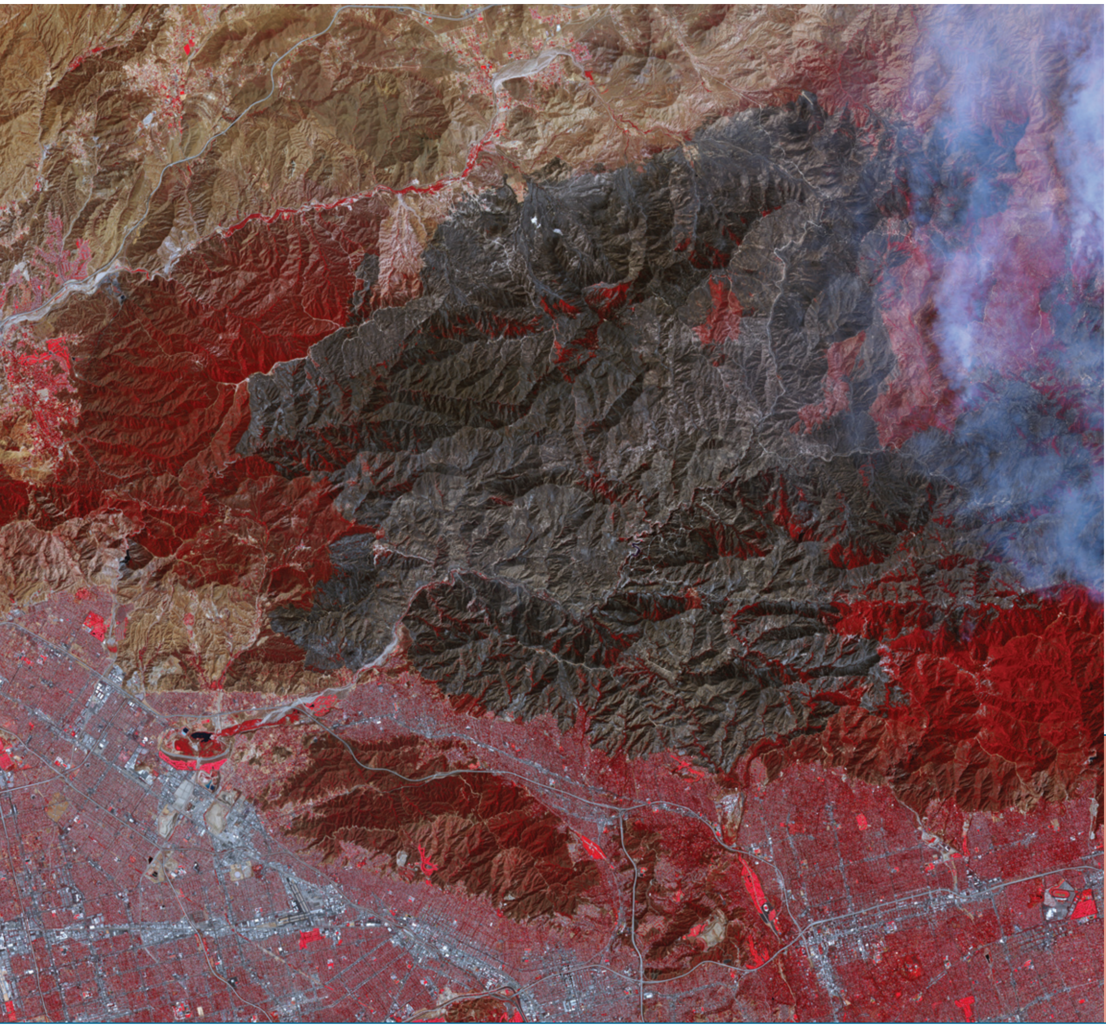
JPL UNDER FIRE

Fueled by triple-digit temperatures and single-digit humidity, the Station Fire has engulfed more than 160,000 acres of the Angeles National Forest in the San Gabriel Mountains north of Pasadena since being ignited by arson on the afternoon of August 26. The fire, which continued to smolder in some inaccessible canyons well into October, is the largest in the recorded history of Los Angeles County, and the 10th biggest wildfire in California since 1933. The fire killed two firefighters, injured 22 people, destroyed more than 200 buildings and homes, and cost about $90 million. Ash from the blaze fell as far away as Las Vegas, and the Los Angeles area was blanketed in a suffocating haze for weeks.

In addition to the hundreds of homes evacuated from Tujunga to Altadena, Caltech's Jet Propulsion Laboratory was closed during the last weekend of August when the inferno came within 0.2 kilometers of the Lab's northern edge. Only skeleton crews essential to keeping the Lab going and our far-flung fleet of spacecraft flying were allowed to report for work.

