News from the University of Chicago Physical Sciences Division

INQUIRY

SPRING 2015

Queen of Carbon

Mildred Dresselhaus, PhD'59, wins nation's highest civilian honor.

THE UNIVERSITY OF CHICAGO

INQUIRY

SPRING 2015

Note from the dean

Building preeminence

In 1923, Robert Millikan won the Nobel Prize in physics for measuring the charge of the electron. He determined this fundamental physical constant, which influenced all physics that followed, while working in a University of Chicago laboratory with equipment and resources suited precisely for his needs. But the laboratories of yesterday can't meet the needs of today. As science advances, so must facilities, becoming more powerful, precise, and indispensable to a vast array of research fields.

In the past decade, the Division of the Physical Sciences has ushered in tremendous growth after half a century of impressive but aging infrastructure. Within five years, every PSD department will have new or renovated facilities. In addition to updating and maintaining core facilities—like nuclear magnetic resonance, crystallography, mass spectrometry, a machine shop, an electronics shop, an engineering center, a new clean room in Searle Chemistry Laboratory, and even a graphic arts design studio and print shop—the PSD has also invested in new construction. The Gordon Center for Integrative Science (2006) is a powerhouse for interdisciplinary research, and the Eckhardt Research Center, opening this fall, will further bolster UChicago's cooperative spirit, hosting some physical science departments and institutes, with a focus on precision science and collaboration-minded space design.

In another sign of our growing footprint, the division has pledged a significant stake in the Giant Magellan Telescope (GMT), a supergiant earth-based telescope under construction in Chile. Astronomer Wendy Freedman (see page 5) perfectly describes why access to the most leading edge technology is essential to science: "Since Galileo turned a telescope to the sky in 1609, every time there's been a jump in capabilities or that next generation of telescopes, we've made discoveries, without exception."

We provide state-of-the-art instrumentation so that PSD scientists can fulfill their potential, and such facilities attract promising new and accomplished researchers who want access to the best technology. Together they continue the division's tradition of discovery.

With all best wishes,

Rocky Kolb

Edward W. "Rocky" Kolb, Dean

Matthew Stephens plots genetic variance data to compare statistical benefits of different algorithms. Photography by Michael Turchin. Photo illustration by Hannah Linton.

Statistics

Statistically speaking

Matthew Stephens discusses statistical variation and repetition.

In October Matthew Stephens, professor of human genetics and statistics, was named one of 14 investigators nationwide in the Gordon and Betty Moore Foundation's Data-Driven Discovery Initiative. Stephens, who applies computation and Bayesian statistics (which deals with conditional probability) to population genetics research, will use the $1.5 million five-year unrestricted grant to study genetic variation and strengthen statistical methodology by improving the way methods are compared.

Describe the field of population genetics.
Population genetics studies genetic variation in "unrelated" individuals as distinct from studying genetic variation in families or related individuals. The interesting thing about unrelated individuals is that they're actually all related, if you go far enough back. The part of population genetics that I'm interested in is how this distant relatedness affects the patterns of genetic variation we see in a population. Most genetic variants have arisen just once in the history of human evolution. If you share a genetic variant that I have, it's usually because we inherited it from a common ancestor.

What will your genetics research focus on for the Data-Driven Discovery Initiative?
We're trying to understand the molecular mechanisms underlying gene regulation, to identify the genetic variants that are affecting what's going on inside a cell. Ultimately we'd like to understand how genetic variants impact the whole organism, but if we can start by understanding how they affect the cell, that's a first step.

If a genetic variant is correlated with something, there's a good chance that it could be causing the change. If X and

Y are correlated, you don't know if X is causing Y, Y is causing X, or neither. But we know that most genetic variants are fixed at birth, and they don't change. We don't have to worry about reverse causality.

Why does research reproducibility matter?
The way people conduct their research can have a big impact on how effective it is. One of the buzzwords in science right now is reproducibility. I'm interested in computational reproducibility, which means simply being able to reproduce your analysis, starting with the data, the code that you ran, and the output of the results. In principle that's not as hard as one lab running an experiment and having another lab obtain the same result; you would think a computer is a controlled environment. But if you have any experience with computers, you'll realize it's not as controlled as you think. It requires incredible discipline for researchers to truly document everything they did in a reproducible way. It means automated workflow and never editing files by hand; a lot of people don't have the computer tools.

Reproducing someone's analysis is usually the first step to taking the next step, building on it, improving it, extending it—a way toward more efficient progress. I'm focusing on comparison of different statistical methods for different problems. Most people will write a paper but not publish the code they used. If they did publish that code and in a standardized framework, other researchers could add a method or a data set, and we could build up repositories of these comparisons.

Can you illustrate how a statistical method is tested and how comparing methods leads to a better outcome?
The usual way of testing a method is to use what's called a training set of data, where you see both the predictors and the outcome and use those to learn about the relationship between the two. Then you give the program predictors; you know the outcome, but it doesn't. It has to predict. An example of this system is movie recommendations. Netflix held a public competition to improve its recommendation algorithm. They used data from user-rated movies, and some of the ratings were presented and others were missing. For the purposes of the competition, Netflix held back ratings to assess whether the method made accurate predictions. There are different methods for doing that kind of thing, and people are developing new ones all the time.

Because the repositories will be open source, and some data—particularly genetic data—may be sensitive, how might you avoid problems with privacy?
There are at least two ways: you have to apply for access, or you have a third party run the programs on sensitive data sets. But there are all sorts of barriers to achieving that in practice. The best chance for a workable solution is for us to become more comfortable sharing genetic data. When I want to be controversial I tell people that in 10 years everyone will have their genomes on Facebook.

