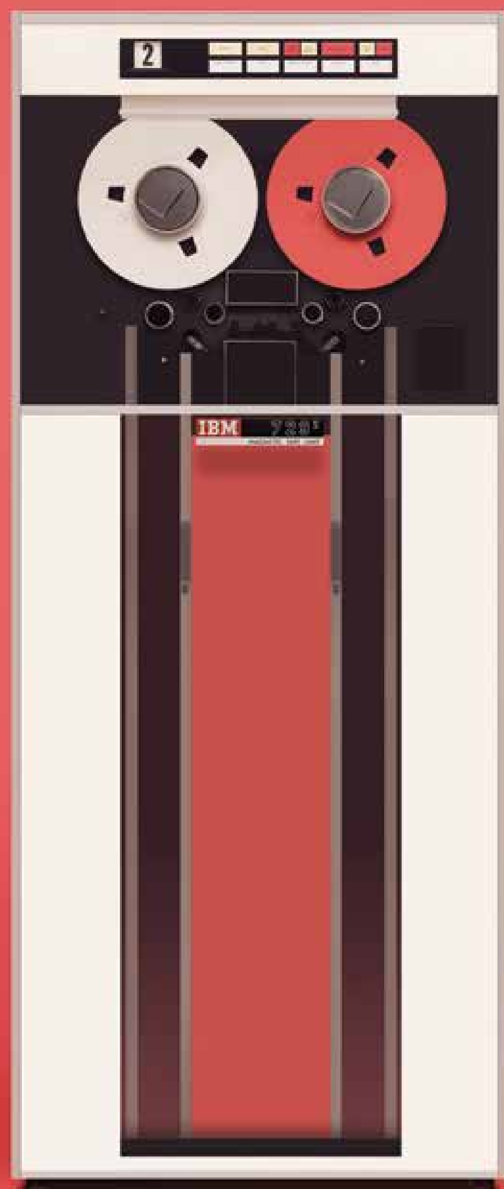
NEWS FROM THE UNIVERSITY OF CHICAGO PHYSICAL SCIENCES DIVISION

2016

INQUIRY



NOTE FROM THE DEAN

A calculated investment

When the computer was invented depends on your definition of "computer." Was it Charles Babbage's Difference Engine (page 64), designed in the mid-19th century but never built? Was it Bell scientist George Stibitz's 1939 "Model K" Adder? Regardless of your definition, history proves these computer things are more than a flash in the pan.

Not just scholarship and education but the very human experience has been transformed by computation. Of growing scientific and societal importance, the field of computer science is at the heart of this transformation. In the past few years, our computer science department has grown by more than a third. With the appointment of Michael Franklin as the Liew Family Chair of Computer Science, the department continues its faculty expansion, building on its excellence in theoretical research and further strengthening its systems research expertise.

The department is also committed to a new focus on data science. Research in virtually every discipline yields massive data sets, while progress simulating complex systems offers platforms for unprecedented analysis. A solid data science sector both reflects and supports the broad influence of computer science.

With the expansion of the department's size and scope and the growing culture of engineering that gave rise to the Institute for Molecular Engineering, we have the opportunity to reconceptualize the computer science department. In a university-wide commitment, computer science will integrate fundamental, engineering, and social science research to drive collaboration across divisions.

To that end, in 2018 the department will relocate to the renovated John Crerar Library, which will also house the Computation Institute, the Research Computing Center, and a computational commons that will support computational services and education. This move is yet another step toward the division's goal of having every department in new or renovated space by 2022.

UChicago's computer science department will serve as a center of gravity to address intense computational problems, to advance data-oriented research, and to serve as an incubator for new ideas and technologies.

Who knows what computers will look like in 100 years. But they'll probably be handy, and we plan to have a hand in that future.

With all best wishes,

Rocky Kolb

Edward W. "Rocky" Kolb
Dean of the Physical Sciences Division

COMPUTER SCIENCE

Scaling up

New computer science chair Michael Franklin discusses the past, present, and future of computation.

Data science scholar, entrepreneur, and software developer **Michael Franklin** has begun his appointment as the Liew Family Chair of Computer Science and senior adviser to the provost on computation and data science.

Franklin joined the University this July from the University of California, Berkeley, where he chaired computer science and led the Algorithms, Machines, and People Laboratory. At UChicago he leads the department in a major expansion of faculty, educational programming, and outreach, increasing the scope and impact of computer and data science and building collaborations on and off campus.

Tell us about your experience in data science.

I've been in the field of databases and data management about 30 years now, investigating how to work with data across different types of computing environments. Most recently my work has involved scalable analytics, where you build systems that can expand as the amount of data needing to be analyzed grows.

I also work with processing data on small devices—how to do data processing in a highly distributed, highly unreliable network. Human computation in crowdsourcing is also of interest—how to get groups of people connected by a network to collect data to solve analytics problems, like reporting traffic, pointing a telescope at the sky, or carrying air pollution sensors.

What exactly is data science?

The term "data science" grew out of industry—web-based companies like Facebook and LinkedIn who were gathering increasingly rapid streams of data. It was obvious that there was value in this data, but they needed a way to extract it. The software, hardware, and even theory that traditional analysts had been using weren't adequate for the volume and diversity of data and the types of questions these companies wanted to answer.

So a new field arose that involves concepts from computer science and statistics, as well as applied math and social science. It spread from industry to academia, but because of its breadth, it's a challenge to figure out exactly where data science "lives" on a university campus.

What are your plans to bolster the CS department?

What's exciting about the University of Chicago is an eagerness to engage with computer science, statistics, and applied math and to work on and solve computationally intense problems.

PHOTOGRAPHY BY JASON SMITH

We need to continue this process of scaling up the computer science department in core areas as well as outreach to other fields. We also need to build on the interdisciplinary work that's traditionally been done at UChicago, particularly projects housed in the Computation Institute. We have a committee working to define the future of the CI and how it will relate to computer science and other departments and divisions as an intellectual nexus for computation and data-oriented research on campus.

Beyond campus, CERES—a center for unstoppable computing—is a project involving UChicago faculty and corporate partners. The city of Chicago has a growing tech ecosystem, and UChicago is poised to increase interaction with city government and business. A strong computation effort will be key to those engagements.

How has computation changed research in fields like social sciences and humanities?

Computation has changed research in almost every field. It's easier to collect interesting data about the behavior of individuals and large groups. The challenge is finding the signal in all that noise. If you can find it, you can see things that weren't visible before.

And it's a two-way street; social science is also going to have a huge impact on computer science because computing has become deeply ingrained in everyday life. Advances in computing will depend on understanding how people interact with technology. My plans for the department include building bridges and training students to move comfortably between traditional, technical questions and also social science questions.