The flames also advanced up the slopes of Mount Wilson, overlooking Pasadena and home to crucial communication towers—including nearly all the local TV and many radio stations—that serve the Los Angeles region. Sharing the summit is the Mount Wilson Observatory, founded in 1904 by Caltech's George Ellery Hale. As the tool with which Edwin Hubble discovered the expanding universe, the 100-inch Hooker Telescope is arguably one of the most important scientific instruments in history. Over 100 firefighters from across California successfully defended the observatory and the antennas, dropping fire retardant from helicopters and setting backfires on the observatory grounds.

While the fire was burning within sight of JPL, JPL instruments on board NASA's Terra and Aqua



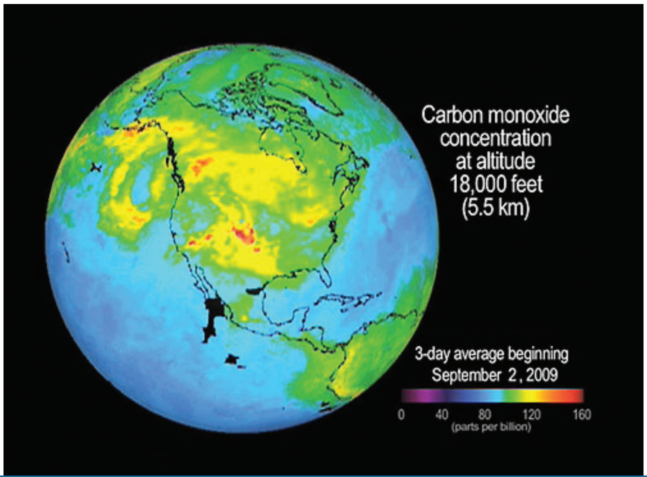
NASA/GSFC/METI/ERSDAC/JAROS, and the U.S./Japan ASTER Science Team

Left: The extent of the burned area (dark gray) as of September 6. This image was taken by Terra's Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), built by Japan's Ministry of Economy, Trade and Industry and run jointly with JPL.

Brent Buffington of the Cassini navigation team snapped this shot from the Devil's Gate Dam around 2:00 a.m. on August 29, as the fire was near its closest approach to JPL.

satellites were watching the fire from space. These satellites' polar orbits bring them back over the same piece of real estate every few days, allowing scientists to track all manner of global changes on a local or regional level. —*MW* e&s

NASA/JPL



NASA/GSFC/LaRC/JPL, MISR Team

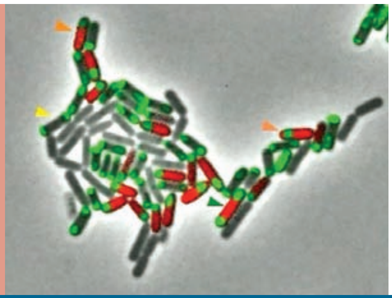
Above: The fire's carbon monoxide plume, seen by the Atmospheric Infrared Sounder (AIRS) on the Aqua satellite, eventually extended across the U.S. Right: Terra's Multi-angle Imaging SpectroRadiometer (MISR) captured this perspective view of white, puffy pyrocumulus clouds rising above the smoke plumes drifting across the Mojave Desert. This shot was taken at an off-vertical angle of 46 degrees and spans a width of almost 250 kilometers.

THE TROUBLE WITH GRADUALISM

What determines how many wings keep an insect aloft? Some have one pair, others two, but how is the correct number decided—was there once some poor intermediate bug blessed with 1.5? Now a team of researchers at Caltech and the Temple University School of Medicine has shown how evolution can be accomplished by "jumping" between forms, rather than going through a series of transitional states. "The intermediate states that occur along the way are not intermediate *forms*, but rather changes in the fraction of individuals that develop one way or the other," explains Michael Elowitz, the Caltech associate professor of biology and applied physics, Bren Scholar, and Howard Hughes Medical Institute investigator who led the research.

The key to this work lies in the fact that a single mutation can suddenly give a simple organism a lot of options, whereas an unmutated specimen always proceeds according to the same tightly scripted plan. "They don't only show a different morphology," says Avigdor Eldar, a postdoctoral scholar at Caltech and the first author of the group's recent *Nature* paper. "They show more variability in their behavior." The degree to which any particular outcome prevails among a population is called its penetrance. "Our work shows how

In this frame from a sporulation movie, the green arrow points to a bacterium (fluorescing red) that has successfully produced two spores (fluorescing green). The orange arrows show bacteria that have produced one spore each, and the yellow arrow points to a bacterium that tried to produce two spores without making a third copy of its DNA for itself.



partial penetrance can play a role in evolution by allowing a species to gradually evolve from producing 100 percent of one form to developing 100 percent of another, qualitatively different, form," says Elowitz.