—Interviewed by Maureen Searcy

> "Most genetic variants have arisen just once in the history of human evolution."
>
> —MATTHEW STEPHENS

Geophysical Sciences

Climate change 101—and beyond

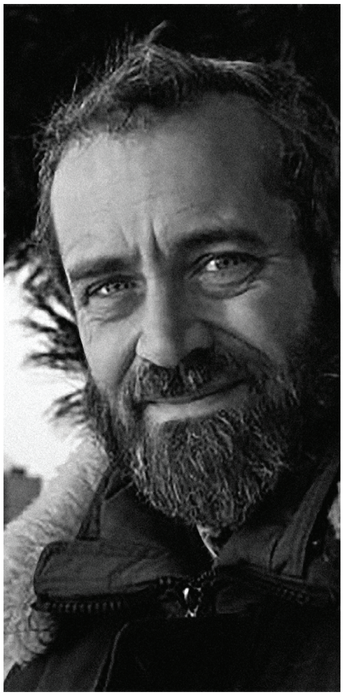
Geophysical Sciences' David Archer has a way with inconvenient truths.

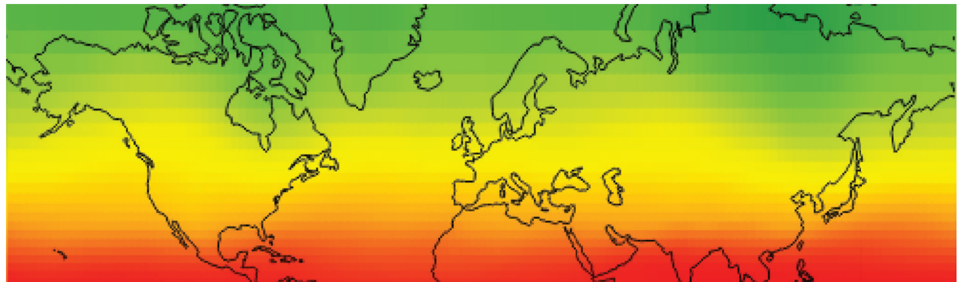
Undergraduates in David Archer's Core class, Climate Change: Understanding the Forecast (PHSC 134), don't have a choice: they have to do the math. The Boltzmann constant pops up early in the first lecture, on heat and light, and by the end of those first 50 minutes in Kent 107, Archer is flinging blackboards up and down to teach these students—resolutely *not* science majors—how to convert calories into joules and joules per second into watts.

For the more casual learners in his online course Global Warming: The Science of Climate Change, launched in fall 2014 and open to anyone with a fast enough internet connection and a curiosity about climate science, Archer is more lenient. He doesn't avoid math altogether but says, "I would hate to have you get turned off by not wanting to deal with math." The online version also skips over quantum mechanics; otherwise the two courses cover much of the same information (see "Accessing Archer," page 3).

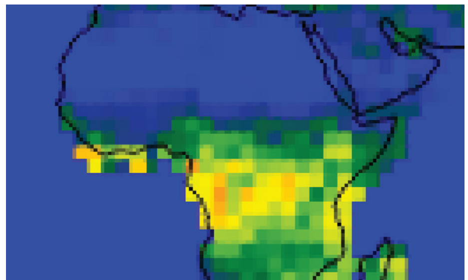
A professor of geophysical sciences, Archer says a course on climate change gives him an opportunity to cover more ground than he can in deep-dive graduate and undergraduate courses like Environmental Chemistry and Global Biogeochemical Cycles. "The question is informed by physics and chemistry and geology, atmospheric sciences, oceanography, energy systems, how social systems work, economics. You get to see a little bit of how all these different disciplines approach a problem, how they think, and how they work by focusing in on this fairly narrow topic."

The Core class and its online cousin are just two venues for Archer—whose





MIROC-ESM Atmospheric Temperature
Annual Mean, 2050 (detail)



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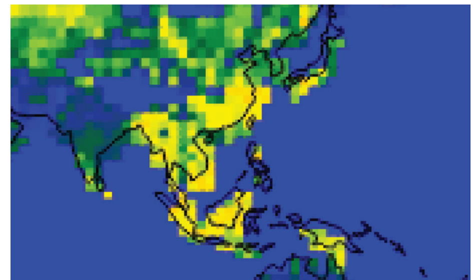
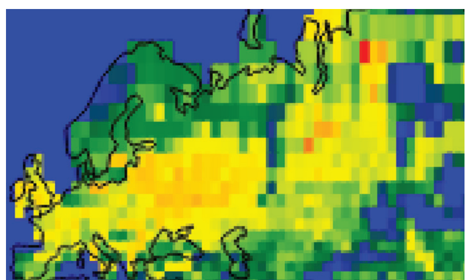
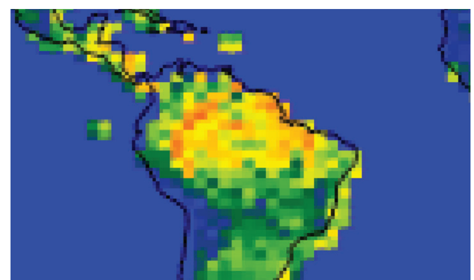
Annual Mean, 2050 (detail)



BNU-ESM Precipitation
Annual Mean, 2050 (detail)



NorESM1-M Snow
Annual Mean, 2050 (detail)



bcc-csm1-1 Leaf Index
Annual Mean, 2050 (detail)

ACCESSING ARCHER

David Archer (above) offers two versions of his climate change course online. Visitors can learn about different topics in bite-sized portions as recorded for Archer's massive open online course. Or they can watch an almost raw stream of PHSC 134, which includes students coughing, shuffling papers, and asking some terrific fundamental questions: "Are light and radiation the same thing?"

Archer also offers the public the same interactive climate change models (right) that PHSC 134 students use in labs. Visit climatemodels.uchicago.edu to try them out.

- Archer's climate change course: forecast.uchicago.edu/lectures.html.
- Archer's posts to realclimate.org: mag.uchicago.edu/archerposts.
- Archer's Convocation address: mag.uchicago.edu/archeraddress.