How far are we from integrating computational devices directly into our bodies?

I don't know, but the trend is clear. Most people already have a cell phone stuck to the side of their heads.

Should we be worried?

With any technology there's potential for great benefit and fear. Part of computer and data science education is teaching students to think about the broader impacts and ethical implications of what they're doing and the technology they're building.

Was there fear during the early days of computers?

There's always been nervousness around any sort of automation. Industrial Revolution workers feared machines would displace them. Mechanical looms were a popular target for British Luddites, who destroyed machines in protest over low wages and poverty. The "programmable" Jacquard loom—one of the inspirations for early computers (page 64)—was fiercely opposed by Parisian silk weavers.

And for computers, absolutely. Look at science fiction. Isaac Asimov—who wrote dozens of robot-based short stories and novels—defined three laws of robotics to make sure robots didn't harm people. There's always concern, but it can and must be managed.

How did you get involved with computer science?

When I was a senior, my high school got a new computer. It wasn't a fancy school, so it was a big deal. I signed up for the class, and it turned out I had an aptitude for it. One day my computer teacher made an offer: if I would write a certain program for him, he'd give me As the rest of the year and I could do whatever I wanted.

He had a friend teaching at another school who was bragging about their new computer and the programs they got for free. Evidently my teacher said, "Well, one of my students could write those programs." And they made a bet.

When I think back to that program, I cringe because I now know how I could have written it so much better. But it worked, and my teacher won the bet. *—Maureen Searcy*

PHOTOGRAPHY BY ROBERT KOZLOFF

PSD dean Rocky Kolb and professor Andrew Chien join Michael Franklin at the CERES research summit last winter.

PHYSICS

A unified theory

The Physics Research Center will unite theorists and experimentalists for the first time in half a century.

In 1961 University of Chicago faculty members conducting space exploration research were spread across and off campus. Physicist John Simpson—a pioneer who flew the first cosmic-ray experiments to Mercury, Mars, Jupiter, and Saturn—proposed a building to unite them: the Laboratory for Astrophysics and Space Research.

In an August 1962 meeting with LASR's architecture firm, Simpson explained that the building would be a departure from the classic physics laboratory. "The physicist must be around but not on top of the applied physicists," he said, suggesting that blackboards be located in strategic points to facilitate collaboration during casual meetings.

Completed in 1965 at 933 East 56th Street, LASR featured a foundation and roof designed with future expansion in mind. Fifty years and 15 Nobel Prizes in Physics later, the University is fulfilling Simpson's vision, adding two floors and undertaking extensive internal renovations to create the University's new Physics Research Center. The building, to be completed in summer 2017, will offer research space for advanced detectors and neutrino, accelerator, and gravitational wave physics.

Simpson's faith in the casual interchange of ideas endures. With offices and laboratories for the Enrico Fermi Institute and the Kadanoff Center for Theoretical Physics, the Physics Research Center will unite theoretical and experimental physicists under the same roof.

Inquiry asked a theorist (associate professor **LianTao Wang**) and an experimentalist (assistant professor **David Schmitz**) how the new facility will affect physics research.

What type of physics do you study?

LW: I work on theoretical high-energy physics, on topics including the properties of the Higgs boson, dark matter in the universe and its signal, and new physics at the Terascale—named for the teravolts (10^{12} volts) of particle accelerator energy produced at the Large Hadron Collider at CERN. My research includes theoretical calculation and derivation, as well as interacting with experimental groups.

DS: Our group studies the physics of neutrinos—the lowest mass but most abundant of the fundamental matter particles that we know. They are electrically neutral and only interact through the so-called weak nuclear force and gravity, which makes them challenging to study but also

UCHICAGO PHOTOGRAPHIC ARCHIVE, APF1-00408, UNIVERSITY OF CHICAGO LIBRARY

Breaking ground—again

When UChicago physicist John Simpson proposed the Laboratory for Astrophysics and Space Research—the first government-sponsored center of its kind—he envisioned not just a structure but an interdisciplinary intellectual space.

"There is great value in the casual interchange of ideas and information between all levels of scientists and engineers as these individuals move about the building performing their various tasks," Simpson told LASR's architects at a 1962 meeting.

On May 1, 1963, Simpson (far left), along with University president George W. Beadle, board of trustees chair Glen A. Lloyd, director of NASA grants and research Thomas L. K. Smull, and chief of NASA lunar and planetary sciences Urner Liddel, broke ground on the new LASR building. With the planned renovation and adaptive reuse, the new Physics Research Center will preserve Simpson's vision.


With two more floors and internal renovations, LASR (left) will transform into the Physics Research Center (right).

makes them a unique and exciting probe of a range of phenomena in the universe. Our group is interested in neutrino oscillations, the process by which they transform between different "flavors."

We are trying to answer whether neutrinos could explain why matter came to dominate over antimatter in the early universe instead of just annihilating each other into a structureless sea of photons. And we are searching for new types of particles called sterile neutrinos, which interact with matter only through gravity.

How might collaboration between a theorist and an experimentalist benefit your research?

LW: A key ingredient of my work is taking inspiration from data, to develop new ideas that can be tested by experimentation and new strategies to look for interesting signals. This cannot happen without active interaction with my experimental colleagues.

DS: In particle physics we are in an exploratory period, trying to figure out where the cracks are in our model of how the universe works. It's critical that experimentalists, who develop the methods to search for new phenomena, and theorists, who provide guidance on where they could or could not be hiding, work together closely. The theory community can also provide important input on dealing with certain systematic uncertainties that impact experiments, so regular communication is vital.

How will the Physics Research Center support research in ways that current facilities haven't?

LW: The renovation of LASR promotes the interaction between experimentalists and theorists as well as between different areas of theoretical physics, which is crucial to catalyze progress.

More than just nice new offices and dining areas, the Physics Research Center will offer faculty, students, and staff a better chance to run into each other—motivating the exchange of ideas and inviting discussions.

This is a distinct feature of many leading institutions. I cannot remember how many times new ideas were born from frequent and spontaneous interactions among colleagues in such spaces.

DS: The renovated facility will be a hub for particle physics research on campus and the Chicagoland area. State-of-the-art detector development will take place across the hall from regular seminars on cutting-edge theoretical ideas. Graduate students and postdocs researching in different fields and working in both experiment and theory will work in close proximity, facilitating more serendipitous exchange of ideas in addition to the more formal channels. This is important to their education as well as to the progress of our research.

What physics mystery, whether in your field or in another, do you most want to see solved during your lifetime?

LW: The mechanism of the electroweak symmetry breaking and how it's connected to other deep questions, such as gravity. Also the nature of dark matter.