Other mutations and nongenetic "noise"—fluctuations in the amounts of certain proteins that act as middlemen in various cellular processes—can influence the penetrance of a particular end state. In fact, this evolutionary pathway depends on noise to work at all. But only recently have scientists been able to analyze this variability, with the aid of such technological advances as time-lapse movies and fluorescent protein markers. In the past, researchers could only observe the average traits of a population of cells by growing colonies of bacteria, killing them at different time intervals, and studying the aftermath. That approach misses both the population dynamics and the fates of individual cells. A study like this one would simply not be possible—the entire phenomenon would be averaged over and lost.

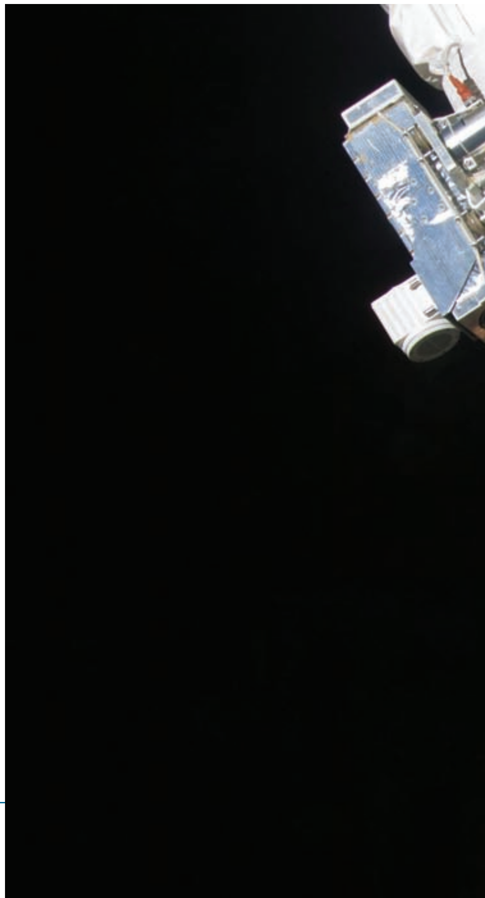
But these experiments put the individual front and center. The group studied the process by which a bacterium called *Bacillus subtilis* produces spores to preserve its genetic material during hard times. In the wild, *B. subtilis* bacteria create just one spore, but in the laboratory, other outcomes are possible. The researchers looked at a strain with a specific mutation that suppresses the signals passing between mother and spore, confusing the mother as to whether or not she has successfully sporulated. "Usually," explains Eldar, "these cells talk with each other, with the spore telling the mother, 'I'm here, and I'm doing OK.' In the wild-type cell, this chatter is loud; in the mutant, it's just a whisper, and the mother can't always hear."

When the mutants fall mute, any of four things could happen. First, the cell might proceed normally, copying its DNA once and producing one spore. The three alternatives involve variations in the number of spores produced and the number of DNA copies made. The cell might try to create two spores while making only one copy of its DNA, in which case one daughter gets the mother's chromosome and the other gets the copy, causing the mother to die before sporulation is complete. Or the mom might overdo it on the DNA copies but only make one spore, resulting in a harmless "extra" copy for herself. And finally, the cell could do both things right, making two copies and two healthy spores—other bacteria are known to do this, and it could offer *B. subtilis* an evolutionary advantage.

The team started by breeding bacteria with the whispering mutation. While all four possible fates were observed, the two-spore outcome was pretty rare. The researchers then added further mutations designed to encourage DNA replication, a move intended to boost the proportions of two of the fates—the twin spores, and the mother with extra DNA—at the expense of the others. As a result, the percentage of bacteria that produced two spores increased dramatically, from 1 to as high as 40 percent. "You can't switch from 1 to 1.1 spores," Eldar explains. "But it's easy to find a mutation that simply changes the frequency of the behavior. If 10 percent of the population makes 2 spores and the rest makes 1, that works. It solves the need for a quantum jump between 1 and 2 spores."

The paper was published online by *Nature* on July 5. The other authors are Caltech staffer Michelle Fontes and grad student Oliver Losón; Vasant Chary, Panagiotis Xenopoulos, and Patrick Piggot from the Temple University School of Medicine; and Jonathan Dworkin from the College of Physicians and Surgeons at Columbia University.

The Howard Hughes Medical Institute, the National Institutes of Health, the National Science Foundation, the International Human Frontier Science Organization, and the European Molecular Biology Organization supported the work. —*MR* e&s