Photo courtesy Department of the Geophysical Sciences.

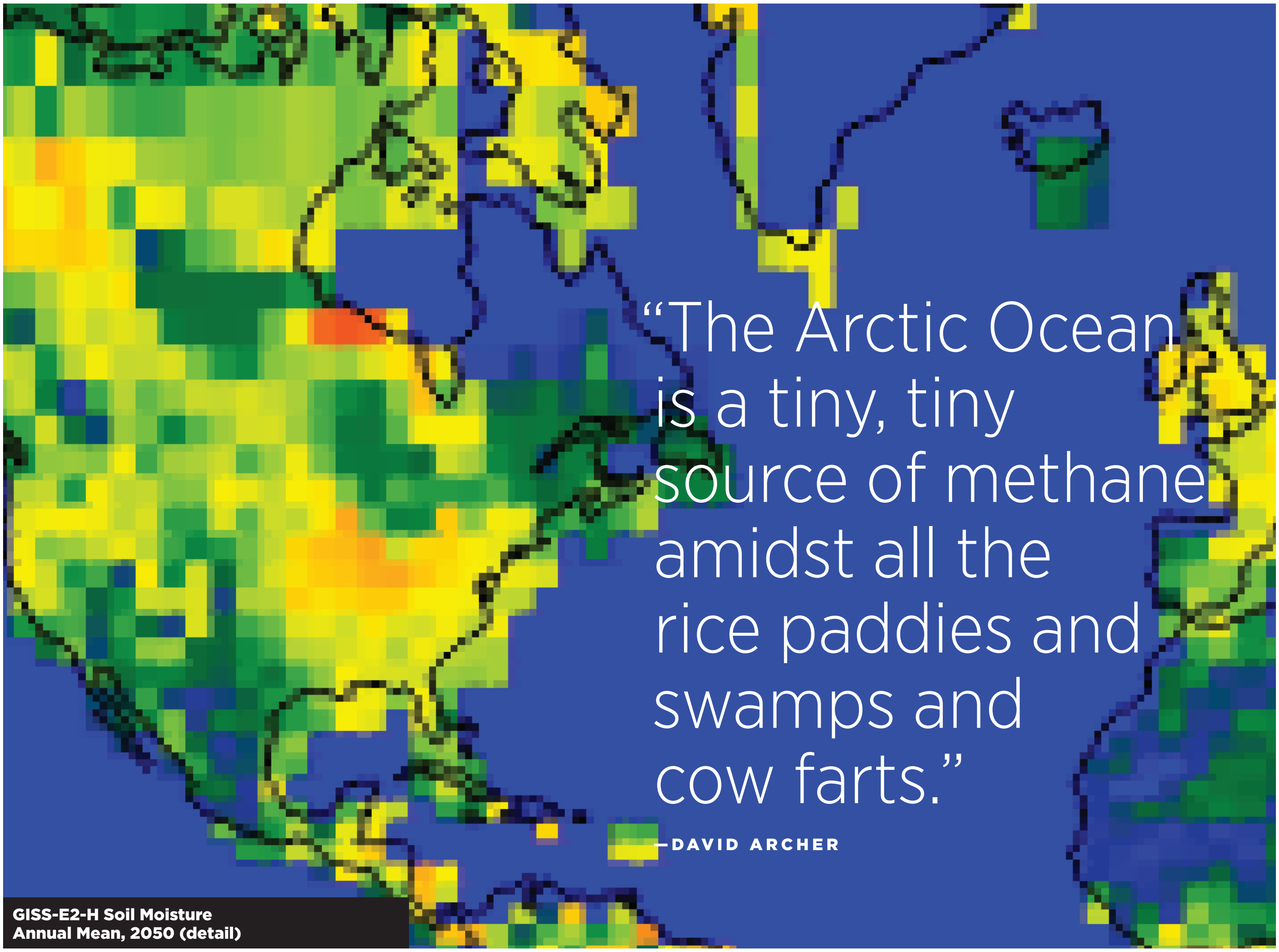
research focuses on how ocean sedimentary processes, such as calcium carbonate dissolution and methane hydrate formation, affect atmospheric carbon dioxide—to share his work with less specialized audiences. Over the years he's spoken at churches, atheist meetings, libraries, physics departments at other universities, retirement communities, and even Chicago's Metropolitan Water Reclamation District's Stickney wastewater treatment plant. "I've stopped flying places to give global warming talks," he says. "They wanted to fly me to Iceland to give a talk at some kind of ceremonial thing. If you want me to fly there, you don't really get what I'm trying to say."

And Archer does have something specific to say.

"There's a lot of concern in the scientific community about greenhouse gases that are very powerful but don't last very long in the atmosphere," he notes, giving methane as an example. Cutting methane emissions is cheaper than cutting CO_2, but the methane released today has no effect on the temperature in 2040, 2050, or 2060, whereas CO_2's longevity will affect the climate that far into the future.

"I'm what they call a CO_2 absolutist in the climate community," Archer says. "I say keep your eye on the ball, and that is carbon dioxide."

One of the most frequent questions he gets is about Arctic methane release—"What about those big explosion marks in Siberia?" His response: "The Arctic Ocean is a tiny, tiny source of methane amidst



GISS-E2-H Soil Moisture
Annual Mean, 2050 (detail)

> "The Arctic Ocean is a tiny, tiny source of methane amidst all the rice paddies and swamps and cow farts."
> —DAVID ARCHER

all the rice paddies and swamps and cow farts." If people start to believe that the natural world is doomed, "they kind of lose all interest in thinking about fighting CO_2 emissions."

Archer does envision a clear way forward. It's not one big change. "There's no single thing we can do today that will fix CO_2 emissions," he says, "because we create CO_2 emissions in so many different ways." Rather, like someone trying to lose weight, it's several smaller changes that add up to a big difference. Those changes are known as wedges. Investing in nuclear power is a wedge. Windmills. "Cars that get 60 miles a gallon instead of 30 could be a wedge," Archer says, "even if there were a lot more cars in the future."