DS: If I have to pick just one mystery, then I'd say detecting some form of dark matter and perhaps opening the door on a whole "dark sector" of matter. The Standard Model of Particle Physics is such a triumph, yet it only tells us about 5 percent of the content of the universe.—*Maureen Searcy*

IMAGES COURTESY PERKINS EASTMAN

astronomy

Lonely planets

Astronomers and planetary scientists debate if and when we'll find extraterrestrial life.

BY MAUREEN SEARCY

The event: an Oxford-style debate. The occasion: a celebration of the Department of Astronomy and Astrophysics's 123rd year, in conjunction with the University of Chicago's 125th anniversary last fall. The place: the William Eckhardt Research Center, the department's new home.

The proposition: by the end of 2042—significant for being 150 years after the department's founding—remote sensing will reveal evidence of extant life on an exoplanet. The fine print: we don't have to physically visit the site; evidence does not mean certain proof; organisms must be currently living; and life forms need not be intelligent. The winner: to be determined by audience vote.

The finer print: the debate deals with life as we know it; alien life could be so alien we might not even recognize it.

WE ARE NOT ALONE (PRO)

DORIAN ABBOT, ASSOCIATE PROFESSOR OF GEOPHYSICAL SCIENCES

Abbot launched the arguments for why we would find life with five points supporting the claim that life is common, particularly microbial life.

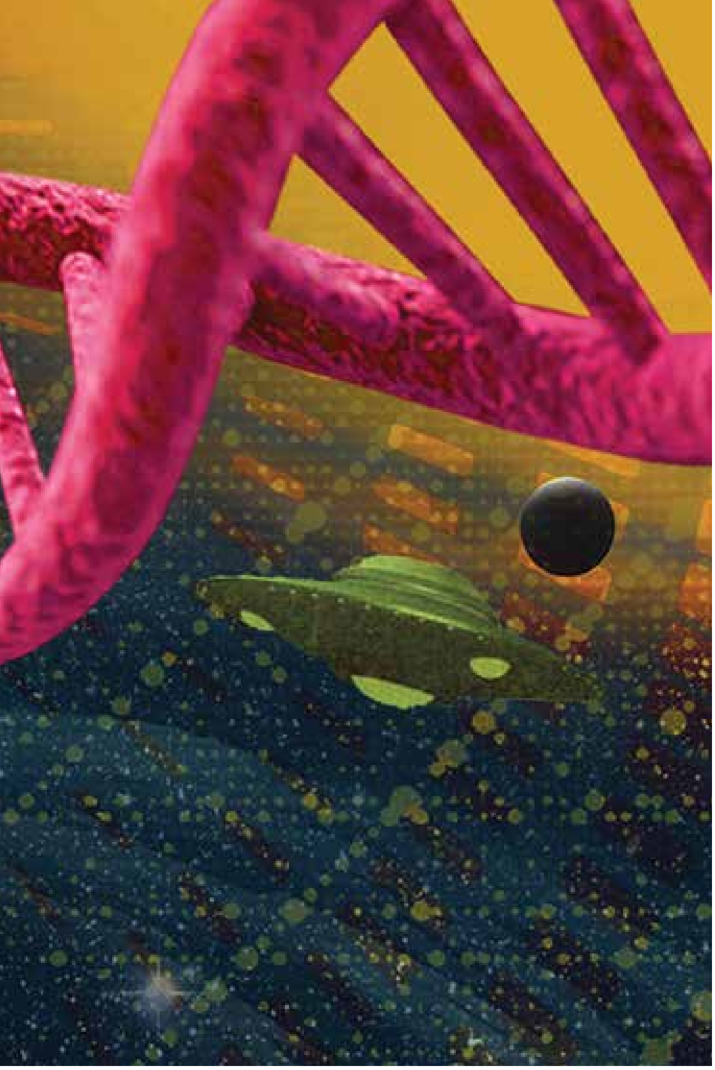
1. Earth-like terrestrial planets are plentiful in the universe, as revealed by the Kepler mission, offering ample opportunity for habitable environments.
2. "The raw materials for life are everywhere," said Abbot. Hydrogen, oxygen, carbon—they can be found on asteroids, moons, other planets, and in interstellar space.
3. As far as scientists can tell, life arose on Earth about as soon as it could have. Earth is 4.5 billion years old, and the earliest geochemical evidence of life appeared 4.1 billion years ago. "If you get those conditions elsewhere, you're probably going to get simple life."
4. Life thrives on Earth in extreme conditions, like in hot springs and deep-sea vents and Antarctica.
5. Life is resilient. "Once it arises, it's hard to get rid of," said Abbot. Asteroid impacts, hothouse climates, and "snowball Earth" events that froze the entire planet—despite mass extinctions, microbial life has persisted.

LESLIE ROGERS, ASSISTANT PROFESSOR OF ASTRONOMY AND ASTROPHYSICS

Rogers discussed how we would detect life through observation and measurement of biosignature gases. "Even simple life will modify its environment," said Rogers. "No matter

COLLAGE BY JOYOLIVIA MILLER

Are we alone in the universe? The Departments of Astronomy and Astrophysics and Geophysical Sciences consider the likelihood of life's existence beyond Earth and our ability to find it.



how 'green' these aliens are, they will inevitably pollute." The question is whether that pollution will be detectable and distinguishable as a biosignature rather than from an abiotic process, like volcanic activity.

The key will be finding an ideal biosignature gas to look for. Water, methane, and carbon dioxide all arise from geophysical processes. Astronomers must find a molecule that doesn't exist naturally in a planet's atmosphere, is not created by planetary processes, is not produced or destroyed quickly by interaction with light, and has a strong enough spectral signature to be detected from a great distance. If an alien species were looking for an ideal biosignature from Earth, O_2 or ammonia would fit the bill.

NO MATTER HOW "GREEN" THESE ALIENS ARE, THEY WILL INEVITABLY POLLUTE THEIR ENVIRONMENT.

LAURA KREIDBERG, SM'13, PHD'16, NSF GRADUATE RESEARCH FELLOW IN ASTRONOMY AND ASTROPHYSICS (NOW AT HARVARD)

Kreidberg addressed technology: "The million dollar question is, will we actually be able to detect these biosignatures by 2042? Actually perhaps more likely the 10 billion dollar question." She explained the main technique used to analyze atmospheres, called transmission spectroscopy. When a planet passes in front of its star from our perspective, molecules in its atmosphere absorb light, producing an observable spectrum, from which astronomers can infer the planet's atmospheric composition and temperature.

