and other campuses, lives in the Bloomberg Center for Physics and Astronomy alongside the Homewood High-Performance Cluster, which serves researchers from the Krieger School of Arts and Sciences and the Whiting School of Engineering.

The future may be hard to predict, but one forecast both Szalay and Ménard are willing to make is that big data science is only going to get bigger. And they strongly recommend that any up-and-coming scientist, regardless of field, pick up some computational skills early on. "My message to young people is that this is a different way of thinking about your science," says Ménard. "I think it's just at the beginning. It's exciting. The possibilities are infinite."



The Mysteries of Magnetism

Complex spin studies lead to new theories

BY TOM SIEGFRIED

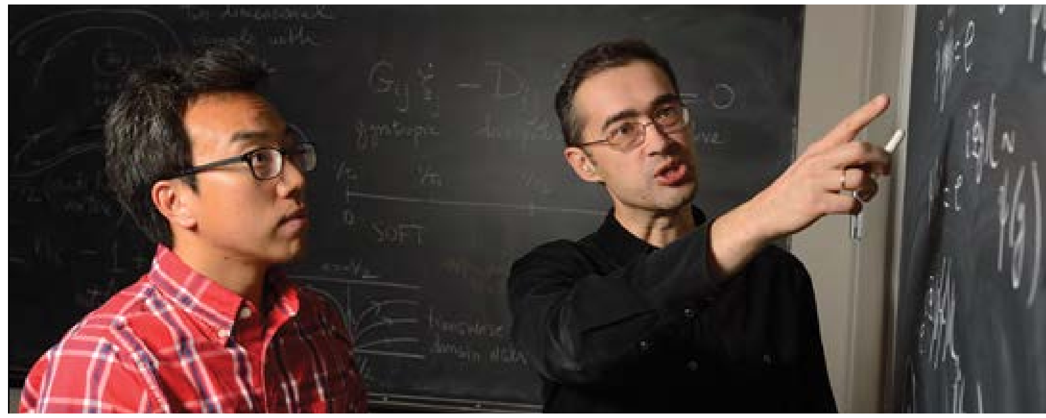
Theoretical physicist Oleg Tchernyshyov and his colleagues in Johns Hopkins' Institute for Quantum Matter study various kinds of magnetic materials from ferromagnets to spin ice and spin liquids. Their recent work is leading to new theories about the intricate and challenging properties of magnetism.

Spin is a key aspect of magnetism because magnetic fields arise from the spinning of electrons, creating electric currents, which in turn generate a magnetic field. A spin generates a magnetic moment pointing in a specific direction, corresponding to the north pole-south pole axis of an ordinary bar magnet.

Tchernyshyov and his collaborators study how spins behave in various magnetic materials, focusing on defects, or textures—spins that don't conform to the orderly arrangement of spins in the material as a whole. In a ferromagnet for instance, where all the spins are neatly aligned to point in the same direction, disturbing one of the spins can cause it to flip, from pointing up, say, to pointing down. That flipped spin will then return to its original direction by inducing its neighbor to flip, which will then induce another neighbor to flip and so on. As the process continues, an oppositely flipped spin will appear to travel through the material as though it were a particle, or "quasiparticle," known as a magnon.

Over the decades, physicists have developed a thorough understanding of dynamic processes such as motion of magnons in systems where spins exist in an orderly arrangement. But things can be more complicated in magnetic materials where the spins don't line up at all. These materials are spin liquids, by analogy with ordinary liquids, in which molecules have no specific arrangement—unlike the orderly arrangement of atoms in solid crystals.

In classical physics, complete information about the state of a system of particles exists when the state of each and every particle is individually specified. In the classical picture, the spins of two electrons can be in one of four states: both pointing up, both pointing down, one pointing up and the other down, and vice versa. Quantum mechanics allows for infinitely many states besides those, including a state in which two spins have opposite orientations, even



Associate Professor Oleg Tchernyshyov and graduate student Se Kwon Kim discuss how a quantum spin ice can contain a string of misaligned spins, leaving a 'monopole on a leash.'

though the orientations of the individual spins are not known. Measuring them would yield random results that are nonetheless perfectly antipodal (one up, the other down, or vice versa). "In a way, the spin of a particle in this entangled state is both up and down at the same time," says Tchernyshyov. "Physicists and computer scientists hope to harness the power of quantum entanglement to parallelize computation."