When Archer explains why it's so important to him to share this message in as many ways as he does, he sounds like a colleague teaching a humanities Core course across the quad in Cobb Hall.

"What if the ancient Greeks had figured out fossil fuels? What if they knew what they were doing but did it anyway?" Archer asks. "You know, left the lights on for a century, just sort of frittered it away. And what if we knew today that the world we lived in was degraded because of that? What right would they have to do that? And what would we think of them?"

Socratic dialogue aside, Archer knows he's not about to be charged with corrupting UChicago's youth. When he's spoken to parents of College students at Family Weekend, he says, "They're all, 'Yes, teach them this.'"

Last fall Archer took his message to the University's 521st Convocation, where he addressed "graduating carbon atoms" from across the University. Even with the title "The Great Carbon Conspiracy," his tone was lighthearted and appropriately inspiring, closing with "a special salute to the sentient carbon atoms—you know who you are. I just want to say watch out for the fossil fuel thing, that's kind of serious. But I know you're good for it, so that's cool." Here, too, he skipped the math.

—Sean Carr, AB'90

Learn more about Geophysical Sciences initiatives: contact Brian Yocum at **773.702.3751** or **byocum@uchicago.edu**.

Photography by John Zich.

Astronomy & Astrophysics

Star witness

Wendy Freedman calculated when the universe began. Now she wants to see it happen.

"We'll actually be able to see [galaxies forming] directly rather than just surmise."

—WENDY FREEDMAN

Wendy Freedman grew up in Northern Ontario and has early memories of dark skies filled with stars. "It never occurred to me when I was young, though, that I would end up a professional astronomer," says Freedman. "That happened in university." Now an acclaimed observational cosmologist, her career was built on peering into the dark skies with ever-advancing technology.

Freedman joined the Department of Astronomy and Astrophysics as a University Professor this past September, following 30 years at the Carnegie Observatories in Pasadena, California—starting as a postdoctoral fellow in 1984, becoming the first woman on the observatories' permanent scientific staff in 1987, and becoming the Crawford H. Greenewalt Director in 2003.

She also has chaired the board of directors of the Giant Magellan Telescope (GMT) Organization since its 2003 inception. The GMT, expected to reach completion in 2021 at the Las Campanas Observatory in Chile, "is on schedule to be the first of the next generation of big telescopes on the air." One of the most powerful telescopes ever built (see "When Stars Align," page 8), the GMT will have seven mirrors, forming a segmented but incredibly accurate surface 80 feet across.

Astronomers will use the GMT to collect light from the earliest objects in the universe. "There's a spectrograph on this telescope that will allow us to take hundreds or maybe in some cases thousands of spectra, where you disperse the light of the faintest and the most distant galaxies," says Freedman. Looking farther out also means looking further back in time, and astronomers will get to *watch* galaxies forming. "We'll actually be able to see that directly rather than just surmise."

Freedman's own research relies on the ability to look as far out and back as possible. She co-led the Hubble Space Telescope Key Project, using the telescope launched in 1990 to measure distances to other galaxies for the first time. "We set out to measure the current expansion rate of the universe—the Hubble constant," says Freedman, "one of the most important parameters in cosmology that sets the age and size scale of the entire observable universe."

The project began in the mid-'80s and concluded in 2001, when the team determined the universe to be 13.7 billion years old, with a 10 percent uncertainty. Now she's leading the Chicago Carnegie Hubble Project, using the Spitzer Space Telescope, the Hubble Space Telescope, and the Chile-based

Magellan telescopes to reduce that uncertainty to just a few percentage points.

To determine expansion rate, explains Freedman, “you need both a distance and a velocity.” Edwin Hubble, SB 1910, PhD 1917, discovered in 1929 that there was a relationship between the two. “It’s the slope of that correlation that we measure,” Freedman says.

Velocity can be determined mathematically by measuring cosmological redshift—when an astronomical object’s spectrum, like the light from a star, shifts into longer, redder wavelengths as it moves farther away, carried by expanding space. It’s similar to the Doppler effect, when an object’s motion changes its observed wavelength.

Distance can be measured by several methods, and with increasing accuracy as telescopes become more powerful and incorporate new detectors. The anchor of the distance scale, stellar parallax, uses an observational effect and simple high school geometry to measure distances to stars within our galaxy (see right). But Freedman’s work requires the ability to measure much greater distances.

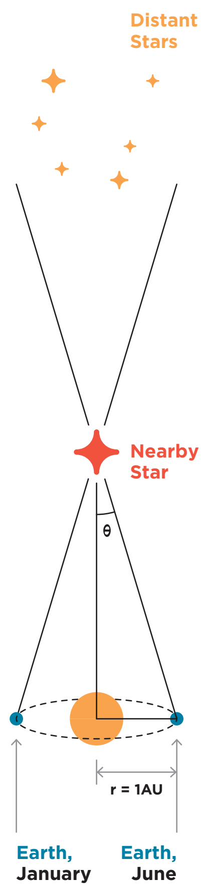
When observing stars far outside the Milky Way, astronomers must consider the difference between brightness (how much light we detect on Earth) and luminosity (how much light an object emits from its surface). Are they seeing a nearby dim star or a far-off bright one?

The Hubble Key Project measured Cepheids, stars with pulsating atmospheres that follow a period-luminosity relation, varying in brightness at regular intervals directly related to how much light they emit. More luminous Cepheids have longer intervals, or periods. Astronomers compare the luminosities of Cepheids to their periods to determine distance using another principle—the inverse square law for light.

