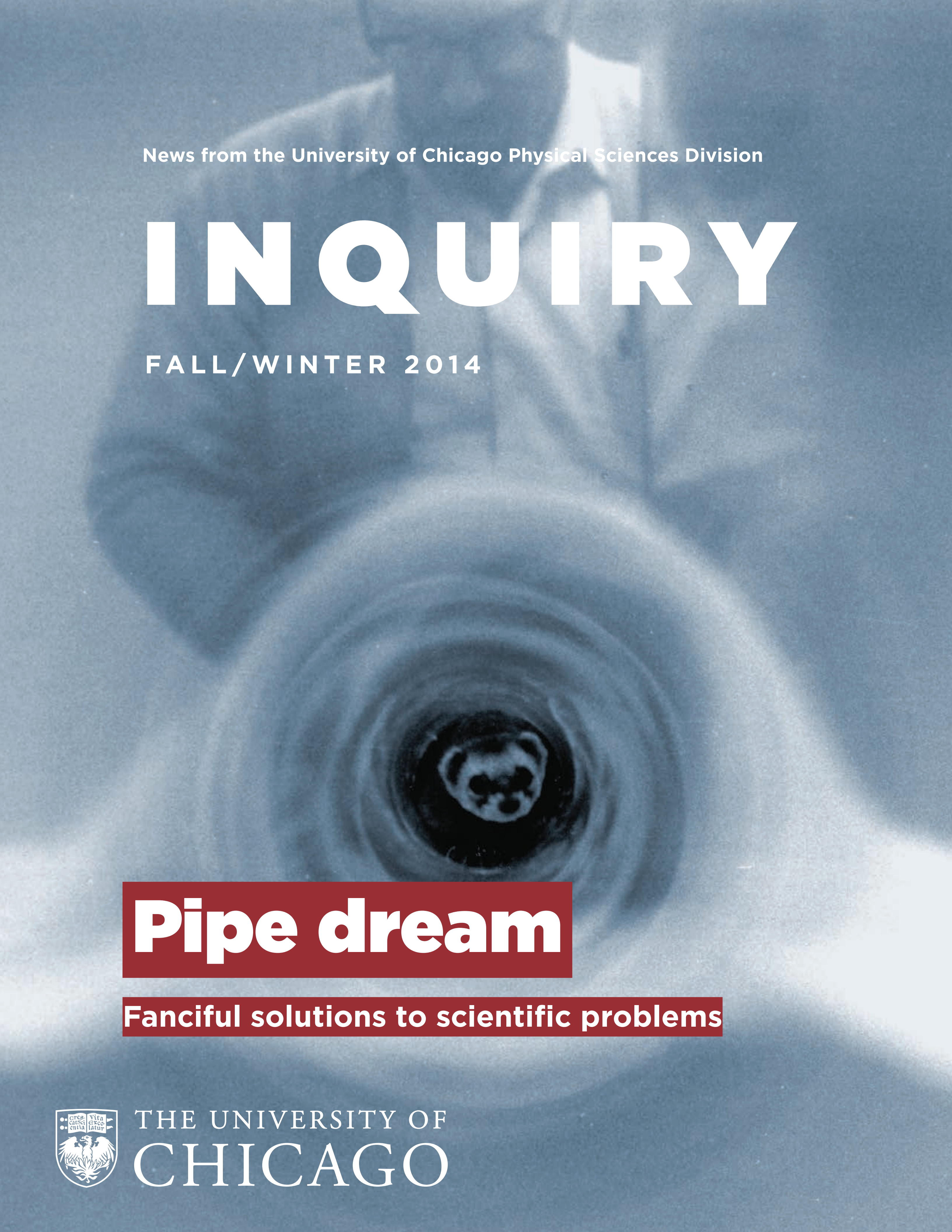

News from the University of Chicago Physical Sciences Division

INQUIRY

FALL/WINTER 2014

Pipe dream

Fanciful solutions to scientific problems

THE UNIVERSITY OF CHICAGO

INQUIRY

FALL 2014

Note from the dean

Asking new questions

Science is driven by a sense of urgency—an irresistible need to push further into the unknown. That urgency pulls researchers out of bed to repeat an experiment that hasn't worked in three weeks, to fly to Chile and spend night after night looking through a telescope, to wrestle with calculations that haven't made sense for months.

At the University of Chicago, faculty and students alike share that urgency to keep pushing forward. But this race requires speed as well as tenacity. Scientific advancement is swift, and maintaining our place at the frontier requires thinking creatively and critically, taking risks, combining areas of study, answering long-standing questions, and, more importantly, asking new ones.

The challenge of asking new questions is that, well, no one has ever thought to ask them. There are no government programs supporting research in these brand-new fields; there are no foundations championing these radical ideas that so often become the bedrock of future research.

It is in this early, pivotal stage that funding is most crucial. Even modest investments can get a project started, help create proof of concept, or simply raise awareness. Readily available divisional funds ensure that bold new proposals stay in the running. Wait for the world to catch up—for grants to be awarded, for institutes to be established—and you may find the world has passed you by. The University of Chicago Campaign: Inquiry and Impact (see page 3) gives you the power to help us set the pace of discovery.

With all best wishes,

Rocky Kolb

Edward W. "Rocky" Kolb, Dean

Illustration by Tom Tian, AB'10

Testing ground

Benson Farb imagines mathematics transformation through collaboration.

Laboratories are a mainstay of experimental science. Mathematics professor Benson Farb, who studies geometry and topology, argues that mathematicians should have that explorative and collaborative experience as well, in a common physical and intellectual space: a math laboratory.

This type of collaboration exists in a few institutes, like the Mathematical Sciences Research Institute in Berkeley, California, but has not yet been incorporated by universities. In an educational environment, says Farb, math laboratories could change the way math is researched and taught, which in turn would have a ripple effect. "Every other science is infused with math, uses the language of math. The underlying way we understand the world is via mathematics."

Historically, mathematics was a solitary effort, but "in the last 30 years, math has become much more collaborative, has undergone a paradigm shift," says Farb. The culture of math research has always included sharing ideas, but with advances in communication—email, document-sharing platforms, social media—researchers find it easier to connect with colleagues, continuing to work together after a conference, for instance.