As a byproduct of this entanglement, quasiparticles in quantum spin liquids can carry fractional amounts of spin (half a unit of angular momentum), whereas magnons in an ordered magnet carry integer spin. But the existence of such materials in real life hasn't been easy to establish.

One proposal for substances with spin liquid status are materials called kagome antiferromagnets. Tchernyshyov and his colleagues have calculated how kagome antiferromagnets would behave in ways that can be tested via neutron scattering. A recent experiment by a group at MIT, in collaboration with Collin Broholm—the Gerhard H. Dieke Professor at Hopkins—used the Tchernyshyov group's predictions to provide evidence that the material actually is a quantum spin liquid.

The theories of Tchernyshyov and his colleagues are being used by experimental physicists to understand quantum effects in other magnetic materials. For example, the Tchernyshyov group has predicted behaviors that would be observed in materials called quantum spin ices. Instead of just a single disturbance moving around, a quantum spin ice can contain a string of misaligned spins. In a paper published last year in *Physical Review Letters*, Tchernyshyov and graduate student Yuan Wan describe such strings in a compound composed of the elements $Yb_2Ti_2O_7$.

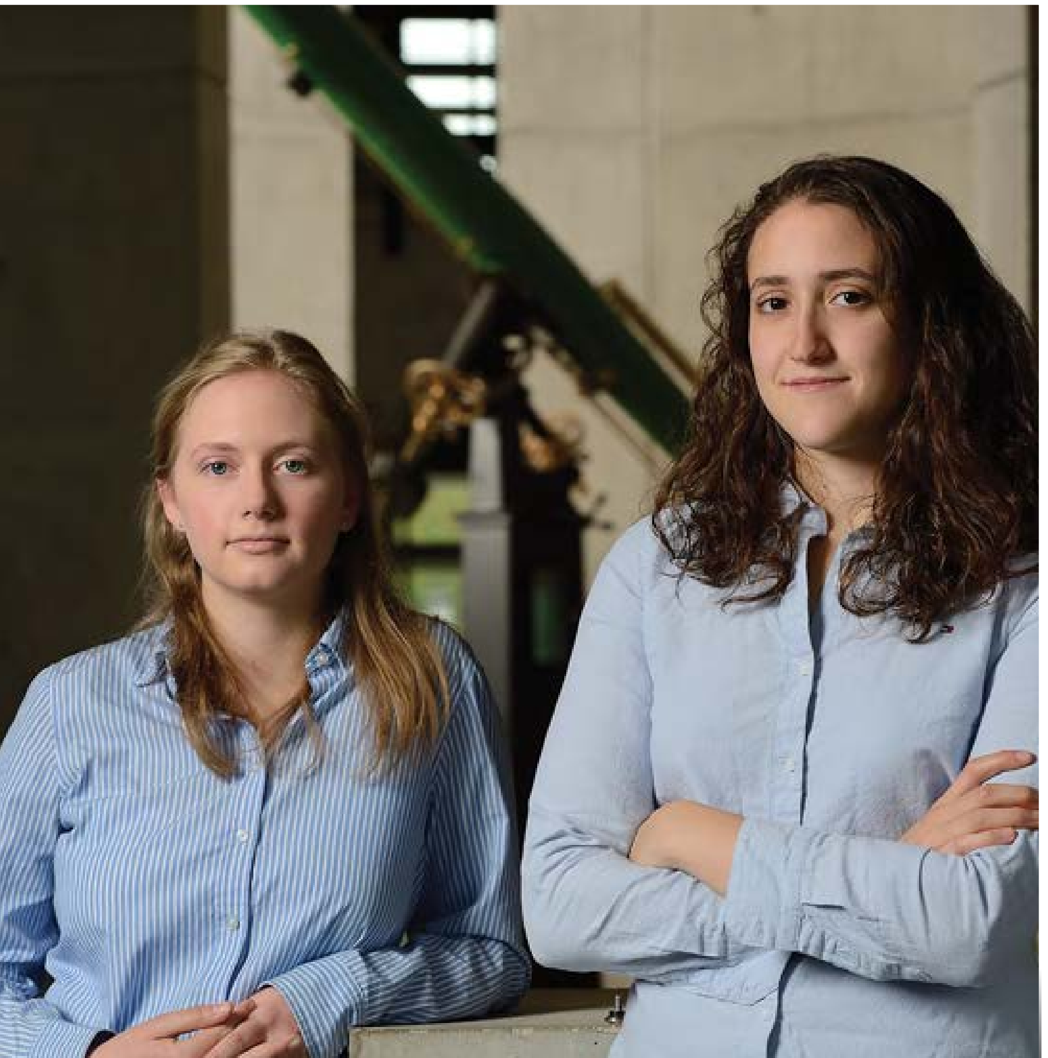
Ordinarily spins, just like ordinary magnets, are dipoles, with both a north and south pole. But in quantum spin ices, a quasiparticle can have a north pole without a south pole, and vice versa. These monopoles would be found at the ends of strings, and so could be thought of as "monopoles on a leash," Tchernyshyov says. (They are similar in concept but technically different from magnetic monopoles discussed in cosmology, which are predicted to exist but not yet observed.) Current experimental work by colleague Peter Armitage, associate professor in the department, has provided hints that the monopoles on a leash described theoretically by Tchernyshyov and Wan may actually exist.