When Cepheids become too faint because they’re too far away, “we use supernovae,” says Freedman—“really bright explosions of stars at the end of their lifetime.” Type Ia supernovae are exploding white dwarf stars, which all reach about the same luminosity at the peak of their explosion and follow a dimming curve. Similar to Cepheids, distance is measured by comparing luminosity to how fast the supernovae dim with time.

Freedman’s current projects measure both Cepheids and supernovae. The Chicago Carnegie Hubble Project makes new observations of Cepheids

Astronomers can observe nearby stars from Earth, then again six months later from the other side of the sun, and measure the angle of apparent displacement (θ). Using the radius of Earth’s orbit as one side of a triangle, they can measure distance.



to continue refining the universe’s current expansion rate, she says, “but we will tie into the nearby sample of supernovae, which we’re observing with the Carnegie Supernova Project.”

The supernova project, which Freedman cofounded in 2004, uses the du Pont, Swope, and Magellan telescopes at Las Campanas Observatory in Chile to measure objects farther out in the universe, and therefore calculate historical expansion rates. By comparing past rates to the current local expansion rate, Freedman can study the universe’s acceleration—which in turn contributes to the study of dark energy, the hypothetical explanation for cosmic acceleration.

When astronomers discovered in the late 1990s that the universe was accelerating, most cosmologists had expected the opposite—that the universe was decelerating. Although evidence for acceleration was compelling, “there was still a question of whether something in the universe was making the supernovae appear dimmer,” says Freedman, such as dust particles in the regions between stars, which can absorb radiation and cause errors in expansion calculations.

The success and credibility of future experiments on acceleration and dark energy rely on the most accurate distance measurements possible. The Carnegie Supernova Project uses infrared spectroscopy to obtain such accuracy—dust doesn’t affect infrared light as much as visible radiation, Freedman says. Her team uses spectroscopy to study supernovae chemical composition as well, which also could affect the visible part of the spectrum.

Although Freedman’s research focuses mostly on the expansion and acceleration of the universe, she is also interested in the possibility of discovering new physics. “Since Galileo turned a telescope to the sky in 1609, every time there’s been a jump in capabilities or that next generation of telescopes, we’ve made discoveries, without exception,” says Freedman. “One of the most interesting and exciting things is what we just don’t know.” The GMT is poised to answer questions astronomers never thought to ask.

—Maureen Searcy

Twenty tons of Ohara E6 borosilicate glass get loaded into the GMT mold at Steward Observatory Mirror Laboratory, University of Arizona. Photography by Ray Bertram.

WHEN STARS ALIGN: GMT BY THE NUMBERS

1	supergiant earth-based telescope
2,516 m	altitude, Las Campanas Observatory, Chile
7	mirrors total when complete, each 8.4 meters across
4	mirrors needed to start collecting data
4 yrs	time to cast one mirror
15,875.7 kg	weight of one mirror
10x	resolution of Hubble Space Telescope
4x	resolution of Magellan telescopes
321.9 km	distance from which you could see a dime's details

2021	2025	10
year predicted for first data	year for all mirrors and instruments to be in place	international partners in GMT consortium

Physics

Superconductor

Physicist, engineer, and violinist Mildred Dresselhaus, PhD’59, forged lasting bonds at UChicago.

UChicago president Robert J. Zimmer presented Dresselhaus with the Alumni Association's highest honor, the Alumni Medal, in June 2008. Photography by Dan Dry.

> "When I joined the MIT faculty in 1967, only 4 percent of undergraduates were women. That's in all subjects, not just physics."
>
> —MILDRED DRESSELHAUS

Mildred Dresselhaus, PhD'59, has some advice for young scholars: "It's a good choice to be in a field that's unpopular and interesting."

In 1960, when she was working at MIT's Lincoln Laboratory, most of her colleagues were working on semiconductors, which Dresselhaus found interesting, but not interesting enough. Her husband, Gene, who also worked at the lab, suggested she look at carbon, specifically graphite.

"Here was a material that had properties like a semiconductor, but it wasn't a semiconductor at all," says Mildred Dresselhaus, professor emerita of physics and electrical engineering at MIT. "It had a very different electronic structure. The little bit I learned made me wonder why no one was interested in it."

Indeed, Dresselhaus's colleagues warned her away from carbon and encouraged her to study something more exciting, like magnetic fields. She ignored their advice to work on popular topics, and through 50 years of research into unpopular, interesting carbon has fundamentally altered the way we understand it.

By studying the optical, conductive, and vibrational properties of carbon at the atomic level, Dresselhaus helped establish new uses for carbon forms in batteries and electronics. Today, graphene—a sheet of pure carbon one atom thick—has multiple potential industrial uses because of its strength and light weight, but it began as a far-fetched idea. "Graphene was something you thought about, but never thought was possible," she says. The theoretical work done by Dresselhaus and others in the 1960s led to its actualization.

Half a century later, carbon still interests her. Dresselhaus's current research focuses on the transport and optical properties of carbon nanowires and nanotubes.

Between then and now, she has won a Kavli Prize in Nanoscience, the Enrico Fermi Award, and in November a Presidential Medal of Freedom, the highest civilian honor in the United States. She's also become known as "the queen of carbon."

Violin lessons and Nobel laureates

The child of immigrants from Eastern Europe, Dresselhaus grew up poor in the Bronx. When she was four, her talent for the violin gained her entry to a music program at a settlement house, where she learned quickly that "the people who had a lot of education were doing a lot better than the people who had less education."

She went to Hunter College intending to do what most bright young women did then: become a schoolteacher. But at the end of her first year, she met Rosalyn Yalow, who at the time was teaching there because she couldn't get a research job.

Yalow was “a very opinionated person and had a strong personality,” Dresselhaus says. “She was an inspiring teacher to me. It was kind of funny that she encouraged me to go after science professionally, and she couldn’t get a job.” Yalow eventually did find research work in medical physics and went on to win a Nobel Prize in Physiology or Medicine for her work developing the radioimmunoassay for measuring insulin.