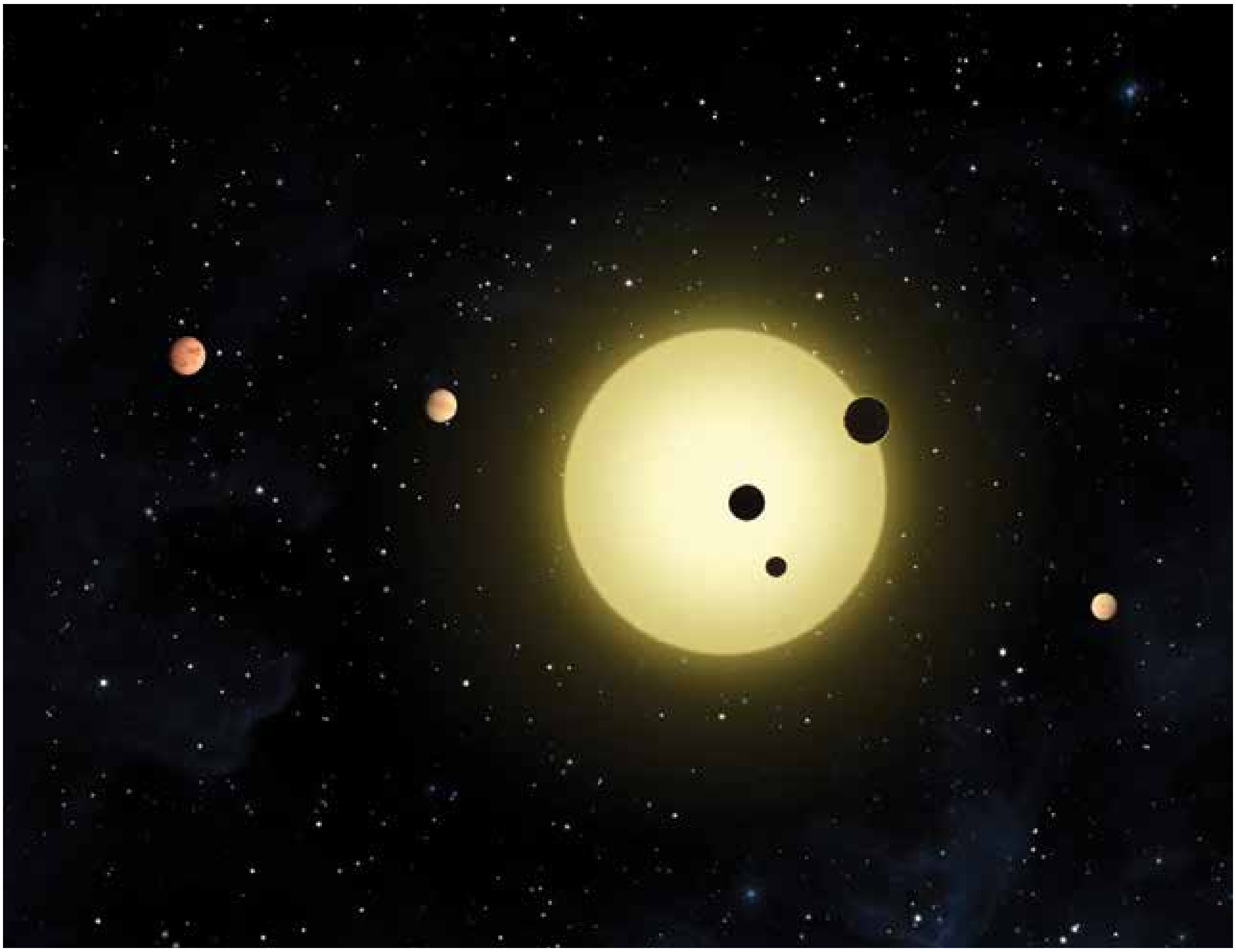
To detect biosignatures reliably, they'll need more precise measurements, which the James Webb Space Telescope will collect when it launches in 2018. To achieve direct imaging, astronomers need an even more powerful telescope, such as the 12-meter ultraviolet-optical-infrared observatory proposed by the Associated Universities for Research in Astronomy for development in the 2030s. "Then," said Kreidberg, "we'd be in business."

WE ARE ALONE—OR MIGHT AS WELL BE (CON)

EDWIN KITE, ASSISTANT PROFESSOR OF GEOPHYSICAL SCIENCES

To kick off the arguments that we won't find evidence of life, Kite considered the likelihood of life arising from chemical reactions. "We all hope that life is widespread in the universe; anything else would seem like a waste of space," said Kite. "But we should vote based on facts, not hopes, and the facts are that the origin of life appears to be very difficult." Scientists have known since Pasteur's 1859 experiment that spontaneous generation doesn't exist, and all efforts to coax life from its necessary components in a laboratory have failed. Nearby planets and moons have had all the prerequisites for life in just the right conditions for millions of years, and still no life has arisen.

The rise of life isn't impossible, Kite noted, because it obviously has happened at least once in the universe. So he laid out two scenarios: life is easy and common (which seems unlikely considering our failed experiments at creating life and nearby observation) or life is rare, spread out across swaths of lifeless space too vast to overcome any time soon. He insisted that the audience shouldn't feel any cognitive dissonance in voting "no." They can still support exoplanet research while acknowledging that it's unlikely to find alien life by 2042.



NASA's Kepler Mission has thus far discovered more than 3,000 exoplanets, including six orbiting a small cool star called Kepler-11 (top). During the debate (lower right), Dorian Abbot argued that Kepler's numerous confirmed terrestrial planets offer plenty of environments for life to arise. Edwin Kite countered that when microbiologist Louis Pasteur, shown in Albert Edelfelt's 1885 painting (lower left), disproved spontaneous generation, we learned that life does not arise easily.

ARTIST RENDITION COURTESY NASA/TIM PYLE (TOP); PHOTOGRAPHY BY NANCY WONG (RIGHT); IMAGE COURTESY MUSÉE D'ORSAY, PUBLIC DOMAIN (LEFT)

DANIEL FABRYCKY, ASSISTANT PROFESSOR OF ASTRONOMY AND ASTROPHYSICS

Fabrycky's discussion on whether we'll find simple life centered on whether we might find—or be found by—intelligent life. He conjured Fermi's paradox, often mentioned when discussing alien life. Put simply (and perhaps incorrectly): If aliens are out there, where is everybody? Why are we not in contact now, and if they've visited, why are there no artifacts? "In this audience, I don't think I have to defend that proposition—that there are no such artifacts," said Fabrycky. "Not even a measly obelisk on the moon."

Fabrycky pointed out that our solar system has traveled around the galaxy 50 times since it formed, with only the help of gravity. "If you have rockets and intelligence propelling you, you can get around the galaxy much quicker." If aliens were coming, they should be here by now.