Much of Tchernyshyov's work is of mostly basic research interest, but understanding how defects move around in magnetic materials does have potential uses. Manipulating defects in magnetic nanowires could be used to store information and even perform computations, for instance.

Efforts along those lines are underway in studies by experimental physicist Stuart Parkin and his colleagues at IBM's Almaden research laboratory in California. Parkin's group recently reported success in guiding the motion of defects in a nanowire network—a sort of artificial spin ice—in work relying on theoretical descriptions of such systems published by Tchernyshyov and graduate student Gia-Wei Chern in 2005.

"When other researchers and basic scientists are using your ideas, it's the best thing a theorist can hope for," says Tchernyshyov.

NEWS BRIEFS



Two Doctoral Students Receive NSF Fellowships

Alexandra Greenbaum (right) and **Schuyler Wolff**, two Johns Hopkins graduate students, both received 2013 fellowships from the National Science Foundation (NSF).

While their research projects are different, both involve the Gemini Planet Imager—new, ground-based instrumentation that images extrasolar planets orbiting nearby stars.

Greenbaums research seeks to use an imaging technique called non-redundant mask interferometry in order to image planet-forming regions and learn how planets form out of the dusty disks of young stars.

Wolff s research investigates the formation of planetary systems through high contrast imaging of systems containing both planets and disks, with a focus on elucidating the timescales and mechanisms that produce Jupiter mass planets and how those planets interact with present disks.

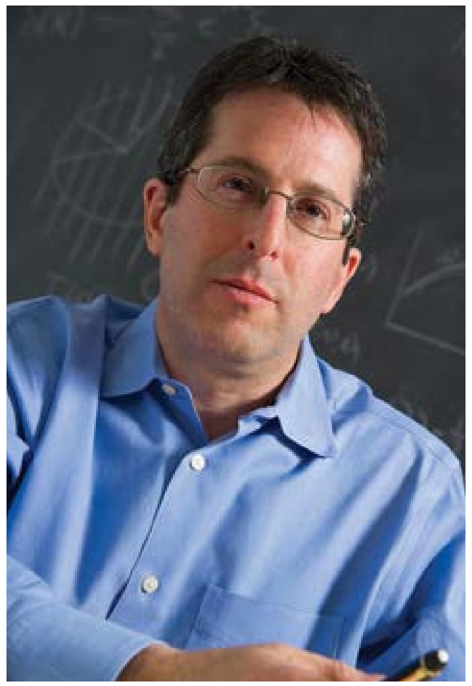
The National Science Foundations Graduate Research Fellowships support outstanding graduate students in NSF-supported science, technology, engineering, and mathematics disciplines.