Farb thinks collaboration could be facilitated even more. "Wouldn't it be great to have something like a lab, where a bunch of professors, perhaps a physicist, a mathematician, or a biologist have offices in one location with space for graduates, undergraduates, and postdocs and a central place where everyone could meet and hang out?" They would benefit from "open doors," physically and psychologically.

> "In the last 30 years, math has become much more collaborative, has undergone a paradigm shift."
>
> —BENSON FARB

Ideally, professors would have a second office in a math lab, where they would devote their energies to a central project. Faculty, students, and postdoctoral fellows would contribute, and the department would also invite experts from outside the University to visit the lab, join the group, present research, and interact with students. They might stay a week, a month, or several months, as a mathematician or scientist-in-residence.

Mathematics department chair Shmuel Weinberger shares Farb's enthusiasm. While there's much work to be done, like securing space and funding for researchers-in-residence, a few possible University math laboratories have been considered. Weinberger has proposed one focusing on geometry, complexity, and theoretical pure science. Professor Amie Wilkinson suggested a project on one of her specialties, dynamical systems, and Panagiotis Souganidis, Charles H. Swift Distinguished Service Professor, could lead a lab based on analysis and applied math.

You can't just throw scientists and mathematicians together and expect a spark, though. Math labs "must start from the bottom up," says Farb. Collaboration must already be in the works, around which a math lab can be built to throw fuel on that existing flame. Four years ago, Farb was working with then-doctoral student Thomas Church, SM'07, PhD'11, and University of Wisconsin professor Jordan Ellenberg when they discovered a pattern—a phenomenon they called representation stability. They found it all over the field of mathematics, says Farb. It would have been a perfect project for a math lab.

Such labs, Farb believes, will speed up problem solving and promote interdisciplinary research. Math labs will also bring students, particularly undergraduates, into the world of investigation. In the classroom, students "are not seeing me fail," says Farb. "They're seeing me present material that I already understand." In math labs, they will see research being performed. They will see how mathematicians' brains work, the methods they use to advance the field.

And the students will help the researchers. By asking questions, they help Farb pinpoint material he thinks he understands but actually doesn't. "Chicago is the absolute perfect place for this to happen, because the students have infinite energy," Farb says. "They would eat this up." The researchers will bring the vision, and the students will provide the energy to sustain a math laboratory.

The department must still determine metrics of success, perhaps number of papers published or students recruited, but "we're coming from a position of strength," says Farb. "Our department is the best it's been since the famous Stone Age in the early '50s," when chair Marshall Stone filled the department with the best mathematicians in every field. "Now is the time to be bold."
—M.S.

For more information about math labs, please contact Brian Yocum at **773.702.3751** or **byocum@uchicago.edu**.

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Computer science

Dot edu

Outlier helps bolster computer science education.

Computers are critical for work in almost any field, yet few students leave high school with computer science training. While teachers can choose from hundreds of curricula and programs to teach math and science, computer science resources remain scarce.

Organizations such as the National Science Foundation and the nonprofit Code.org have pushed to improve computer science education in the United States, particularly in urban schools and for minority students underexposed to the discipline. Both groups have engaged with Outlier, the research and evaluation arm of the Center for Elementary Mathematics and Science Education (CEMSE) in the Physical Sciences Division devoted to improving science, technology, engineering, and mathematics education for grades pre-K–12+ learners.

Since 2002 CEMSE has worked with schools, districts, and government and private sector clients to develop and assess curricula, support programs, and create new tools for educators. "Stimulating the curiosity of today's young students for math and science is critical for creating tomorrow's physicists, mathematicians, and cosmologists," says PSD dean Rocky Kolb.

Outlier was rebranded in early 2014, distinguishing itself from the other parts of CEMSE, which produce instructional materials for students, professional development tools and guidance for teachers, and planning materials for school and district leaders. Outlier conducts studies, measuring programs by collecting data through surveys, focus groups, and observations for clients such as the Field Museum, Google, and higher education programs within the University. The group also studies complex issues affecting STEM education, including STEM school models, educational interventions, and innovations in schools.

Increasingly, Outlier has expanded its work to include computer science education, a discipline not usually included in the STEM conversation despite its close relationship to all four components. "There is no doubt that if we are to make progress as a nation," says Jeanne Century, director of Outlier, "we need to elevate the visibility and credibility of computer science as an essential part of K–12 public education."

The National Science Foundation aims to meet that demand through a program called CS10K, whose goal is to get 10,000 "well-trained" educators to teach engaging, rigorous high school computer science courses by 2016. But many questions remain. Should computer science be a required course? Can it be folded into math, science, or even foreign language classes? Most importantly, do teachers and students have a clear sense of what computer science is and how it is essential for many different careers?

To understand the broader landscape of American computer science education, in 2012 the Association of Computing Machinery, in partnership with the NSF, Google, Microsoft, and other groups, commissioned Outlier—in collaboration with the Urban Education Institute—to produce the *Building an Operating System for Computer Science* (*OS4CS*) report. The project was a first-of-its-kind assessment of CS education, presented online as an interactive report to reach a diverse audience of practitioners, researchers, policy makers, and advocates, says Sarah Rand, former associate project director at Outlier.

"Overall, the research showed that there are many strong advocates working hard to advance computer science education," Century says, "but there is still much ground to cover in terms of ensuring

> "Stimulating the curiosity of today's young students for math and science is critical for creating tomorrow's physicists, mathematicians, and cosmologists."
>
> —ROCKY KOLB

that all learners have access to quality instructional resources and teaching."

After completing the *OS4CS* report, Outlier received a $1 million NSF grant for additional research: the Barriers and Supports to Implementing Computer Science, or BASICS, study. The study examines a new introductory computer science course in several large school districts, in different environments and with different student populations. It will identify the key supports for and barriers to realizing computer science education for all students as it expands into more communities as part of CS10K, says NSF program officer Jan Cuny. "Our hope is to find best practices and approaches that can be scaled."

—Rob Mitchum

Read more at **outlier.uchicago.edu.**

Physical Sciences Division

Envision

The Physical Sciences Division looks to the future.

In October UChicago formally launched the public phase of the University of Chicago Campaign: Inquiry and Impact, a $4.5 billion fundraising campaign expected to last through 2019. The quiet phase has already raised more than $2 billion, including 182,000 gifts from alumni and friends.

The campaign serves as an important moment for the division, says dean Rocky Kolb. "We pioneer scientific discovery; philanthropists provide us the means, and in doing so become an integral part of the work we do."