For contact to be made, a series of states must be achieved, according to the Drake equation.

1. There must be terrestrial planets older than Earth.
2. Nonliving molecules must form into living, replicating organisms.
3. Life must evolve from simple organisms to complex, intelligent life.
4. Intelligent life must develop technology advanced enough to populate the galaxy.

Robin Hanson, AM'84, SM'84, a physics-trained economist, proposed the "great filter" argument, Fabrycky noted, that somewhere in that series of states exists an insurmountable obstacle, which is why our galaxy isn't swarming with alien life. But at which stage is the filter?

Kepler has found numerous suitable exoplanets as well as star systems far older than our own, so no problem there. Once step two is passed, where raw materials become life, there would be biosignatures, and the debate's proposition could be true. Fabrycky thinks this is the filter. Humans are in step three, having evolved into intelligent beings via a process well understood and documented (and thus not likely the filter).

IF YOU HAVE ROCKETS AND INTELLIGENCE PROPELLING YOU, YOU CAN GET AROUND THE GALAXY MUCH QUICKER.

So, in Fabrycky's argument, the filter is either the origin of life or our capacity for interstellar travel. If you believe that we will find evidence of simple life, then you believe that the filter is ahead of us, that neither we nor any other intelligent species will ever leave our solar system. "By voting 'yes' on your post-debate slip, you are dooming humanity. To vote 'yes' to the future of humanity, you must vote 'no' to biosignatures."

JACOB BEAN, ASSISTANT PROFESSOR OF ASTRONOMY AND ASTROPHYSICS

Closing out the con side, Bean reiterated that any search for life would face technological, scientific, and procedural challenges. But the greatest challenges will be ideological and economic—getting exoplanet researchers to agree on the right strategy and then convincing the broader astronomical community, the public, and the government to buy in. "Science aside, technology aside, my pessimism about human nature suggests that we are not going to pull that off by 2042. It's going to be the money that limits us, not the ability to do the observations or to interpret the measurements."

A BRIEF REBUTTAL

Abbot rebutted Kite's rare life claim, suggesting that life could have arisen multiple times on Earth but been outcompeted by a more dominant form.

He also suggested that Fabrycky overestimated the ease of evolution, noting it took three billion years to get to our current state. "Intelligent life doesn't seem Darwinianly favorable. Cows are doing fine not building radio telescopes."

Kreidberg pushed back on Bean—who happens to be her adviser and who convinced her to pursue exoplanet research—saying that he discounts tremendous public fascination with the search for alien life and human ingenuity to develop cheaper methods for exploration.

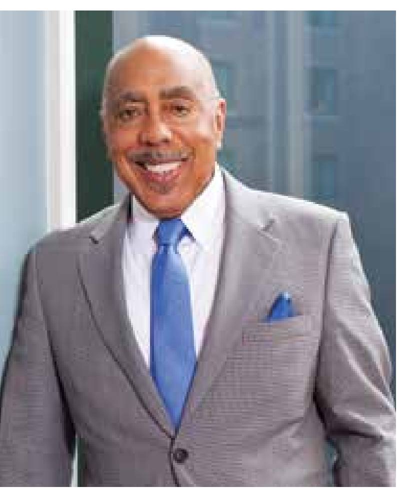
Kite rebutted the use of certain gases as biomarkers: "Oxygen sucks." When light breaks down water, hydrogen escapes into space easily, leaving oxygen to build up, increasing the chance of a false positive.

Bean admitted that he "actually should be sitting on the other side." His argument was more of a challenge to get people on board and "make this happen."

THE VERDICT

Before the debate, the audience voted 38 for "yes," we will find life, and 33 for "no," we're on our own. Afterward, 38 for "yes," 40 for "no." Astronomy and astrophysics chair **Angela Olinto** joked, "I think we are following the Chicago tradition of voting often," before declaring a tie. ◆






profile

Change of state

Former Argonne director; UChicago VP of research, trustee, and now representative on the Giant Magellan Telescope board; physicist; and retiring art school president Walter E. Massey enters a new phase.

BY MAUREEN SEARCY

Whether working with heads of state (with president Jimmy Carter in 1980) or art school undergrads (speaking at an SAIC orientation), Walter E. Massey has been a leader, an educator, and a mentor across his diverse career.

OPPOSITE PAGE: PHOTO COURTESY ARGONNE NATIONAL LABORATORY (TOP LEFT); ALL OTHER PHOTOS COURTESY THE SCHOOL OF THE ART INSTITUTE OF CHICAGO

Often the question, "So what's next for you?" comes at the end of a profile about a notable person leaving a prominent position. But for **Walter E. Massey**, who stepped down as the president of the School of the Art Institute of Chicago in June, the end of each career stage has been the beginning of something equally if not more remarkable.

Sitting in his eighth-floor office overlooking Millennium Park, three days before the end of his six-year term, Massey explains that he will remain as SAIC's chancellor, participating in fundraising and outreach efforts. The part-time position grants him more time to participate as UChicago's representative on the board of the Giant Magellan Telescope Organization, a consortium of about a dozen US and international institutions that oversees the construction and management of a super giant telescope in Chile's Las Campanas Observatory. The segmented-mirror telescope, scheduled to be operational by 2022, promises to "if not answer, then shed light—no pun intended—on our biggest questions about the universe," says Massey.

An emeritus trustee of the University since 2008, Massey joined the GMTO board in February, filling the spot vacated by Physical Sciences Division dean Rocky Kolb. Massey, a physicist with extensive advisory board experience—Bank of America, the Mellon Foundation, and the Marine Biological Laboratory, to name a few—has been affiliated with UChicago longer than with any other institution.

His wife, Shirley Anne Massey, has been involved with UChicago even longer. She grew up in Hyde Park, and her father was the first black janitor at the Laboratory Schools, says Massey. One son, **Eric Massey**, LAB'89, AB'94, who works in environmental research, has a daughter, Eva, enrolled at Lab. "Our family," Walter Massey says, "is part of the UChicago community."

Born in Hattiesburg, Mississippi, in 1938, Massey loved math and in the 10th grade was awarded a scholarship to Morehouse College in Atlanta. His parents believed education was essential, and Massey went into theoretical physics in part to rise above the discrimination of his childhood. As he told *Physics Today* in October 1990, "When you're black and you grow up segregated, so much depends on how people think of you. In theoretical physics, no one reading your papers would know if you were black or white. There's no such thing as black physics."

After earning his PhD in physics from Washington University in St. Louis, he joined Argonne National Laboratory as a postdoc. "That was 1966," says Massey. "Fifty years—my god!"