JHU Physicists Receive $1.3 Million to Study Origins of the Universe

Three Johns Hopkins theoretical physicists have received a $1.3 million grant from the John Templeton Foundation to develop new ideas about the origins of the universe and ways to test those ideas. The project will be led by Professor **Marc Kamionkowski**, with Professor **Alex Szalay** and Professor **Joseph Silk** as co-leaders.

The grant will also be used to support a post-doctoral program for young scientists in theoretical research and to create a visitors program to bring notable scientists in the field to the university to collaborate with researchers. The three-year grant will fund six post-doctoral scientists at the university.

Of particular interest to the researchers is the expansion of the early universe. Current measurements suggest the Big Bang began with inflation, which provided the initial conditions for the evolution of the universe and for the growth of stars, galaxies, and clusters of galaxies within it. The scientists will try to understand the new physics responsible for inflation, what set inflation in motion, and what, if anything, happened before inflation.



Marc Kamionkowski

New Faculty Member Explores Holographic Principle

Jared Kaplan

Theoretical physicist **Jared Kaplan** prefers to explore his field from the bottom up, rather than the top down. "I'm most motivated by things that are generic and general," says the Department of Physics and Astronomy's new assistant professor. "I'm more interested in the robust, general features of physical systems as opposed to studying one particular system in great detail."

Kaplan's research incorporates everything from effective field theory, particle physics, and cosmology to the formal aspects of scattering amplitudes, conformal field theory, and holography.

Kaplan arrived at Johns Hopkins in August after completing graduate school at Harvard University and a post-doc at Stanford University. But the Chicago native didn't initially set out to become a theorist. "In grad school I started out really wanting to do things that were practical and related to experiments, so I focused on the Large Hadron Collider, which was the big thing when I entered school," he says.

But as his studies continued, he found himself shifting to the more mathematical, more formal side of the field in his quest to understand the holographic principle—the idea that our three-dimensional reality is a projection of information stored on a distant, two-dimensional surface. Now he says, he "pitches a tent between string theory and phenomenology. It's sort of this weird niche, and the people who have occupied it tend to be relatively young."

He has since become one of several dozen researchers worldwide to employ anti-de Sitter/conformal field theory correspondence (AdS/CFT) to try to explain the holographic principle. "This has been a very exciting area, and there has been a lot of progress in the past 10 or 15 years," he says of the theory, first proposed in 1997 by the Argentine physicist Juan Maldacena. Kaplan admits that his take on AdS/CFT is somewhat different than that of other physicists, but he says "it's totally reformatted the big questions that I've been looking at. Now there's kind of a concrete way of answering properties of conformal field theory."

In the fall semester, Kaplan taught a graduate-level course on AdS/CFT from the point of view of effective field theory and the conformal bootstrap, a technique to constrain and discover strongly interacting conformal field theories. The theory dates back to the mid-1970s, but the feasibility of the method only came back into favor about five years ago. Since then, Kaplan has attended several international conferences called Back to the Bootstrap. "There are a lot of really good young people who have been doing work in the field," he says. "Again, the conformal bootstrap theory is a very bottom-up approach in an attempt to completely solve these conformal field theories. You pull yourself up by your bootstrap."

Kaplan says he's enjoyed his time at Hopkins so far. And after living in San Francisco he's happy to be back in a place with changing seasons—and affordable rents. He's also been impressed by the physics and astronomy department. "There is a lot of enthusiasm for science, and I appreciate the intellectual freedom to pursue my research. I'm very happy to be here."