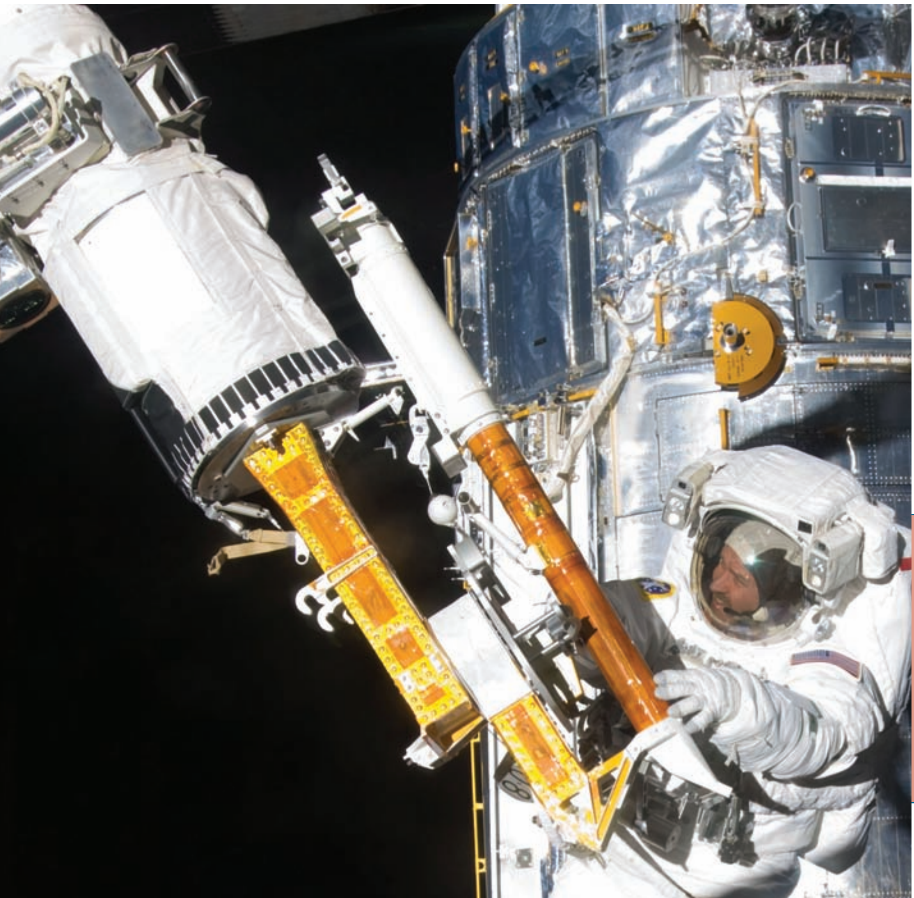
STAYING FIRM UNDER PRESSURE

Back in the day, before the meter was defined in terms of the speed of light, it was set as 1/10,000,000 of the distance between the equator and either pole along the meridian that passes through Paris. Rather than sending out surveyors whenever someone needed to know the exact length of a meter, the French Academy of Sciences created a meter-long metal bar known as the prototype. Made out of an unusually thermally stable but very expensive platinum-iridium alloy, the prototype was kept in a vault at the International Bureau of Weights and Measures in Sèvres, France, near Paris. Replicas of the prototype would be made and distributed as needed. The replicas were created using the same alloy, making them unaffordable to most people. Using cheaper materials was undesirable due to thermal expansion—until 1896, when Swiss scientist Charles Édouard Guillaume, head of the bureau, discovered an inexpensive iron-nickel alloy that would not expand when heated. Since then, several other "Invar" materials (so named because of their temperature-invariant properties) have been discovered. Though their internal mechanics remain controversial, modern Invar alloys find applications in many everyday items, such as toasters, computers, watches, and light bulbs.

Now Caltech grad student Michael Winterrose, Professor of Materials Science and Applied Physics Brent Fultz, and their colleagues have found a new way to induce Invar behavior in materials. By placing an iron-palladium alloy under high pressure, they were able to change it from an alloy that displayed no Invar behaviors to one that undoubtedly did.

Winterrose and Fultz were studying alloys composed of one part iron and three parts nickel, palladium, or platinum. Though nickel and iron atoms are nearly the same size, palladium and platinum are much larger. Winterrose and Fultz had planned to investigate the effects of high pressure on materials made of atoms of mismatched sizes, versus alloys of similarly sized atoms, hoping to discover interesting volume effects.

Winterrose and Fultz would place tiny samples of their alloys between two diamonds in what is called a diamond anvil cell. Tightening six screws forces the diamonds together, generating pressures of up to 33 gigapascals (GPa), or more than



Former Caltech Senior Research Fellow in Physics John Grunsfeld on the fifth and final spacewalk of the STS-125 shuttle mission to service the Hubble Space Telescope in May. Astronauts installed two new instruments—the Wide Field Camera 3 and the Cosmic Origins Spectrograph—and repaired two others, swapping out circuit boards that were never intended to be replaced.

300,000 times atmospheric pressure. With temperature kept constant, if pressure is increased, most materials contract at a relatively constant rate.

For the palladium-iron sample, however, that was not the case. At around 10 GPa, the Pd_3Fe sample began to compress more easily than before, and at around 15 GPa, the material became stiffer than it had been originally. This strange pressure-volume curve was baffling—that is, until Winterrose recalled that similar curves appear in a few other iron alloys. However, those curves were associated with Invar materials, which have unique magnetic properties that cancel out thermal expansion—properties that Pd_3Fe does not normally exhibit.