IN THEORETICAL PHYSICS, NO ONE READING YOUR PAPERS WOULD KNOW IF YOU WERE BLACK OR WHITE.

Starting in graduate school, Massey studied theoretical condensed matter physics—the study of solid-, liquid-, and plasma-state matter and the physical properties of each—focusing on the application of quantum theory to helium.

At Washington University and later as an assistant professor at the University of Illinois at Urbana-Champaign (UIUC) and a professor at Brown University, he studied superfluidity of liquid helium, which exhibits unusual properties such as frictionless flow and the apparent ability to defy gravity at extremely low temperatures.

While continuing the solitary endeavor of his research, Massey also turned his attention to broader interests, motivated by the 1960s civil rights movement to engage with society. He became a founding trustee of the Illinois Mathematics and Science Academy, a public high school for students interested in a science or math career. While at Brown he developed a program to educate future teachers for inner city schools and also served as dean of the college.

In 1979 Massey returned to Argonne—this time as director and UChicago professor of physics—now in a position to drive scientific discovery on a broader scale. Under Massey's leadership Argonne developed a new technology for nuclear reactors, the Liquid Metal Reactor, which, he says, "may in fact be one of the technologies that comes back if nuclear power has a resurgence." (He hopes it does.) The lab also developed what ultimately became the Advanced Photon Source, which provides ultra-bright, high-energy x-ray beams for research in almost all scientific disciplines.

In 1983 Massey was appointed UChicago's vice president of research, cofounding and chairing the Argonne-Chicago Development Corporation—one of the first organizations in the country designed to commercialize academic research. The predecessor to such entities as UChicagoTech and the Polsky Center for Entrepreneurship and Innovation, ARCH "was unique and interesting," Massey says, "in that it involved Argonne scientists and engineers, UChicago faculty from both science and business, graduate students, and trustees."

At UChicago's Hack Arts Lab, SAIC MFA candidate Keeley Haftner uses a filament extruder.

PHOTO COURTESY ARTS, SCIENCE, AND CULTURE INITIATIVE

"Back then the climate was not conducive to commercialization," he says, noting that ARCH was formed not long after the 1980 passage of the Bayh-Dole Act, which granted universities and businesses exclusive control over government-funded inventions. "Now it's taken for granted. Potential for commercialization is just part of young faculty's career paths."

Application not only connects the University to the world outside, he says, but also demonstrates that governmental investment in science and technology benefits the country's economy. Well versed in how the government thinks about funding science, in 1991 Massey, a Democrat, was appointed by George H. W. Bush to be director of the National Science Foundation. He also served on the President's Council of Advisors on Science and Technology for both George H. W. and George W. Bush.

While leading the NSF, Massey helped persuade Congress to fund what, in 1992, was the NSF's single largest investment to date: the Laser Interferometer Gravitational-Wave Observatory. Designed to detect the gravitational waves predicted by Albert Einstein as part of his general theory of relativity, LIGO was a tough sell. Much of the astronomy community was opposed to it, arguing such waves couldn't be detected by available—or even proposed—technology. Massey and LIGO's leaders argued that both the science and technology that came from LIGO would benefit research beyond the search for gravitational waves.

It took 25 years, but LIGO finally detected the waves in September 2015 and again in December. Though he had been certain the project was a solid investment, Massey was still "dumbfounded" when he heard the news: "It's one of those things—you wonder if it'll ever happen."

A lifelong advocate for science, Massey has also advocated for scientists themselves, in particular pushing for greater gender and racial equality in science, technology, engineering, and mathematical (STEM) fields. He believes one path to parity is mentorship, having benefited so greatly himself from mentors.

The only physics major in his class at Morehouse, he was mentored by Sabinus H. Christensen, a white professor at the historically black college who, says Massey, inspired a good proportion of black physicists to earn their doctorates—still a tiny percentage then. In a June 1992 article about Massey, *Scientific American* cites NSF data showing only 340 black PhDs in science and engineering out of 14,776 total in 1990. In that same article, Massey half jokingly says he used to give speeches urging universities to double their number of black PhDs, but because many had none, he changed his recommendation to "double plus one."

A cofounder of the National Society of Black Physicists, Massey has long worked to encourage women and underrepresented minorities in STEM, founding outreach groups at UIUC and Brown, and later as provost and vice president of academic affairs at the University of California and then as president of his alma mater, Morehouse.

Over his career he's seen "tremendous" progress, Massey says, "but still not enough." While women have made great strides in representation, particularly in the biological sciences, "there's still a great need to push these issues and provide funding, especially for African Americans and Hispanics." While the number of PhDs in STEM has increased a staggering 5,333 percent since 1990, from roughly 15,000 to 800,000, the percentage of those who are black increased only a fraction—from 2.3 to 3 percent, according to the NSF's 2013 survey. (By comparison, the Census Bureau estimates the US population to be 13.3 percent black or African American.)

So how do we improve those numbers? "It always comes back to high school," says Massey. "We need to build the pool and then provide financial support for bright young students in college interested in pursuing these fields. We also need to make a better case that STEM can be as economically attractive as other careers." The transition from undergraduate to graduate study is another hurdle. "That's where financial aid and scholarship funds become crucial." And Massey believes in providing mentors to students from underrepresented groups who may face a dearth of role models—to show what they too can achieve.

In 2010 Massey was appointed president of the School of the Art Institute of Chicago, initially on an interim basis and not without some controversy in the local art scene, where skeptics raised an eyebrow at his corporate background. Yet he proved a successful choice, overseeing construction of the Leroy Neiman Center, the first ever student center at the school; launching programs to better engage the school with the city; and starting a $50 million

Massey, who believes in the interconnectedness of art and science and supports collaborative programs between UChicago and SAIC, joins students in SAIC's Science Lab.

PHOTO COURTESY THE SCHOOL OF THE ART INSTITUTE OF CHICAGO

fundraising campaign for student scholarships and faculty chairs. During his tenure the school's programs consistently ranked in the top four nationally.

Massey enjoyed the shift to the art and design world. Surrounded by artists and designers, he and his wife say they felt more present, more aware of their surroundings. "It adds so much richness to your life."

His experience as a scientist is not so incongruous with his post as president of SAIC, he explained while accepting the Illinois Humanities Council's 2016 Public Humanities Award, which honored his efforts in developing creativity in young people, increasing access to education, and strengthening the ties between humanities and the sciences.

In that speech, he also quoted Carlo Rovelli, an Italian theoretical physicist whose 2015 book *Seven Brief Lessons on Physics* describes the work of science: "Science begins with a vision. Scientific thought is fed by the capacity to 'see' things differently than they have previously been seen."