Although Dresselhaus did not study carbon at the University of Chicago—her dissertation focused on superconductivity—she credits the University, and especially Enrico Fermi, with her ability to shift easily into a different physics subfield after graduating, and to keep moving from one field to another.

“What I learned from him is that you should be master of your subject, with both deep and broad knowledge, and have a capability for working in the field,” she says. MIT boasts a large number of UChicago physics alumni, and Dresselhaus, who fondly remembers regular home-cooked Italian dinners at Fermi’s house, says they get together periodically to talk about the old days.

The physics faculty at the time “were almost like a team,” she says. “It wasn’t only in science during the day, but they were socially close.”

Strength in numbers

In the early 1960s, following the three births of her sons Carl, Paul, and Eliot, Dresselhaus took five days off from her work at MIT’s Lincoln Laboratory. Total. (Her daughter, Marianne, was born in 1959, when she was a postdoc.)

Dresselhaus doesn’t think of her actions then as particularly unusual: just what she had to do as one of two women in a laboratory with 1,000 men. “In those days, it wasn’t so easy for women to be taken seriously,” she says. “If you weren’t dedicated to your job, they’d think you didn’t want to be there.”

By shouldering his share of household responsibilities on top of his own research, Gene Dresselhaus helped Mildred balance a top-flight research career with a family, as did the services of a longtime babysitter. Another factor in those early days was the moral support she gained from her friendship with Laura Roth, the other woman at Lincoln Labs, with whom she stayed in touch for years. Dresselhaus received a Carnegie Foundation grant in 1973 to encourage women to study in traditionally male-dominated fields and to this day makes efforts to support women in science.

The first woman to earn a doctorate under Dresselhaus at MIT was Deborah Chung, who completed her PhD in 1977. The two shared a love of music, but, Chung says, “I chose her as my thesis supervisor not because she is a woman and not because she is a musician, but because I took her solid state physics course and loved it. She is a great teacher.” Chung, a professor of mechanical and aerospace engineering at SUNY Buffalo who won the Pettinos Award from the American Carbon Society, says it wasn’t

A(NOTHER) VISIT TO THE WHITE HOUSE

The award ceremony for the Presidential Medal of Freedom in November was not Mildred Dresselhaus’s first trip to the White House—not even under the current administration. President Barack Obama hosted her once when she and Burton Richter won the 2012 Enrico Fermi Award, and again in 2013 when she won the 2012 Kavli Prize in Nanoscience. Dresselhaus also received the National Medal of Science from President George Bush in 1990.

Still, the honor was far from routine for Dresselhaus. “All these things are a big surprise,” she says.

With the five tickets the White House gave her, Dresselhaus brought two of her children and three granddaughters to the medal ceremony and, she says, “had a ball.”

The honorees—“all very interesting people,” Dresselhaus says—mingled with each other a bit, though they also had their own guests to talk to. The avid violinist did not, however, get a chance to talk music with fellow medalist Stevie Wonder.

> “What I learned from [Enrico Fermi] is that you should be master of your subject, with both deep and broad knowledge, and have a capability for working in the field.”
>
> —MILDRED DRESSELHAUS

Dresselhaus’s words but her actions that instilled in Chung career motivation and dedication to research.

While women in science have not achieved parity with men, Dresselhaus has been pleased by the strides they have made. “When I joined the MIT faculty in 1967, only 4 percent of undergraduates were women,” she says. “That’s in all subjects, not just physics.” MIT’s undergraduate student body is now about 46 percent women. “I thought it would take more than my lifetime to be anywhere close to 50 percent.”

“I keep quite busy”

Dresselhaus still plays the violin but no longer teaches physics. She continues to go to her lab at MIT—where she leads an active research group of graduate students, postdocs, and international scholars—every day, though she missed a few days during Boston’s snowstorms this winter. “Coming to the lab is the place where I meet all the young people again,” she says. “Believe it or not, people appreciate me. I keep quite busy.”

She also stays current with the younger generation through her granddaughter, Leora Cooper, a graduate student in physical chemistry at MIT whom she meets for lunch every Wednesday. Cooper’s work focuses on shock waves and has nothing to do with carbon. Still, Dresselhaus says, “We can understand each other’s research very well.”

—Jeanie Chung

Divisional News

FACULTY AWARD AND HONOR HIGHLIGHTS

Jacob Bean (Astronomy & Astrophysics)	Received a Packard Fellowship in Science and Engineering
Stephen Berry (Chemistry)	Received a Camille and Henry Dreyfus Foundation 2014 Senior Scientist Mentor Award
Andrew Chien (Computer Science)	Named a William Eckhardt Distinguished Service Professor
Cheng Chin (Physics)	Elected an American Physical Society Fellow
Jian Ding (Statistics)	Received a 2015 Sloan Research Fellowship
Margaret Gardel (Physics)	Elected an American Physical Society Fellow
Craig Hogan (Astronomy & Astrophysics)	Received a 2015 Breakthrough Prize in Fundamental Physics
Wayne Hu (Astronomy & Astrophysics)	Named the Horace B. Horton Professor
Susan Kidwell (Geophysical Sciences)	Received the Mary Clark Thompson Medal
Takeshi Oka (Chemistry)	Received a Camille and Henry Dreyfus Foundation 2014 Senior Scientist Mentor Award
Stuart Rice (Chemistry)	Received a Camille and Henry Dreyfus Foundation 2014 Senior Scientist Mentor Award
Norbert Scherer, SB’82 (Chemistry)	Elected an Optical Society of America Fellow
Tiffany Shaw (Geophysical Sciences)	Received a 2015 Sloan Research Fellowship
Michael Stein (Statistics)	Received a Distinguished Achievement Award from the American Statistical Association Section on Statistics and the Environment
Matthew Stephens (Statistics)	Received a Moore Investigator in Data-Driven Discovery Award
Bozhi Tian (Chemistry)	Received an AFOSR Young Investigator Award

Methods

Rosetta's stone

Thomas Stephan catches up with a comet.