A computer simulation suggested that the high-pressure stiffening of the material might be due to a magnetic transition. "Perhaps the best early hint was found in the calculations of electron energies in Pd_3Fe. For high pressures, the spectrum of electron energies showed the fingerprints of an instability, where the magnetism was about to collapse, and a different set of electron levels would then become occupied," recalls Fultz.

Armed with their sample, Winterrose, Fultz, and company went to the Advanced Photon Source at the Argonne National Laboratory. There, they used a technique called nuclear forward scattering that allowed them to excite the magnetic states of their material, confirming that such a transition was indeed taking place—in fact, at the same pressures where the volume collapse occurred. As the electron configuration changed, the energy structure became closer to that of the traditional Invar material Fe_3Pd. "In this way," Winterrose says, "it's like alchemy. We've coaxed one material into behaving like another."

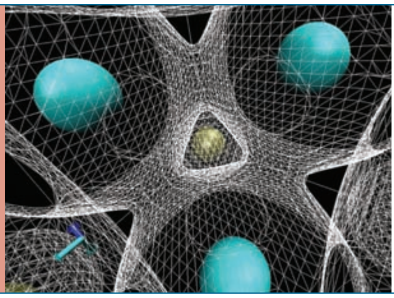
Finally convinced that they had an Invar material on their hands, Winterrose and Fultz performed one last test—they heated their troublesome alloy while it was being pressurized. And sure enough, they found that it did not expand at temperatures up to 250 degrees Celsius.

"Now that we've found an electronic structure change associated with Invar behavior, perhaps we will be able to find other means to cause similar changes and so create new Invar materials at lower pressures," Winterrose says. "This also demonstrates the possibility of manipulating the electronic properties of matter using simple mechanical force, and offers insight into the materials existing at high pressures that make up a large part of the matter in our solar system."

A paper describing their work was published in the June 12 issue of *Physical Review Letters*. In addition to Winterrose and Fultz, the coauthors are Matthew S. Lucas (MS '05, PhD '09), grad students Alan F. Yue, Lisa Mauger, and Jorge Muñoz (MS '09), and visiting scientist Itzhak Halevy, from Caltech; Jingzhu Hu, from the University of Chicago; and Michael Lerche, from the Carnegie Institution for Science.

The work was supported by the Carnegie–Department of Energy (DOE) Alliance Center, funded by the DOE through the Stewardship Sciences Academic Alliance of the National Nuclear Security Administration; by the DOE's Office of Science, Office of Basic Energy Sciences; by the National Science Foundation and its Consortium for Materials Properties Research in Earth Sciences (COMPRES); and by the W. M. Keck Foundation. —*AL*

A rendering of electron density surfaces surrounding the iron (yellow) and palladium (blue) atomic cores in Pd_3Fe, based on calculations from first-principles quantum mechanical simulations. At a pressure of 12 GPa, the electron density begins to migrate toward the iron atoms, leading to Invar behavior.



THERE'S WATER ON THE MOON . . .

When the Apollo astronauts landed on the moon, they found its airless surface to be bone-dry. Now, 30 years later, a fleet of spacecraft have discovered traces of water there. But before you plan your trip to a lunar beach, bear in mind that the wet stuff exists as molecules embedded here and there in the regolith, the lunar equivalent of soil.

JPL's Moon Minerology Mapper (M^3) on the Indian spacecraft Chandrayaan-1 found traces of water and hydroxyl, a molecule consisting of one oxygen atom and one hydrogen atom, in the top two millimeters of the regolith. M^3 measured the sunlight reflected from the lunar surface and found that a wavelength of around three microns was being absorbed, the spectral signature of an O—H bond. The signal appeared all over, but was strongest near the poles.

Two other spacecraft confirmed the discovery, which was reported in the online edition of *Science* on September 24. Previously unpublished data from Cassini, which passed the moon in 1999 en route to Saturn, showed a similar signal. And comet hunter EPOXI, née Deep Impact, sealed the deal in a flyby in June with its high-resolution spectrometer.

Scientists aren't sure how much water there is, but models estimate that the abundance could be as much as 1,000 parts per million. In other words, wringing out one ton of the lunar surface would just fill your 32-ounce sipper bottle. —*MW* e&s

. . . AND MORE ICE ON MARS

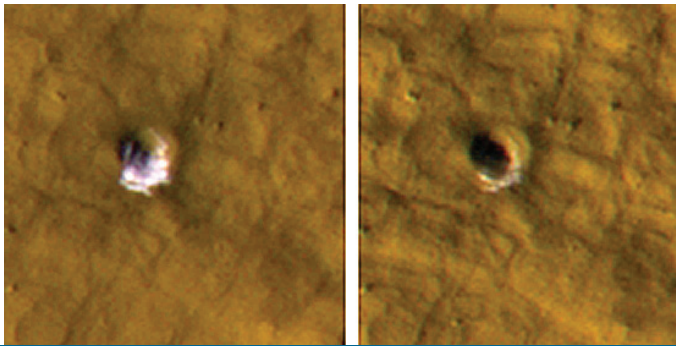
The poles aren't the only places on Mars with ice. JPL's Mars Reconnaissance Orbiter (MRO) found that several small meteorites had struck Mars in the last year, uncovering bright white water ice in the resulting craters. The fact that there was ice at all was surprising—the icy craters were in latitudes thought to be too low, and therefore too dry, for ice to exist.