As part of the campaign, the Physical Sciences Division is raising funds to advance a set of ambitious goals, focusing on

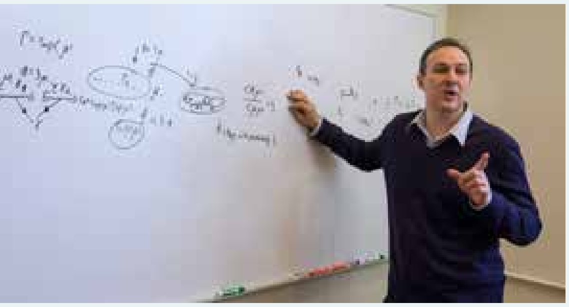
pursuits—developing ambitious research agendas and programs, maintaining and fostering the division's tradition of discovery;

people—attracting and supporting the best students, postdoctoral fellows, and faculty by building and advancing core facilities and equipment and promoting a strong collaborative community;

place—serving as an intellectual destination where researchers from around the globe present and hone their breakthroughs.

These initiatives, Kolb says, will continue—and bolster—the PSD's history of producing research and scientists that push boundaries, ask difficult questions, and create new fields of study.

At right are the division's departmental campaign priorities.



Astronomy and Astrophysics
Big glass

Telescopes are time machines, and the biggest and most advanced telescopes bring us ever closer to the big bang. Construction is expected to be complete by 2020 on the Giant Magellan Telescope, a segmented-mirror scope in the Chilean Andes Mountains with more than 12 times the light-gathering area of the Large Binocular Telescope in Arizona, currently the world's largest telescope. The University of Chicago has pledged a significant stake in the GMT as well as in the two existing Magellan telescopes, ensuring that UChicago astronomers and astrophysicists have access to the best observational equipment in the world.

Computer Science
Systems research and innovation hub

Computing devices have transformed nearly every aspect of our lives, yet computer systems are still wasteful, fragile, and insecure. The goal of the computer science department's new CERES Center is to engineer "unstoppable computing" by exploring hardware and software architectures that exceed current energy efficiency and function, building resilience to large-scale failure, and achieving total defense against malicious attacks.

Geophysical Sciences
Planet habitability

Understanding planet habitability—the ability to develop and sustain life—is crucial to human existence here and the search for life out there. The geophysical sciences department studies the complex dynamics among life, rocks, oceans, and atmospheres on Earth and creates models for potential exoplanet habitability, which can then be tested with increasingly powerful telescopes.

Physics
Kadanoff Center

Condensed matter physics deals with the physics of everyday and exotic materials. The Kadanoff Center for Theoretical Physics, which has historically focused on particle physics, aims to strengthen its efforts in condensed matter physics, uniting experts in string theory, general relativity, condensed matter physics, and hydrodynamics to study problems shared by both fields.

Mathematics
Math labs and postdoctoral instructorships

The mathematics department seeks to revolutionize the way math is researched and taught by establishing math laboratories (see "Testing Ground," page 1). The department also plans to create a cadre of postdoctoral instructors—recent PhDs who have exhibited exemplary teaching skills—who will provide expert-level education for its growing undergraduate mathematics population.

Statistics
Data analysis

Computation is vital for the future of all research, the humanities and social sciences as well as physical and life sciences. The PSD is providing undergraduates with training to understand and use computation in their post-College lives. Based on student input and demand, the College has approved a new major in computation and applied mathematics that includes course work in the departments of statistics (which leads the initiative), mathematics, and computer science.

Chemistry
Project Prometheus

Project Prometheus represents the next step in a decades-long chemical research revolution. Solar energy could eliminate our reliance on fossil fuels, but today's methods of harvesting and storing it are inefficient and incomplete. The project focuses on capturing sunlight, storing energy in chemical bonds, and chemically converting artificial photosynthesis products.

THE UNIVERSITY OF CHICAGO CAMPAIGN INQUIRY & IMPACT

For more information, a complete list of campaign goals, and information on how to give to the PSD, visit **campaign.uchicago.edu**.

The MicroBooNE detector moves three miles across Fermilab grounds from its construction site to the Liquid Argon Test Facility. Photography by Reidar Hahn, courtesy Fermi National Accelerator Laboratory.

Physics

A nu venture

David Schmitz's search for a new type of neutrino makes headway.

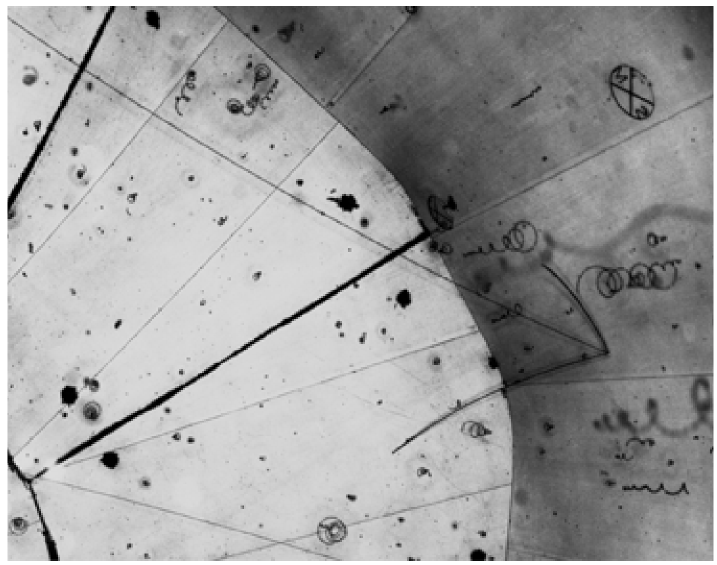
This winter University of Chicago assistant professor David Schmitz will begin collecting data with Fermilab's new liquid argon time projection chamber (LArTPC), installed this past summer and scheduled to be filled in January with 170 tons of pure liquid argon. Schmitz, along with more than 100 collaborators from 23 institutions, will use the detector to study neutrino interactions and oscillations in an experiment called MicroBooNE.

Uncharged, nearly massless elementary particles denoted by the Greek letter ν, neutrinos come in three "flavors," named for the charged particle they produce when they collide with a nucleus: the electron neutrino (ν_e), muon neutrino (ν_μ), and tau neutrino (ν_τ). Those charged particles leave a signature by which the neutrinos, which can't be observed directly, can be studied.