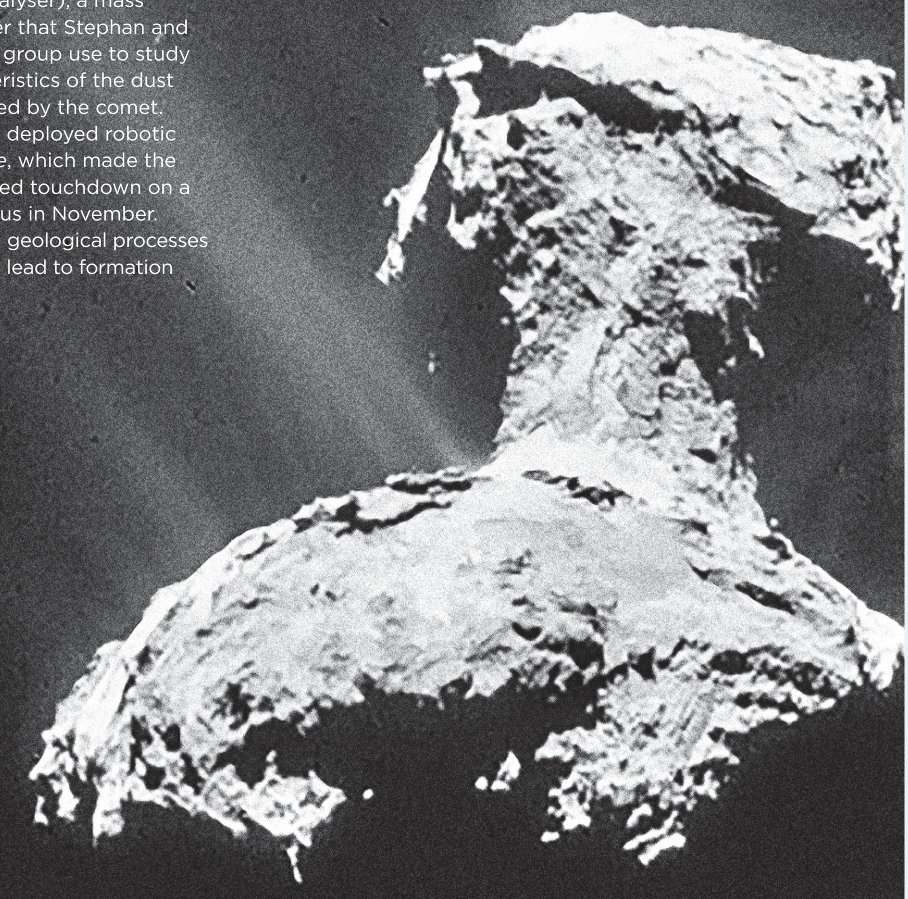
In August 2014, the European Space Agency's spacecraft *Rosetta* arrived at comet 67P/Churyumov–Gerasimenko, settling into orbit around the dusty ball of ice. Thomas Stephan, a senior scientist in the Geophysical Sciences Department, is part of the team collecting data and investigating how the comet changes on its journey around the solar system, particularly when it gets close to the sun.

Rosetta has several instruments on board, including COSIMA (Cometary Secondary Ion Mass Analyser), a mass spectrometer that Stephan and his research group use to study the characteristics of the dust grains emitted by the comet. *Rosetta* also deployed robotic lander *Philae*, which made the first controlled touchdown on a comet nucleus in November.

"On Earth, geological processes permanently lead to formation and destruction of terrestrial rocks," Stephan says. "But comets, which formed 4.6 billion years ago when our solar system formed, spend most of their lifetime in the outer parts of the solar system, far away from the sun, and remain largely unchanged. To learn about the formation and early history of the solar system, comets or asteroids—where most meteorites come from—are the ideal samples."

Rosetta's mission will draw to a close in December 2015, after escorting the comet for more than a year.

—Maureen Searcy



This single frame *Rosetta* navigation camera image—processed to bring out the details of the comet's activity—was taken from a distance of 124 km from the center of Comet 67P/Churyumov-Gerasimenko on February 6, 2015. Photo courtesy European Space Agency (ESA).

A steel scrap from a Manhattan Project pumpkin bomb.

Materials

Smashing pumpkins

Henry Frisch shares a piece of atomic history.

Seventy years ago, at 5:30 a.m. on July 16, 1945, Los Alamos scientists conducted the Trinity test, detonating a plutonium bomb nicknamed the Gadget in the New Mexico desert—the first of only three atomic bombs ever detonated. The other two were Fat Man (Trinity's twin) and the uranium-based Little Boy, both used in Japan.