The icy craters were between the latitudes of 45 and 55 degrees north—near where Viking 2 landed in 1976. In fact, had Viking dug just 10 centimeters deeper into the ground, it likely would've hit ice. Instead, the discovery had to wait another 33 years.

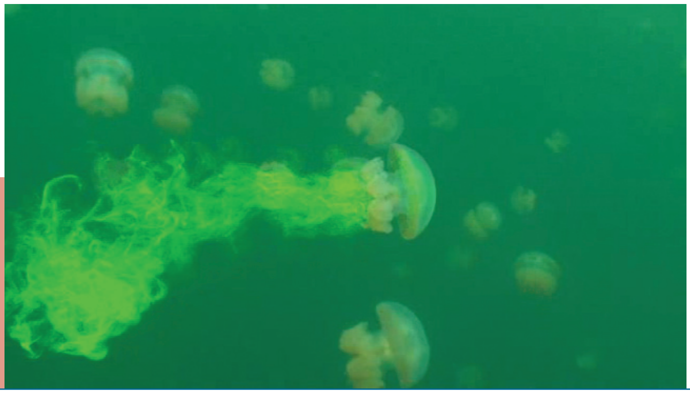
On August 10, 2008, MRO's Context Camera, which returns images of Mars in 30-kilometer-wide swaths, noticed a meteor crater that hadn't been there just 67 days before. Scientists then took a closer look with the High Resolution Imaging Science Experiment (HiRISE), and they saw brilliant white. The area was too small for MRO's onboard spectrometer to analyze, but the researchers found a larger, newly formed crater nearby and confirmed the suspicious material to indeed be water ice. In total, the team found ice in five small craters, which ranged in depth from a half-meter to 2.5 meters deep. After a few months, much of the whiteness disappeared as the ice sublimated and became mixed in with dust.

The 18 researchers from six institutions reported their findings in the September 25 issue of *Science*.
—*MW* e&s

NASA/JPL-Caltech/University of Arizona



This brand-new, six-meter-diameter crater was shot by HiRISE on (left) October 18, 2008, and (right) January 14, 2009. The bright material in the left-hand image is water ice exposed at the crater's bottom, which is estimated to be 1.3 meters deep. In the right-hand image, the ice has sublimated away in the northern-hemisphere summer or has been obscured by fresh dust.



In this still from a video, fluorescent dye gets dragged along right behind the jellyfish before eventually trailing off in its wake.

PLANKTON STIRS THE OCEANS

The winds, the tides, and—say *what?*—the ocean's tiniest swimmers may have roughly equal effects on the large-scale mixing that distributes heat, nutrients, and gases throughout the world's oceans, according to a new Caltech study. Oceanographers had previously assumed that water's viscosity would damp out any turbulence created by weak-swimming plankton. But John Dabiri (MS '03, PhD '05), associate professor of aeronautics and bioengineering, and grad student Kakani Katija think that so-called Darwinian mixing, named for Charles Darwin—no, not that Darwin; his grandson—might be able to transport huge volumes of water in very small batches.

"Darwin's grandson discovered a mechanism for mixing, similar in principle to the idea of drafting in aerodynamics, whereby an individual organism literally drags the surrounding water with it as it goes," Dabiri explains. Every day, billions of tiny krill and copepods migrate hundreds of meters from the depths of the ocean toward the surface. Darwin's mechanism suggests that they might drag some of the colder, heavier bottom water up with them toward the warmer, lighter water at the top. This would create instability, and eventually the water would flip, mixing itself as it went.

When Dabiri and Katija modeled this mathematically, they found that at very small scales, the water's viscosity actually *enhanced* Darwin's mechanism, magnifying the effect. "It's like a human swimming through honey," Dabiri explains. "What happens is that even more fluid ends up being carried up with a copepod, relatively speaking, than would be carried up by a whale."

Katija and collaborators Monty Graham (from the Dauphin Island Sea Laboratory), Jack Costello (from Providence College), and Mike Dawson (from the University of California, Merced) then traveled to the South Pacific island of Palau to study this effect among jellyfish, which are the focus of much of Dabiri's work and much easier to see than krill. When fluorescent dye was injected into the water in front of the jellyfish, the dye traveled right along with them, often for long distances.