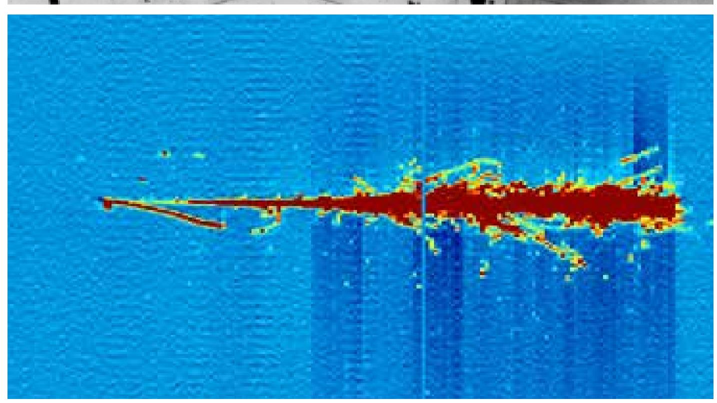
The 40-foot-long LArTPC detector sits in the path of Fermilab's Booster neutrino beam, which accelerates protons and smashes them into a beryllium target, producing mostly muon neutrinos. The neutrinos travel 470 meters before some collide with argon nuclei inside MicroBooNE and create a spray of charged particles. As these particles "propagate through the argon," explains Schmitz, "they knock loose electrons from other argon atoms through electromagnetic interactions, losing some of their energy and imparting it to those electrons." This ionization results in free electrons drifting in the liquid argon.

The detector's electric field "sucks the electrons to one side of the detector," Schmitz says, "where there's a mesh of fine wires, like a giant piano, that the charge collects on and gets read as an 'event.'" A noble gas, argon makes an ideal medium because of its full valence shell; electrons knocked free can travel to the mesh wires without being "sucked back up."

The next step in neutrino research, argon technology builds on the work of MiniBooNE, another Fermilab experiment—and the basis for Schmitz's doctoral dissertation—that used a liquid scintillator neutrino detector. When a charged particle passes through a scintillator, the energy from that particle



Top: A neutrino interaction was first observed in 1970 by Argonne's 12-foot hydrogen bubble chamber. The neutrino strikes a proton (right) and creates three tracks: a μ-meson, which the neutrino turned into (long center path); the proton (short upper path); and a π-meson produced by the collision (medium lower path). Image courtesy Argonne National Laboratory.



Bottom: A neutrino interaction produces a spray of particles in a small-scale liquid argon time projection chamber used by the ArgoNeuT experiment at Fermilab. Image courtesy David Schmitz.

The MicroBooNE cryostat is lowered into its home in the Liquid Argon Test Facility. Photography by Cindy Arnold, courtesy Fermi National Accelerator Laboratory.

"We're building detectors the size of a school bus, convincing ourselves we really know how the technology works, and exercising it by doing real physics. Then we can scale it up."

—DAVID SCHMITZ

excites the atoms, creating light. In MiniBooNE the light traveled to the perimeter of the detector, which contained about 1,000 specialized photon detectors. The signals from each detector were compiled to make an event, like pixels in a photograph.

A liquid argon detector is more sensitive. In addition to seeing the scintillation light, an argon detector measures the freed ionization electrons on 10,000 closely spaced wires, making it better able to distinguish between the charged particles and photons generated by the initial neutrino-nucleus interaction.

This capability is important because MiniBooNE produced interesting but inconclusive data, indicating perhaps a new flavor of neutrino. The theoretical sterile neutrino, so named because only gravity influences it, is more challenging to detect than the known neutrinos, which are subject to both gravity and the weak force. MicroBooNE seeks to search for the hypothetical particle with more precision and accuracy using the LArTPC technology.

The way to search for sterile neutrinos is by observing neutrino oscillations—the ability of neutrinos to change between flavors as they propagate through space. Oscillation wavelength—the distance it takes for a neutrino to change flavor—has been measured many times among standard neutrino types. Researchers have defined the known neutrinos of distinct masses as ν_1, ν_2, and ν_3, as they can determine only relative, not absolute, mass. If MicroBooNE detects an oscillation at an additional wavelength not seen before, it would indicate a new type of neutrino.

Understanding neutrino oscillations is a piece of another important puzzle in physics: why there is more matter than antimatter. “These experiments are intended to serve as a stepping stone toward the types of experiments that will address why the universe is asymmetric,” says Schmitz. “But in order to do those, we’ll have to build liquid argon detectors the size of this building.” He gestures to Wilson Hall, Fermilab’s central laboratory building. “In the meantime, we’re building detectors the size of a school bus, convincing ourselves we really know how the technology works, and exercising it by doing real physics. Then we can scale it up.”

Schmitz and his team also plan to build a second detector, the LAr1 Near Detector, to work in tandem with MicroBooNE. The combination will increase sensitivity even further in the search for the sterile neutrino. He hopes to be collecting data from this new detector by 2018.

—M.S.

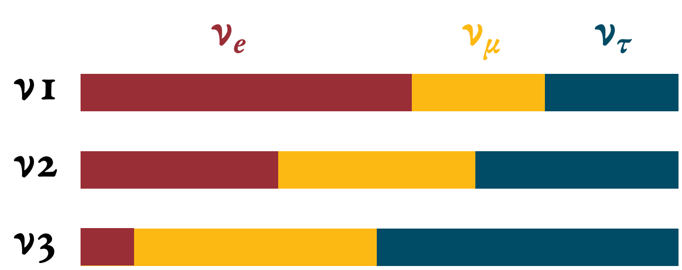
QUANTUM WEIRDNESS

The three known types of neutrinos have been classified in two ways, weak-type ($\nu_{e,\mu,\tau}$) and mass-type ($\nu_{1,2,3}$), but the two categories do not “map onto each other one to one,” Schmitz says. It’s “perfectly valid,” he says, to think of neutrinos as either particles of distinct flavors or particles of distinct masses, but the two views are not equivalent. “It’s kind of a weird quantum mechanical thing,” says Schmitz.