—Joe Sugarman

COURTESY OF SLOAN DIGITAL SKY SURVEY

The Sloan Digital Sky Survey collaboration operates a dedicated 2.5 meter telescope, an instrument that surveys a large part of the sky at Apache Point Observatory in New Mexico.

NSF Awards $9.5 Million for Big Data Research

A team of scientists at Johns Hopkins has received a grant for $9.5 million over five years to develop, build, and maintain large-scale data sets that will allow for greater access and better usability of the information by the science community.

Alex Szalay, the Alumni Centennial Professor of Astronomy, is the principal investigator on the Data Infrastructure Building Blocks, or DIBBs, project. The funding was awarded in October and is part of a larger collaborative agreement between the university and the National Science Foundation's Advanced Cyberinfrastructure division. Partners on the project include the Sloan Digital Sky Survey, or SDSS; the Virtual Astronomy Observatory; the GalaxyZoo project; the San Diego Supercomputer Center; and Towson University. Additional collaborators include scientists from Microsoft and Google. (For more about big data at Johns Hopkins, see pgs. 4-5.)

NEWS BRIEFS

Guy Marcus

Young Physicist Wins Apker Award

First-year graduate student **Guy Marcus** has been selected by the American Physical Society to receive the 2013 LeRoy Apker Award for his undergraduate research at Wesleyan University, where he worked with Professor Greg Voth to develop a method for 3D printing small anisotropic particles and developed new image processing algorithms to extract the particles' time-resolved solid body rotation from experimental video data. The Apker Award is given annually; one recipient is chosen from among all PhD-granting institutions for his or her "demonstrated great potential for future scientific accomplishment."

Charles Bennett Receives 2013 Jansky Prize

Astrophysicist **Charles Bennett** was selected to receive the 2013 Jansky Prize for his leadership in the establishment of precision cosmology through studies of the Cosmic Microwave Background radiation.

Bennett, the Alumni Centennial Professor of Physics and Astronomy, is the first Johns Hopkins faculty member to receive the honor. The Karl G. Jansky Lectureship was established in 1966 to recognize outstanding contributions in the advancement of radio astronomy. The National Radio Astronomy Observatory, an affiliate of the National Science Foundation, sponsors the prestigious award.

Bennett's research is in the area of experimental cosmology, building instruments and telescopes for the observational study of the origin and evolution of the universe. His work studying Cosmic Microwave Background radiation has garnered international recognition.

2013 Gardner Fellow Analyzes "Space Fossils"

Liang Dai is a cosmic paleontologist of sorts. The second-year PhD candidate and 2012 recipient of the department's William Gardner Fellowship, has been analyzing "space fossils," traces of matter and radiation, left behind when the nascent universe expanded. The hope is that these relics will help explain how it all began.

Dai, who hails from China, arrived at Johns Hopkins last year and has already collaborated on nine papers with his adviser Professor Marc Kamionkowski. "He's a very smart guy, with excellent technical chops and an affinity for interesting problems," says Kamionkowski. "And he's getting things done at a remarkable clip. He's completed some very substantial work already."

Dai concentrated on particle physics as an undergrad at Peking University but chose to study cosmology at Hopkins. "The past one or two decades has really become the golden age of cosmology," he says. "In the past, the field had been less quantitative compared to other branches of physics. In cosmology, even an accuracy of 50 percent used to be quite acceptable, but since technology has advanced, cosmology has entered an age of precision measurement. It's no longer a qualitative study; it's a quantitative science and that provides lots of research opportunities for study."

Dai and his adviser have been using data collected from observations of the Cosmic Microwave Background (CMB) and the universe's large scale structure to analyze the inhomogeneous distributions of matter/radiation, or relics, left behind during the period known as inflation, when the universe expanded rapidly in the milliseconds after the Big Bang. The cosmologists hope to use the information to glean a better idea of the nature of inflation and how the universe began.