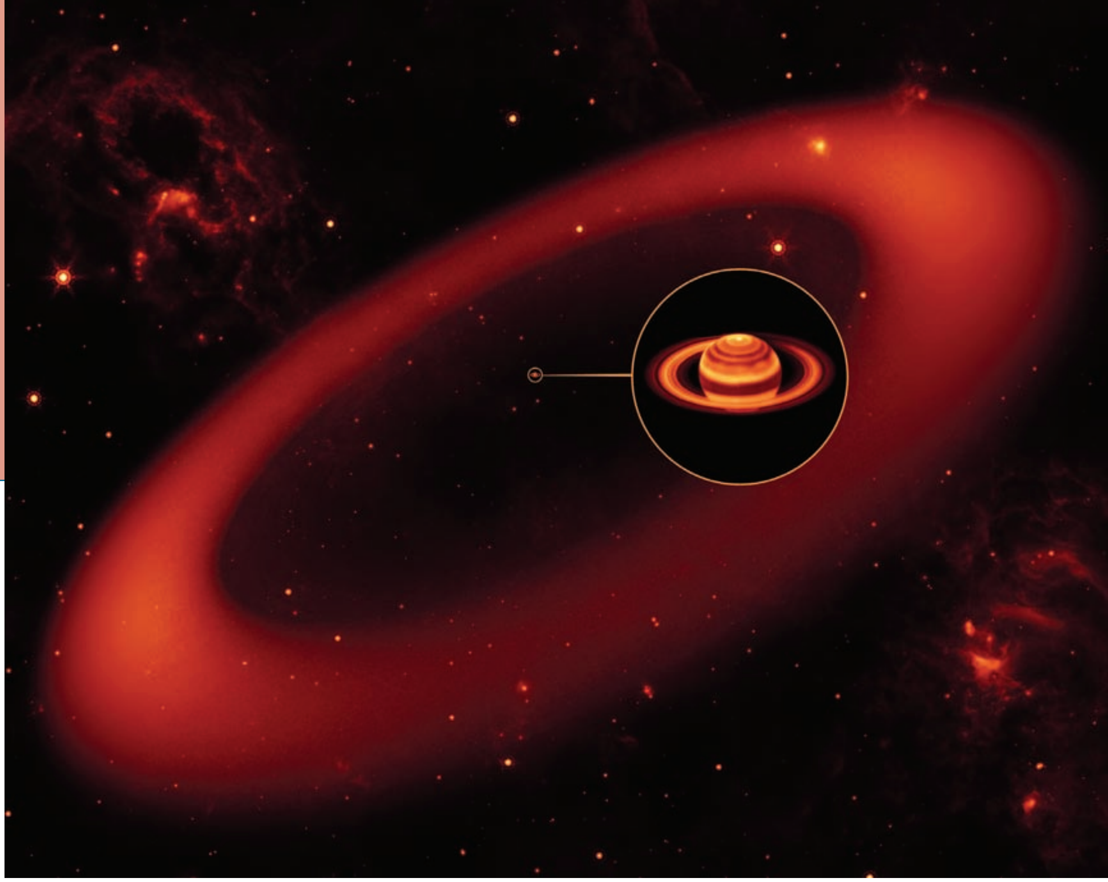
Dabiri and Katija calculated the impact of this so-called biogenic ocean mixing for a broad range of species. Says Dabiri, "There are enough of these small animals in the ocean that, on the whole, the global power input from this process is as much as a trillion watts of energy—comparable to that of wind forcing and tidal forcing."

And then there's a downbound process that they have yet to analyze, says Dabiri. Fecal pellets and marine "snow" made up of falling organic debris probably pull surface water toward the deeps. "This may have an impact on carbon sequestration on the ocean floor," says Dabiri. "It's something we need to look at in the future." Both effects will need to be incorporated into the computer models of global ocean circulation used to study climate change.

A paper on the work, written by Katija and Dabiri, appeared in the July 30 issue of *Nature*. The work was supported by grants from the National Science Foundation, the Office of Naval Research, the Department of Defense, and the Charles Lee Powell Foundation. —*LO* E&S

Listen to a podcast of John Dabiri talking about his work with jellyfish.

The Spizter Space Telescope has discovered a gigantic ring, visible in the infrared, around Saturn. If the ring, shown here in an artist's rendition, were visible on Earth, it would be twice the width of the full moon. The new ring is tilted 27 degrees from the main ring plane and follows the orbit of Saturn's retrograde moon Phoebe, which is the presumed source of the ring's material. The discovery team was led by Anne Verbiscer at the University of Virginia, Charlottesville.