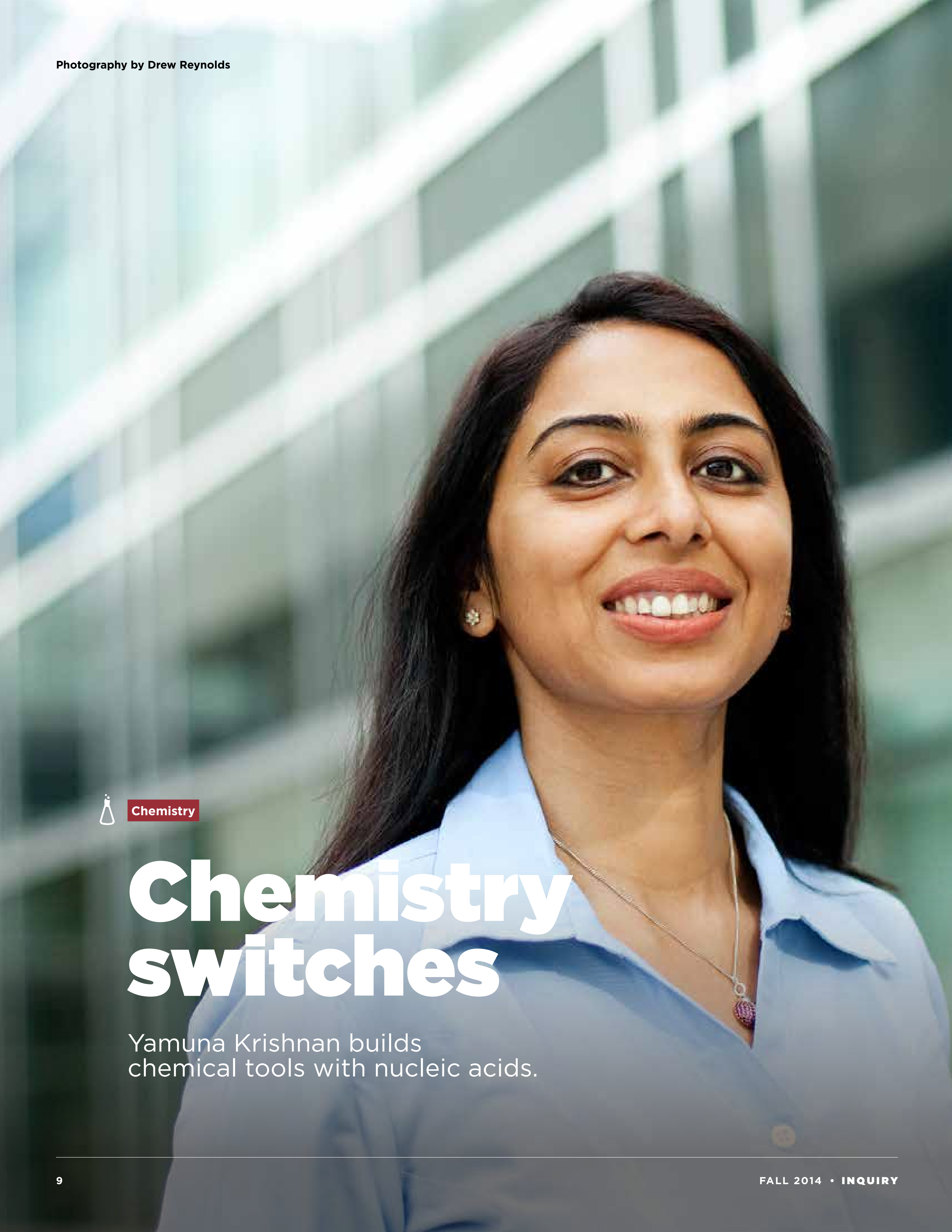
“The electron neutrino is actually a combination of the three masses, and the lowest mass state is actually a combination of the electron, muon, and tau neutrinos.” A muon neutrino is also a mixture of the three mass states, but in a different ratio, and so on (figure).

“It’s exactly that mixture between the mass perspective and the flavor perspective that enables oscillations,” explains Schmitz. When a neutrino moves through space, its different mass-types travel at slightly different velocities—too small to measure but cumulatively effective. The different velocities change the ratio of the flavor mixture as the neutrino travels.

But if these are elementary particles, how can they be a mix? The word *mixture* is not quite accurate; it’s a near translation of a concept that doesn’t exist in classical physics called quantum superposition, which states that a particle exists in all its possible states simultaneously but can be observed in only one state. “The concept is not very comfortable for people in a macroscopic world,” Schmitz says, “but at the quantum level it’s totally OK.”



Photography by Drew Reynolds



Chemistry

Chemistry switches

Yamuna Krishnan builds chemical tools with nucleic acids.

> "It's a very sophisticated naturally occurring device. The ribosome basically turns food into babies."
>
> —YAMUNA KRISHNAN

Professor Yamuna Krishnan has always loved making things. When she was a child, she and her sister would cook meals, make invisible ink, and grow sugar and salt crystals. They would use whatever they could find in their mother's kitchen and father's garden to create something new.

Thinking she would carry this passion for building into a career, Krishnan wanted to study architecture. Yet at Women's Christian College in Chennai, India, she took a chemistry course, where she felt both engaged and adept. She changed fields and now works with chemical architectures, using nucleic acids to build biocompatible synthetic nanoscale machines.

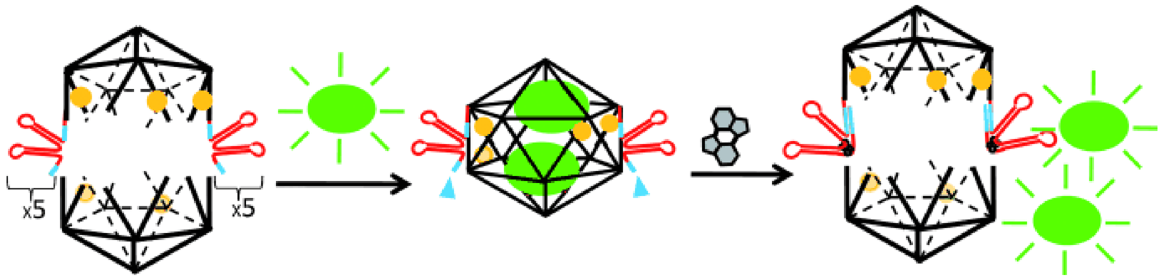
Krishnan's work is influenced by naturally occurring nucleic devices. She cites the ribosome, the cellular machine that arranges amino acids from our diet into all the proteins that make up the human body, using RNA's template. "It's a very sophisticated naturally occurring device," she says. "The ribosome basically turns food into babies."