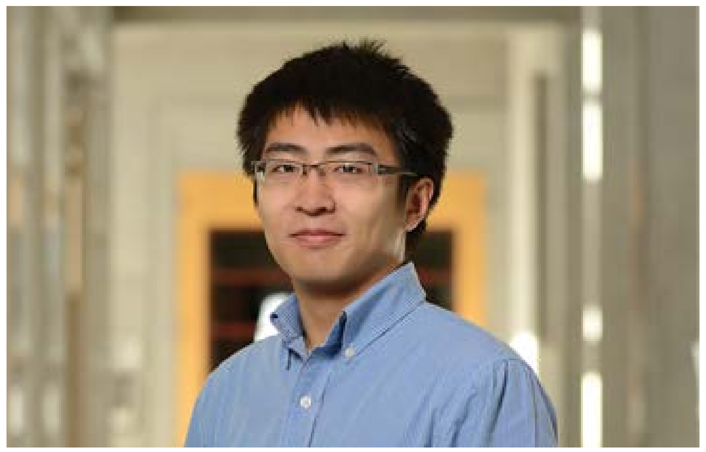
"[The experimentalists] find all these bones and dig them up, but the job isn't over until you take them home and figure out how to fit them together," says Kamionkowski. "That's the job of the theorist. And Liang has made tangible contributions to this quest."

The fellowship allows Dai to spend more time on research instead of teaching. After earning his doctorate, he hopes to pursue a career as a research scientist at an institute or university. "I want to work with the best people in the world," he says.

Until then, Kamionkowski is just happy to have Dai on his team. "It's in my best interest for him to stick around as long as possible," he says with a laugh. "He's a very promising student. He's definitely going to be somebody."

Dai is the fifth 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.

—*JS*



Liang Dai

Holland Ford Receives NASA Award for Hubble Research

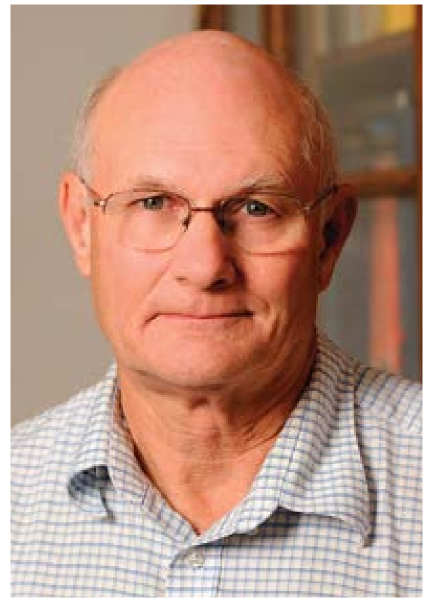
Astrophysicist **Holland Ford** received NASA's highest form of recognition—the Distinguished Public Service Medal—for his outstanding contributions to the Hubble Space Telescope. The medal is awarded to someone who has made a profound impact on the success of a NASA mission.

Ford's involvement in the Hubble mission began years before the telescope launched in 1990; he was a co-investigator on the Faint Object Spectrograph, one of Hubble's first-generation instruments. When scientists discovered a flaw in the telescope's primary mirror, Ford was chosen to help organize a panel to develop a solution.