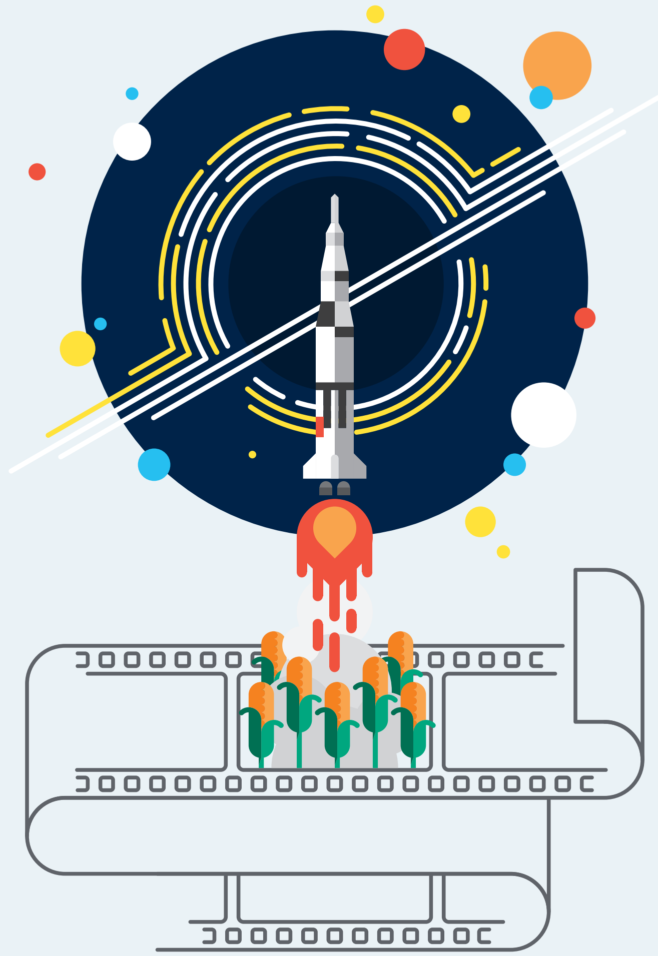
Born in Los Alamos while his father and mother, physicist David H. Frisch and geneticist Rose E. Frisch, worked on the Manhattan Project, physics professor Henry Frisch has a memento of that history—a hunk of steel shell from a pumpkin bomb, given to him by John Coster-Mullen, author of *Atom Bombs: The Top Secret Inside Story of Little Boy and Fat Man*.

Pumpkin bombs were Gadget and Fat Man–style devices—sometimes inert, sometimes explosive—used to test the structure's stability and the logistics of avoiding a crash during takeoff, dropping the bomb, and escaping the blast. Pumpkins contained no plutonium, says Frisch, so there was no danger of "dropping nuclear weapons on American soil" during practice.

Frisch keeps the pumpkin shell in his High Energy Physics building office, but he and others hope that it and other Manhattan Project artifacts will eventually be housed in a permanent display on campus, stewarded by the Enrico Fermi Institute.

—Maureen Searcy

Illustration by Tom Tian, AB’10.



Discussion

Silver 47 Ag 107.87 Screen

PSD faculty members discuss Hollywood’s portrayal of science and scientists.

Science and scientist-based films had a big year in 2014. Three high-profile movies earned Academy Awards—two biopics and a modern space odyssey. *Inquiry* asks a computer scientist, a physicist, and a planetary scientist to weigh in on the films’ scientific and historical accuracy.

The Imitation Game *chronicles Alan Turing’s work with a team of code breakers during World War II trying to crack Germany’s Enigma machine. Best Writing, Adapted Screenplay (Graham Moore, LAB’99).*

The Imitation Game shines a much-deserved light on Turing, a fascinating historical figure who was relatively unknown outside of the computer science community. It is thrilling, well paced, and phenomenally well acted. It is also, unfortunately, a subpar biography. By their own admission, the filmmakers took considerable dramatic license. Turing is portrayed as borderline autistic, perpetuating the stereotype of the oddball scientist, and his code-breaking efforts at Bletchley Park are elevated to heroic proportions. But his contributions to computer science, as well as his persecution for homosexuality, humiliating chemical castration, and tragic demise of an apparent suicide in 1954, are touched upon only superficially.

In reality, Turing was considered affable and well adjusted, albeit a bit shy. Although he made crucial contributions to the code-breaking effort, he was not a lone wolf who antagonized all his peers; he was a team player embedded in a deeply collaborative effort. If you want to get the whole picture, pick up a copy of Andrew Hodges’s *Alan Turing: The Enigma*, on which the movie is based.

—Borja Sotomayor, SM’07, PhD’10, Lecturer and Associate Director for Technology, Computer Science

> “How often are we like the farmers in the movie, celebrating small victories while ignoring the larger game?”
>
> —EDWIN KITE

The Theory of Everything *chronicles Stephen Hawking’s life and his relationship with his first wife, Jane, based on her memoir. Best Performance by an Actor in a Leading Role (Eddie Redmayne).*

The Theory of Everything follows Hawking from his Cambridge graduate student days in the mid-1960s through approximately the late 1980s. There is very little science in the movie apart from passing references to what Hawking is working on and depictions of his PhD oral defense, a lecture by Roger Penrose, and Hawking’s seminar presenting his most famous work on particle creation by black holes.

These depictions display the usual Hollywood conception of scientists more interested in passing judgment (negative or positive) than inquiring about the work or its ramifications. Indeed, Hawking’s PhD oral is the first I have seen where no question was asked of the candidate. However, what is said in these depictions is not scientific nonsense, and the descriptions of Hawking’s work are not unlike what one might expect Hawking to say to a non-scientist. Some scientific details in the movie are very well done; for example, in Hawking’s seminar one can see on the blackboard a correctly drawn space-time diagram of a black hole that forms from collapse and then evaporates.

The portrayals of the scientists other than Hawking bear no resemblance to their real-life counterparts, but the portrayal of Hawking himself is truly remarkable. Eddie Redmayne looks like Hawking, acts like Hawking, and says the kinds of things Hawking would say. At many points in the movie, I felt I was taken back in time to see Hawking as I had known him in the 1970s and 1980s.

—Robert M. Wald, Charles H. Swift Distinguished Service Professor, Physics

Interstellar *sends a team of astronauts from a dying earth through a wormhole searching for viable new homes for humanity. Best Achievement in Visual Effects.*

This movie asked many subversive questions. How often are we like the farmers in the movie, celebrating small victories while ignoring the larger game? In what ways does our culture—on the surface, very open to better technology—shut down or sideline paths of inquiry that could change the future? Is the Earth the only planet in our long-term future? Is it more human to grow to accept the limits of living on a single planet, or to push past them? We now know there are about 100,000,000,000 habitable-zone Earth-radius planets in the galaxy—wouldn’t it be a shame if the other 99,999,999,999 are always uninhabited?

—Edwin Kite, Assistant Professor, Geophysical Sciences