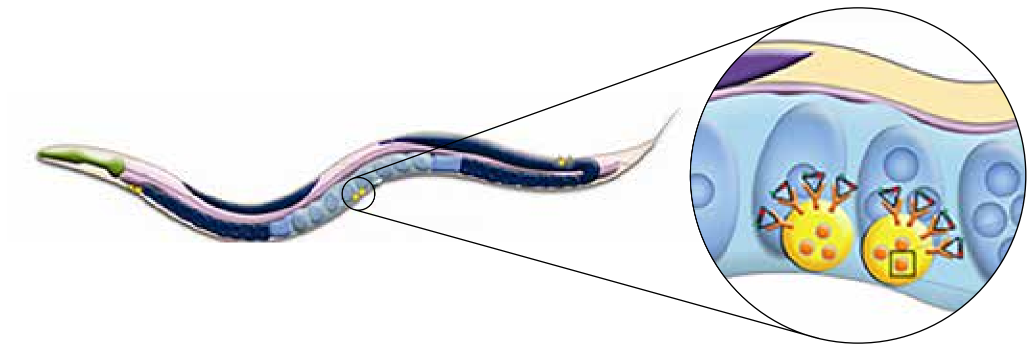
She enjoys the challenge of complex organizations, where "multitudes of processes perform in concert." Such complex systems, common in biology's realm, have become fodder for chemists, notes chemistry chair Richard Jordan. Advances in technology—spectroscopy, microscopy, imaging, and molecular and computational modeling—have allowed chemists to move from studying "relatively simple systems, like conventional organic or inorganic chemicals at a very detailed level," to complex systems, like the processes that work together to make up a living organism.

Krishnan joined the University this summer, one of four biologically inclined chemists hired to help the department both reflect and advance chemistry's changing landscape. Throughout the past decade, the field has expanded "beyond the classical core areas of organic, inorganic, and physical chemistry into other areas of science where a molecular level of understanding is beneficial," says Jordan. Those areas include materials science and chemical biology, which both involve complex systems.

There's no clear distinction between chemical biology and the better-known field of biochemistry, Jordan says, but there may be differences in ultimate intention: "Chemical biology describes trying to determine the structures and reactivity of key biomolecules in living systems, how they interact, how they control the processes of life." Chemical biologists hope to "not only study what's going on but to manipulate and change it," relying heavily on chemical synthesis—engineering reactions to create a desired product.

One way chemical biologists like Krishnan exploit synthesis is by building molecular tools designed to





Top: A DNA icosahedron (black) held together with aptamers (red)—molecules designed to bind to a specific target—encapsulates molecular cargo (green). A trigger (gray hexagons) folds back the aptamers, opening the icosahedron and releasing the cargo.

Bottom: The I-switch, a DNA pH sensor, functions in a soil-dwelling roundworm's coelomocytes, which serve as scavenger cells for the worm. Images courtesy Yamuna Krishnan.

enter a living cell and perform a particular function. For instance, the ability to measure pH inside an organelle could help to detect and treat diseases. Just as a fever can indicate illness in humans, acidic conditions can indicate illness in cells; lysosomal storage disorders, including Tay-Sachs disease, are associated with acidic conditions in the lysosome. The challenge is getting a tool to work as well in a complex living organism as it does in a petri dish.

At her previous institution, India's National Centre for Biological Sciences in Bangalore, Krishnan developed the first—and as yet only—such device: the I-switch. The DNA-based device "uses a structure called the i-motif, which is at the heart of its switching mechanism," explains Krishnan.

Compared to the complex ribosome, the I-switch is an extremely simple structure that resembles a pair of tongs, closing up under acidic conditions and remaining open under neutral conditions. Attaching molecules called fluorophores, which glow green in the open state, red in the closed state, and yellow and orange in between, Krishnan created a pH meter, a sort of internal litmus test. The switch has thus far worked in worms, and Krishnan hopes eventually to implement it in other living organisms.

Also in Bangalore, Krishnan's lab developed a 3D nanostructure with a hollow center, called a DNA icosahedron, that helps deliver macromolecules, like drugs or bio-imaging agents, directly where they're needed. The 20-faced capsule has the most complex solid shape possible to maximize volume and minimize open spaces where the cargo could leak out.

To achieve the geometry, she engineered DNA sequences with regions that attract each other; under ideal conditions, the strands fold and connect into an icosahedron. Krishnan designed the structure as a sort of Trojan horse molecule, incorporating a responsive module that opens the capsule in the presence of a chemical trigger, releasing the cargo at its intended target and preventing degradation along the way.

At UChicago, Krishnan hopes to apply her synthetic nanomachines to disease models and also develop new devices. While continuing to link her work to detecting and treating disease, she also hopes to focus on fundamental issues of biology on a molecular level, a goal she shares with the department's other new chemical biologists (see "Roll Call," facing). She is excited to be back in the classroom. "The best way to connect with and integrate into a new environment is to teach a course," Krishnan says. "I love teaching chemistry, and I have sorely missed that."

—M.S.

To learn more about chemistry department initiatives, please contact Brian Yocum at **773.702.3751** or **byocum@uchicago.edu**.

ROLL CALL

In addition to Krishnan, three other biofocused researchers joined the chemistry department this year.

Bryan Dickinson
Assistant professor

Research areas	Synthetic chemistry, protein engineering, molecular evolution, and cell biology
Focus	Developing new technologies to study biological systems, in particular decoding mammalian metabolic regulation, to help understand the mechanisms of and therapeutics for metabolic disease
Means	Fluorescent probes, protein sensors, and reprogrammed enzymes

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Raymond Moellering
Assistant professor (January 1, 2015)

Research areas	Chemical biology, synthetic chemistry, biochemistry, and proteomics
Focus	Protein modifications and interaction networks in metabolic diseases; synthetically modified protein and peptide therapeutics
Means	Chemical proteomics, bioorganic synthesis, and cellular and in vivo model systems

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Suriyanarayanan Vaikuntanathan
Assistant professor

Research areas	Physical chemistry, soft condensed matter physics, and biophysics
Focus	Developing and using tools to study complex equilibrium and nonequilibrium systems with the goal of understanding how the organization and information processing of microscopic biological systems behave in a controlled way
Means	Theoretical and simulation methodologies and statistical mechanics