Back in his SAIC office, he conjures this concept of vision again while explaining the similarities between the artistic and scientific communities. Curiosity and the ability to look beyond and challenge what's accepted—scientists and artists both engage in this form of re-vision to solve seemingly unsolvable problems or to express an idea in a novel way. "Both communities in the very best circumstances have a tolerance for ambiguity. They may not have the right solution, but they see their way forward."

This isn't just lip service—a pat response prepared for the numerous journalists who ask about his background in science and how it relates to art. He backs it up by supporting programs at SAIC, such as Conversations on Art and Science, visiting scientists, and collaborations among art and science students. For the past two years, UChicago's Art, Science, and Culture Initiative Graduate Collaboration Grants have paired UChicago science students with SAIC art students for interdisciplinary research.

One collaboration in the 2015–16 cycle paired Keeley Haftner, an Art Institute MFA candidate in fiber and material studies, with UChicago biophysics PhD candidate Will McFadden. Their project, Filament Findings, explored 3-D printing and cytoskeletal structures, focusing on organic and inorganic materials.

"It's gratifying that we've come to the point of doing substantive collaborative work," says Massey, rather than artists simply illustrating scientific results. "Each side seems to be learning from the other, gaining skills from each other to help solve their own problems."

As Massey vacates the presidency, new SAIC president Elissa Tenny will continue those initiatives, and he will assist her and the board in any way "she sees fit," he says with a smile. Which brings us back the question: what *is* next for Walter Massey?

He laughs at the notion of "getting back into science." He won't be doing science—"it's way beyond that" for him. But he's active in the science community and looks forward to spending more time learning about UChicago's ongoing research. And his responsibilities to the Giant Magellan Telescope Organization board take time.

He's excited by what the telescope might find: "At the last meeting of the board, we discussed the possibility of detecting oxygen on exoplanets." That could be an indicator of life. The telescope could also aid discoveries regarding dark matter, dark energy, and black holes. "But one of the most exciting possibilities—and likelihoods—is that none of the above will be the most interesting thing," says Massey. "If the only thing you learn confirms something you predicted, that would be great, but that wouldn't be nearly as exciting as unearthing—or unplanetarizing—things you never suspected."

In his last annual report before stepping down as SAIC president, Massey wrote about such scientific discoveries and his own evolving career: "As a physicist, leading a school of art and design has certainly been a learning experience, but as Nobel laureate Richard Feynman once wrote: 'In order to make progress, one must leave the door to the unknown ajar.'" ◆

history

A pattern of progress

How an automated loom inspired the earliest computer inventors.

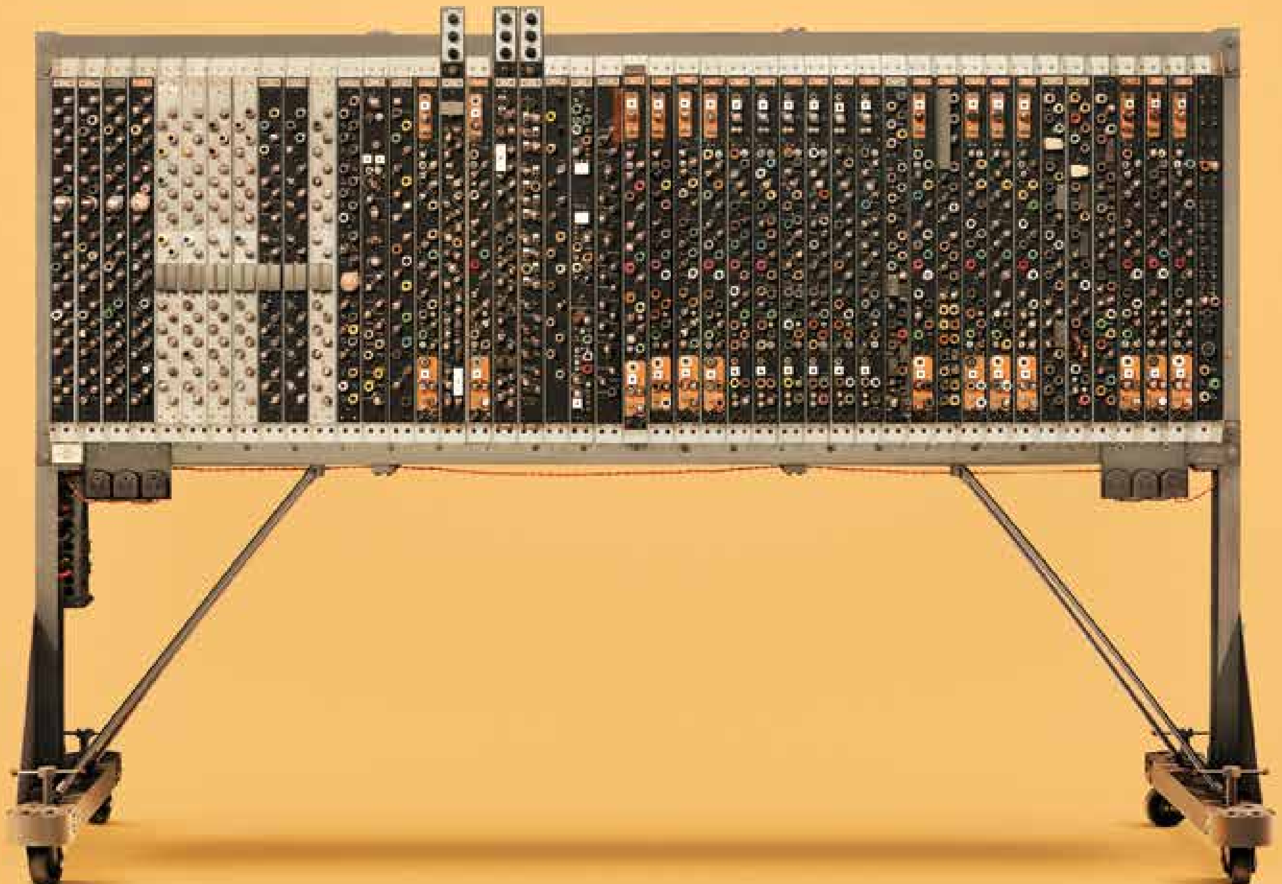
BY MAUREEN SEARCY

IMAGE COURTESY THE NEW YORK PUBLIC LIBRARY

In 1801 French weaver and inventor Joseph Marie Jacquard debuted a "programmable" automated loom* at an industrial exhibition in Paris. What became known as the Jacquard loom was actually an attachment controlled by a chain of punch cards, in which one complete card dictated one row of a pattern. A hook and its corresponding thread were raised or lowered depending on the code, creating intricate patterns that could be quickly replicated by a single weaver. Traditional looms required a weaver and an assistant.