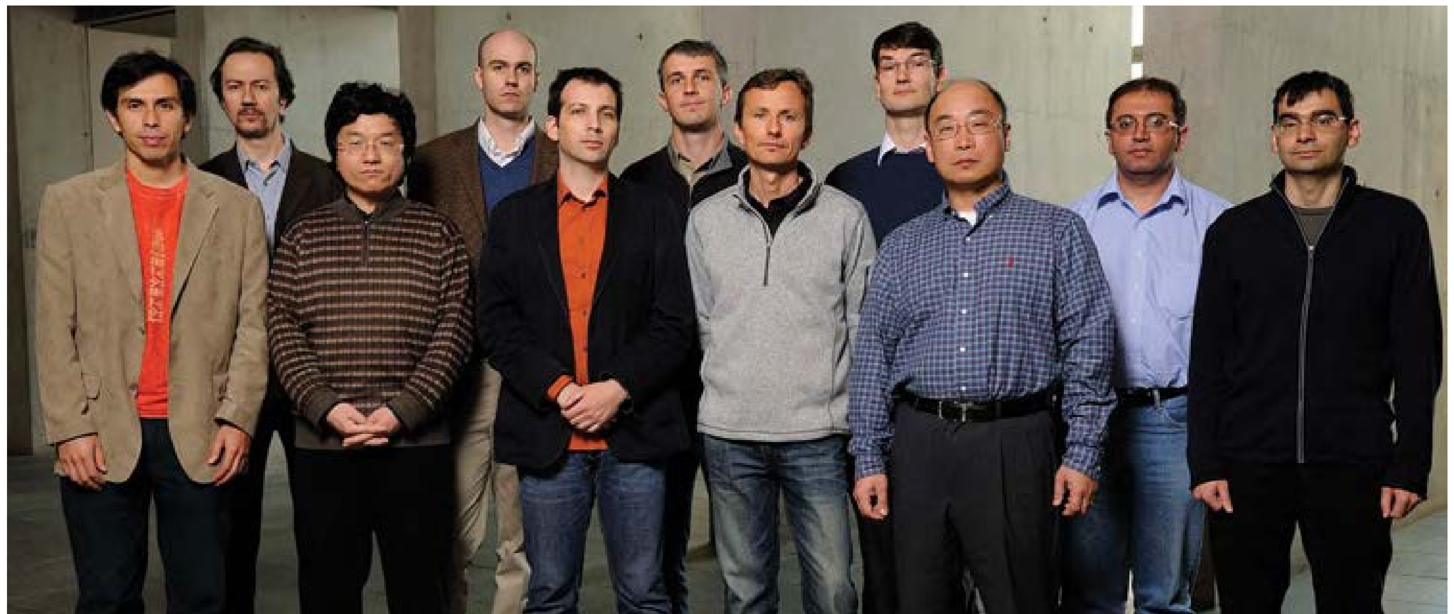
Ford later was the leader of a team that developed the Advanced Camera for Surveys, which significantly increased Hubble's survey capability. The ACS made one of the longest and deepest visible-light images of the universe, called the Hubble Ultra Deep Field. The ACS team published more than 100 papers with more than 7,000 citations on topics ranging from planet-forming debris disks around nearby stars to galaxies forming during the first years of the universe.

Ford's Hubble observations helped provide the first evidence for the existence of supermassive black holes in the cores of most galaxies. Using the Faint Object Spectrograph, Ford and the team identified the presence of a 3-billion-solar-mass black hole in the active galaxy M87.

Ford came to Johns Hopkins in 1988 and was a full professor until his retirement in 2011. He remains active as a research professor in the department.



Holland Ford



Remembering Zlatko Tesanovic

Scientists from around the world gathered at the Bloomberg Building in March for a condensed matter symposium in honor of Professor Zlatko Tesanovic (inset), who died in July 2012. Pictured here are some of Tesanovic s former graduate students and postdocs who attended the event: (l to r w/ PhD year unless otherwise noted): Andres Concha, 2010; Igor Herbut, 1995; Jian Kang, 2013; Adrain Del Maestro, IQM fellow 2010-11; Vladimir Cvetkovic, post-doc 2006-09; James Murray, 2003; Marcel Franz, TIPAC fellow 1996-99; Oskar Vafek, 2003; Ju H. Kim, post-doc 1992-95; Ashot Melikyan, 2004; and Valentin Stanev, 2010.

New Classroom, New Way of Teaching

Associate Professor Bob Leheny (top center) says the newly renovated classroom is one step in reimagining the way General Physics and other introductory science courses are taught.

Associate Professor **Bob Leheny**'s General Physics for Physical Sciences Majors 1 class doesn't look like your typical freshman lecture. In fact, Leheny isn't even talking. Instead, the 50 or so students in his class are all on their feet trying to solve a work-kinetic energy problem at the large white boards that ring newly refurbished Room 478 in the Bloomberg Center. Leheny and his teaching assistants walk throughout the room offering assistance.