Divisional News

FACULTY ADDITIONS

Bradford Benson
Assistant professor in astronomy and astrophysics

Ravi Chugh
Assistant professor in computer science

Laurent Demanet
Professor in statistics (July 1, 2015)

Andrew Drucker
Assistant professor in computer science (July 1, 2015)

Aaron Elmore, SM'09
Assistant professor in computer science (July 1, 2015)

Ariel Feldman
Assistant professor in computer science

Wendy Freedman
University Professor in astronomy and astrophysics

Yamuna Krishnan
Professor in chemistry

Shan Lu
Associate professor in computer science

Raymond Moellering
Assistant professor in chemistry (January 1, 2015)

Tiffany Shaw
Assistant professor in geophysical sciences (January 1, 2015)

Graham Slater
Assistant professor in geophysical sciences (July 1, 2015)

Mircea Voda
Assistant professor in mathematics

RETIREMENTS

Edward Kibblewhite
Professor in astronomy and astrophysics

Niels Nygaard
Professor in mathematics

Donald York, PhD'71
Professor in astronomy and astrophysics

FACULTY AWARD AND HONOR HIGHLIGHTS

Fred Ciesla (geophysical sciences)
Elected a fellow of the Meteoritical Society

Greg Engel (chemistry); **Norbert Scherer, SB'82 (chemistry)**
Named National Security Science and Engineering Faculty Fellows

Alex Eskin (mathematics)
Selected as a 2014 Simon Investigator

Lawrence Grossman (geophysical sciences); **Wayne Hu (astronomy and astrophysics)**
Elected to the American Academy of Arts and Sciences

Jeff Harvey (physics)
Elected to the National Academy of Sciences

Chuan He (chemistry)
Received the John T. Wilson Distinguished Service Professorship

Michael Hopkins (chemistry); **Anne Rogers (computer science)**
Selected to receive the Arthur L. Kelly Faculty Prize for Exceptional Service

Carlos Kenig, SM'75, PhD'78 (mathematics); **Dam Thanh Son (physics)**
Elected to the American Academy of Arts and Sciences and the National Academy of Sciences

David Mazziotti (chemistry)
Received the 2014 Quantrell Award for Excellence in Undergraduate Teaching

James Pilcher (physics)
Received the US ATLAS Lifetime Achievement Award

L. Ridgway Scott (computer science)
Selected as a Society for Industrial and Applied Mathematics Fellow

Andrei Tokmakoff (chemistry)
Received the Ellis R. Lippincott Award from the Optical Society

Images courtesy Fermilab History and Archives Project

Method

A fuzzy concept

Scientists turned to nature to solve a high-tech problem.

What do particle physicists and English poachers have in common? They both used ferrets to do their dirty work.

In 1971, Fermilab, then called the National Accelerator Laboratory, was constructing its Main Ring proton beam, welding together pipes that would eventually form its four-mile path. These vacuum tubes needed to be spotless before physicists could send elementary particles zooming through them, but they were littered with dust and specks of steel.

Mechanical designer Walter Pelczarski was tasked with developing a pipe-cleaning method, but it was visiting British scientist Robert Sheldon who devised a possible solution. He remembered that poachers used to send ferrets—who naturally seek out holes and burrows and can silently evade gamekeepers—after rabbits on English estates.

For $35, NAL purchased a 15-inch-long female ferret (chosen for her small size, even for a ferret), and trained her to scurry through 300 feet of pipe, carrying a string attached to her collar. When she reached the end of the tube, technicians tied a swab doused in chemical cleaner to the string and pulled it back through, sweeping the pipe of all debris.

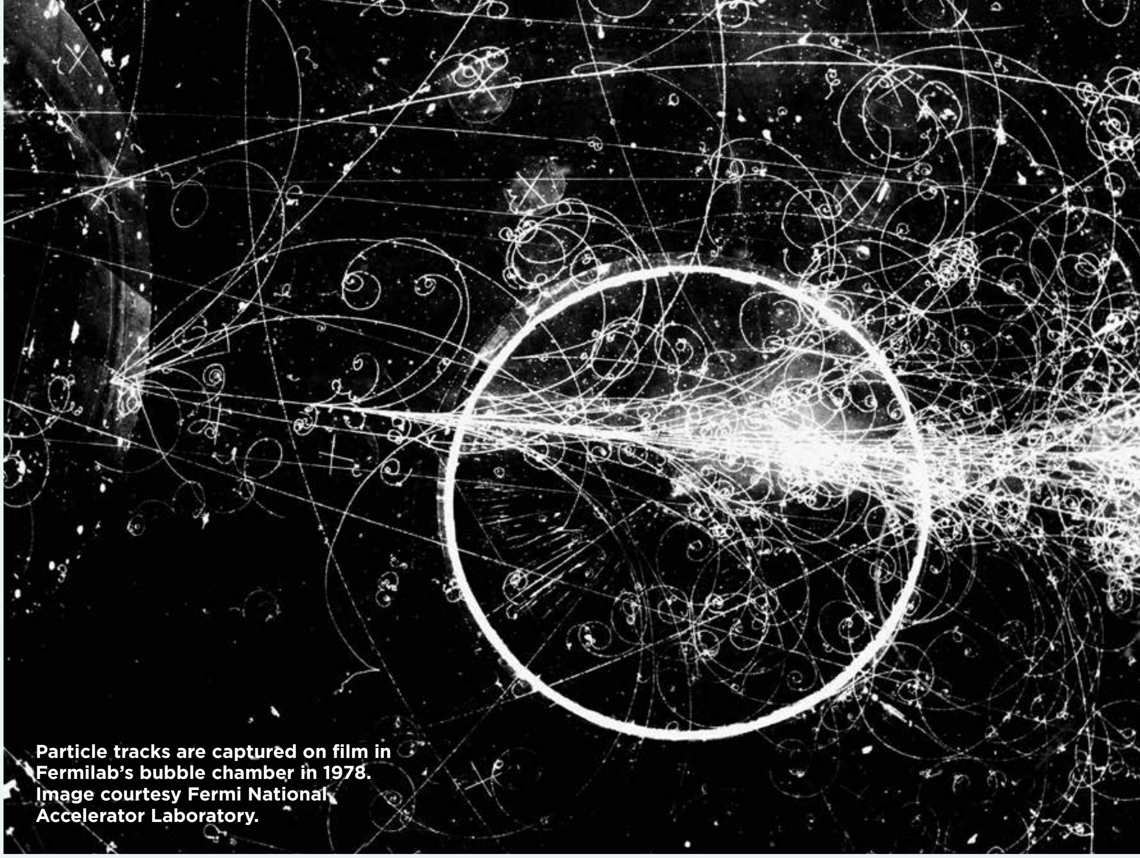
Felicia, as she was lovingly called, became a local, national, and international sensation—appearing in newspaper stories, *Time* magazine, and on television and radio. Unfortunately, as the pipeline grew, the length exceeded Felicia's capacity (or willingness), so engineer Hans Kautzky invented a robotic mechanical spear that pulled a magnetic cord through thousands of feet of vacuum tube. He called the device a magnetic ferret, and Felicia retired after about a dozen runs.