The Jacquard loom was one of many automation advancements that marked the Industrial Revolution, transforming the European textile industry. It also set the stage for the invention of computer technology, as noted by School of the Art Institute MFA student Dylan Fish and UChicago mathematics PhD candidate **Daniel Johnstone**, SM'13, during their May collaboration grant presentation, which explored computational concepts through cloth production.

In the early 19th century, English mathematician Charles Babbage designed a calculating machine—the Difference



The Jacquard loom and its punch-card design (left) laid the foundation for computer technology, such as Alan Turing's Pilot ACE (above), completed at National Physical Laboratory in 1951 and in operation for about five years.

PHOTOGRAPHY BY DOCUBYTE

Engine. But it was his follow-up design, the 1834 Analytical Engine—based on Jacquard's punch cards—that introduced computer programming.

Never built in his lifetime, his engines laid the foundation for general-purpose computers, largely thanks to the English poet Lord Byron's daughter, Ada Lovelace. She had mathematical training and helped popularize the idea that Babbage's Analytical Engine could perform step-by-step calculations (programs) and move beyond numbers to manipulate symbols using rules.

Also inspired by Jacquard's punch cards was US Census Bureau staff member Herman Hollerith, who was looking for a more efficient way to assess the country's population. In 1884 he filed a patent for a device that rapidly read information encoded in holes punched on paper, which reduced the census process from eight years to one. Hollerith founded the Tabulating Machine Company, which eventually became IBM.

Fast forward to 1951, when the UK's National Physical Laboratory completed the Pilot ACE (Automatic Computing Engine), a general-purpose computer based on English mathematician Alan Turing's design. The Pilot ACE used Hollerith 80-column punch-card input and output equipment, with the input device running at 200 cards per minute and the output device at 100 cards per minute.

Today's computers no longer use punch cards, having evolved in leaps and bounds. "As the exponential curve on one technology's advancement dies out," says **Michael Franklin**, the Liew Family Chair of Computer Science, "another technology takes over."

With the exploration of quantum computing, tomorrow's computer technology likely won't even be constrained by the laws of classical physics. And it all started with an ambitious weaver.

** Jacquard's was not the first automated loom—just the first to be successfully adopted by the textile industry. The first loom using a punched-paper technique was designed around 1750 by French engineer Jacques de Vaucanson, who is also credited with inventing the world's first robots.*

Mirror image

Jonathan Simon blurs the line between matter and light.

Light and matter are distinct entities in classical physics. In the context of quantum mechanics, they are alike in that they both can act as a particle or a wave. Neubauer Family Assistant Professor of Physics **Jonathan Simon** and his lab have taken advantage of this similarity to explore quantum mechanics in matter by harnessing light.

Simon's recent research deals with the quantum Hall effect, a variation of the Hall effect, named after its discoverer, physicist Edwin Hall. The Hall effect is a phenomenon in which electrons moving straight through a conductive material will deflect into a curved path when subjected to a magnetic field, creating a voltage across the material and affecting the material's resistance. The quantum Hall effect is observed when a material in a powerful magnetic field and at very low temperatures shows a step-wise, rather than linear, change in resistance.

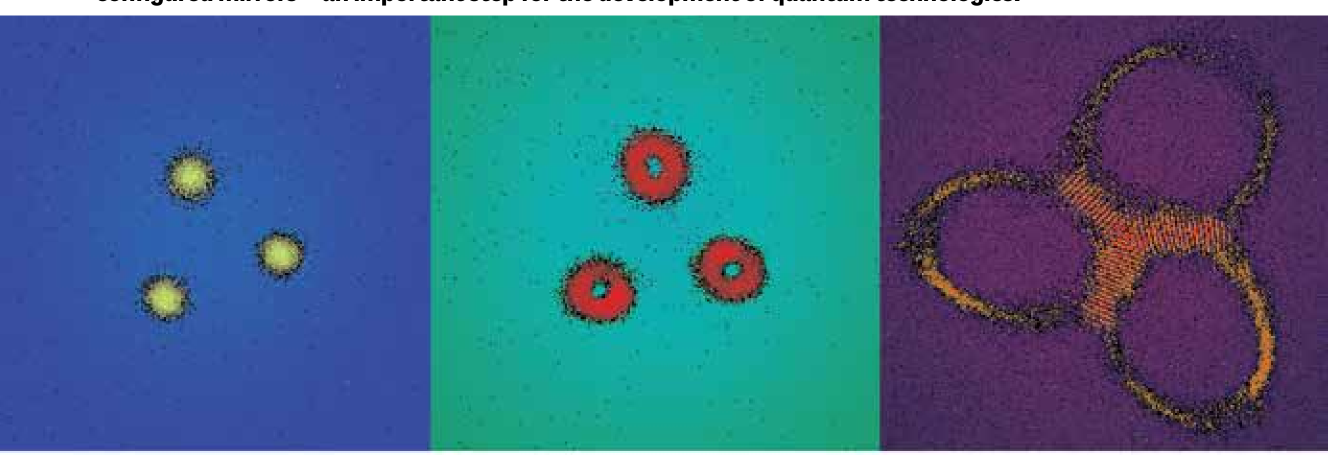
Two characteristics that solid-state quantum Hall materials exhibit are low electrical resistance and quantum entanglement, in which the state of one electron influences the state of the rest. These properties are promising for such applications as quantum computation.

Simon's lab created a photonic (or light-based) quantum Hall material by shining infrared lasers at specially configured mirrors, creating the false-color images seen below. When the photons bounce between the mirrors—arranged in such a way to make the photons twist—their side-to-side motion parallels the electron behavior in solid-state quantum Hall materials.

Using advanced optical systems, the physicists also made the photons act like they were on the surface of a cone, a feat not yet achievable with electrons. This experiment led to the first observation of the quantum Hall effect in curved space. In conjunction with ongoing work in the Simon lab to induce the photons to collide with one another, it opens the door to creating synthetic materials from light.

—*Maureen Searcy*

These false-color images show light-based quantum Hall material, created by shining infrared laser light at specially configured mirrors—an important step for the development of quantum technologies.



IMAGES COURTESY NATHAN SCHINE, SM'14; ALBERT RYOU, SM'13; ANDREY GROMOV; ARIEL SOMMER; AND JONATHAN SIMON

To learn more about the Physical Sciences Division's academic and research priorities—and how you can help—contact director of development Brian Yocum at 773.702.3751; byocum@uchicago.edu; or William Eckhardt Research Center, 5640 South Ellis Avenue, Suite 319, Chicago, IL 60637.

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Page 51: The IBM 729 Magnetic Tape Unit; photography by Docubyte