When the students do take a seat it's at one of 11 round tables—each with a microphone at its center. At Leheny's urging, students press buttons on their remote "iClickers," registering one of several multiple-choice answers to the problem, which appear as bar graphs on the seven large video monitors hanging throughout the airy room. When Leheny sees the answers divided between A, B, and C, he has the students try to convince one another that their own answer is correct. Overall, the scene looks more like a spirited conference room than a lecture hall.

Welcome to the Freshman Lecture 2.0, aka the "flipped classroom," where students use class time to work collaboratively on problem solving with help from their teachers and watch podcasts of the lectures at home.

Bloomberg's newest classroom was funded via a grant through the university's Gateway Sciences Initiative, a multidimensional program to improve and enrich the learning of these introductory science classes at Johns Hopkins for undergraduate and graduate students.

Nationally, roughly one-third of students entering college aspire to STEM, or science, technology, engineering, or math, majors, but less than half of these go on to earn a degree in a STEM field. At Johns Hopkins, the rate is better, with 63 percent of entering students interested in science or technology and 57 percent graduating with a related degree. But that percentage could be higher.

The Gateway Sciences Initiative hopes to retain students by not only re-imagining the freshman lecture but also by using class time to work on projects with the students' academic interests clearly in mind.

Leheny was part of a physics and astronomy department committee that studied similar classrooms at other universities and made recommendations for the room at Bloomberg. "What's making this work is technology. For decades instructors would say, 'Read the textbook before you arrive to class.' But in physics and most sciences, many students don't do it. But students will watch these videos at home. And with them prepared in this way, we can then use the classroom time in a different way to actively engage in the material—answering questions, debating with each other, and working on problems."

Leheny, accustomed to teaching at the front of the room as the center of attention, admits he's had to alter his teaching methods. "My role is different in the flipped classroom," he says. "I'm more of a facilitator. I have to manage time and work the room like a waiter making sure the dinner groups are not being neglected."

But students seem to relish the change. "It's a much more intimate setting than a lecture hall," says freshman chemical engineering major Bitsiti Hagos. "Here, everybody is struggling to figure out the problems together. I'm a person that learns by actually doing the work. I may not get the problem at home, but I will here."

And in this new paradigm, that's exactly the idea.

—JS

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Already garnering rave reviews at some of the world's prominent film festivals, a new documentary called *Particle Fever* was produced by one of Johns Hopkins' physicists.

Theoretical physicist **David Kaplan** studies dark matter, supersymmetry, and the properties of the Higgs boson. A former film student, Kaplan saw the cinematic possibilities of bringing the story of the Large Hadron Collider to the big screen.

The documentary gives viewers an up close look at one of the most significant scientific break throughs as it is happening: the creation of the Large Hadron Collider. The full-length feature film follows six scientists as they attempt to recreate con ditions that existed just moments after the Big Bang and could potentially explain the origin of all matter.

"The intensity of the scientists we follow is palpable," Kaplan said. "You see, once you start, you can't stop. Particle physics is addic tive, like puzzles are to some people. These are just the greatest puzzles of all time, literally."

The film was edited by the esteemed Walter Murch, a 1965 graduate of Johns Hopkins and editor of such timeless films as *Apocalypse Now, The English Patient,* and *The Godfather* trilogy.

Particle Fever will be distributed to theaters nationwide in March, but glowing reviews are already coming out.

Scientific American said, "The movie isn't a simple feel-good story of triumph. By the time the Higgs boson is found, the audience feels almost as invested in what its mass will be as the waiting physicists, because we've heard from camps hoping for one outcome or another."

The entertainment publication *Variety* called *Particle Fever* a "surefire crowd-pleaser with ravish ing imagery and immensely likable subjects."

Kaplan said the goal of working on the film has always been "to produce something that would appeal beyond the scientifically literate—to tell the emotional and very human story behind scientific discovery."