Introduction

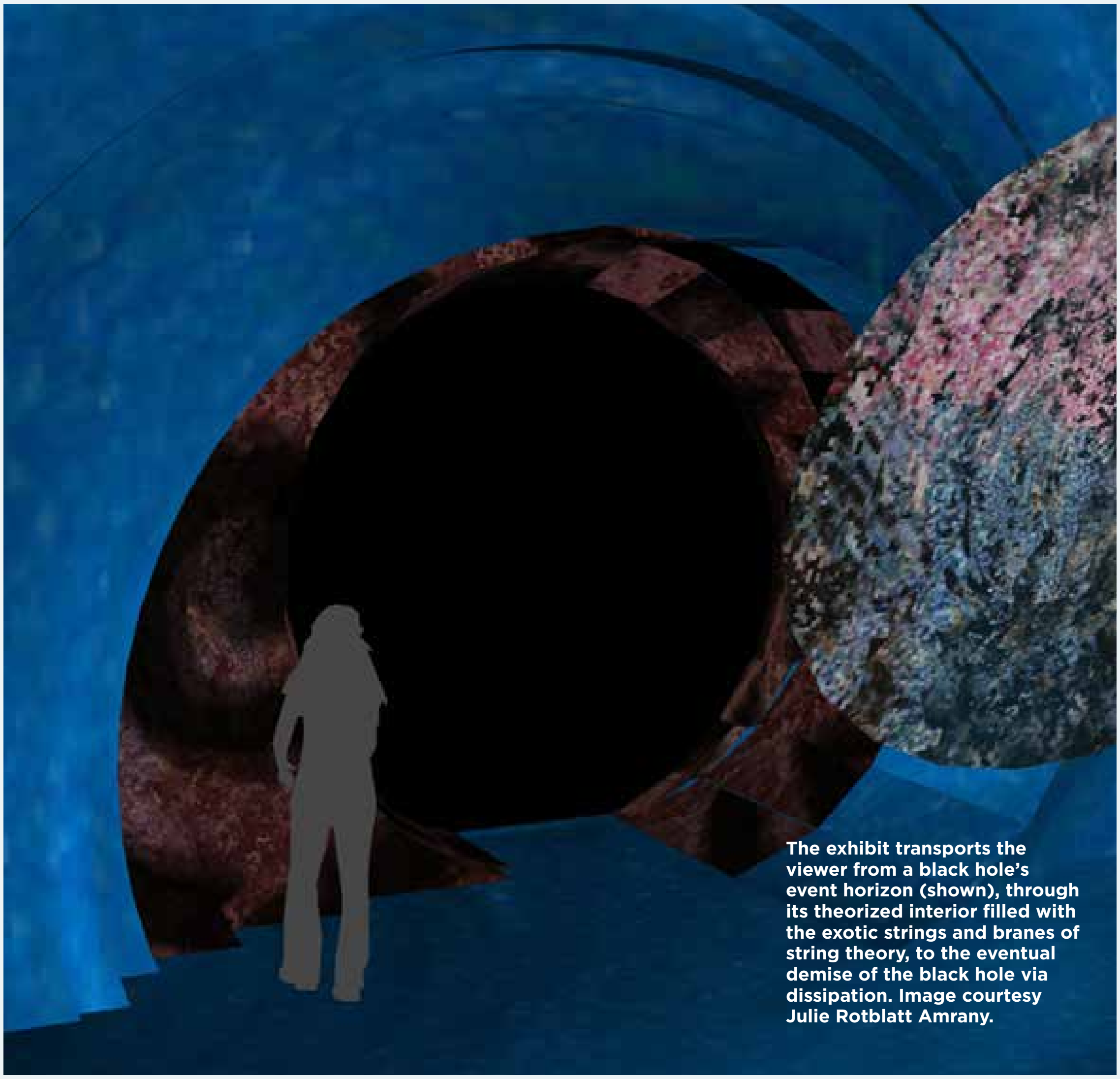
Early exposure

A precursor to the liquid argon time projection chamber shows particles in motion.

Invented in 1952 by Donald Glaser, for which he won the 1960 Nobel Prize in Physics, a bubble chamber is a tank filled with pressurized, superheated transparent liquid, often hydrogen or a hydrogen-neon mix. Just before an accelerator beam enters the chamber, the pressure is reduced, and the charged particles boil the liquid, forming bubbles along their paths, which curve in a magnetic field, allowing researchers to study particle momentum.



Particle tracks are captured on film in Fermilab's bubble chamber in 1978. Image courtesy Fermi National Accelerator Laboratory.



The exhibit transports the viewer from a black hole's event horizon (shown), through its theorized interior filled with the exotic strings and branes of string theory, to the eventual demise of the black hole via dissipation. Image courtesy Julie Rotblatt Amrany.

Abstract

Fabric of the universe

Art and science join forces to imagine the unknown.

Chicagoland artist and sculptor Julie Rotblatt Amrany and UChicago professor of physics Emil Martinec have teamed up to imagine and visualize the *Inner Life of Black Holes*. Amrany wanted to engulf the viewer in an environment—to feel, see, and hear what it might be like to travel through a black hole. She spent months working with Martinec, who specializes in string theory, to integrate what is known and what is theorized into an installation using sculpture, fabric, painting, interactive light, projection, and sound. Amrany and Martinec hope to secure a venue and funding to create the piece as a permanent or semipermanent exhibit.

For a virtual tour of the installation, visit Amrany's website at **jramrany.com /portfolio/video.**

For more information, contact Amrany at **jramrany@att.net.**