Main image: NASA/JPL-Caltech/R.Hurt (SSC); Inset image: NASA/W.M.Keck Observatory/JPL-G. Orton

ULYSSES ENDS ITS ODYSSEY

After more than 18 years and almost three complete polar orbits around the sun, JPL's controllers of the Ulysses spacecraft have called it a mission. The joint NASA/ESA spacecraft was shut down on June 30 as it began to slowly succumb to the cold of deep space. (Ulysses' six-year orbit takes it out to Jupiter and back.) The doughty probe had exceeded its designed lifetime by nearly fourfold and covered almost two complete 11-year cycles of solar activity, providing grist for more than 1,000 scientific papers and two books so far.

Ulysses was the first mission to survey the north and south polar regions of the heliosphere, the "bubble" created by the solar wind. Besides monitoring the solar wind and the local magnetic field, the spacecraft measured radio, X-ray, gamma-ray, and particle emissions from the sun, Jupiter, deep space, and even a couple of passing comets, flying through their tails. —*DS* e&s

PICTURE CREDITS
4 — Avigdor Eldar; 4-5 — NASA; 6 — Michael Winterrose; 8 — Kakani Katija and John Dabiri

CCAT TAKES THE TORCH

A rough road switchbacks up the flanks of Cerro Chajnantor in Chile's Atacama Desert and levels out on a small plateau 80 feet below the summit. If you stood on that plateau, 18,500 feet above sea level in the driest desert on Earth, you might first notice the absence of life—no plants rustle in the wind, no lizards dart among the rocks. Below, golden desert stretches between the coastal mountains and the Andes, isolated by their rain shadows from both ocean storms and humid gusts from the Amazon Basin. The great plain has no correspondingly great river, the peaks no glaciers, and the air almost no moisture. If you set a glass on the dirt and condensed all the water vapor in the air above the glass into it, the collected water would stand at less than a millimeter. With its thin, parched atmosphere, this is the premier location for CCAT, a planned submillimeter-wavelength observatory that goes by the working title of Cerro Chajnantor Atacama Telescope. According to CCAT deputy project manager Simon Radford, our view of the submillimeter sky, which is limited by atmospheric water vapor, is better here than anywhere except Antarctica and space, where construction and upgrades would cost a bit more.

When the veil of water vapor is lifted, the universe is as bright at submillimeter wavelengths as it is in visible and ultraviolet light combined. Clouds of gas and dust that appear dark to our eyes and to optical telescopes shine in submillimeter light, revealing massive stellar nurseries and hidden galaxies.

Nobel laureate in physics Robert Wilson, PhD '62, who chaired the observatory's technical review committee, predicts that CCAT "will revolutionize astronomy" in the submillimeter and far-infrared band and "enable significant progress in unraveling the cosmic origins of stars, planets, and galaxies." He emphasizes, "CCAT is very timely and cannot wait."

CCAT will succeed the legendary Caltech Submillimeter Observatory on Mauna Kea, which captured its first data in 1987. (See *E&S* Summer 1988.) When CCAT's eye opens in 2016, the CSO's eye will close. "The timing of this works very nicely," says Tom Phillips, CSO's director and the Altair Professor of Physics. "The international community of astronomers that relies on the CSO will have a seamless transition as CCAT comes online." After a good solid party in the CSO's honor, the telescope's site will be returned to nature. Though the site may appear as it once did, the universe never will.

The CSO was the brainchild of Robert Leighton (BS '41, MS '44, PhD '47), a physicist fascinated with underexplored wavelengths who taught at Caltech until his retirement in 1985 and often spent evenings building balsa-wood telescope models in his garage. Equipped with a 10.4-meter Leighton Dish and a state-of-the-art single-pixel receiver invented by Phillips, the CSO helped astronomers gain insight into the chemistry of space, the birth of nearby galaxies and stars, the composition of comets and planets, and the origins of terrestrial water. Designed for upgradability, the CSO also enabled tests of new detectors.

CCAT will see a broader wavelength range—from 200 micrometers to 2.2 millimeters—using the latest detectors. While the CSO started off with a single-pixel receiver, CCAT will sport two 50-kilopixel cameras based on Microwave Kinetic Inductance Detectors, or MKIDs. Invented by Jonas Zmuidzinas (BS '81), professor of physics and director of JPL's microdevices laboratory, along with JPL Senior Research Scientist Henry "Rick" LeDuc, MKIDs are superconducting photon detectors that are cheaper to fabricate and easier to assemble into large arrays than transition edge sensors, the competing technology. MKID arrays are also considered more likely to be scalable into megapixel cameras, for which CCAT's designers have thoughtfully left room. But MKIDs are relatively new. Zmuidzinas began working on them in 2000 with seed funding from Trustee Alex Lidow, BS '75, and the first prototype camera was installed on the CSO in 2007.

CCAT's dish, 2.5 times bigger and nearly twice as smooth as the CSO's, will gather more light and focus more sharply. David Woody, a key contributor to many Caltech telescope projects, is honing the design of the primary mirror and its support, in which some 1,800 reflector tiles premounted in groups on 200 "rafts" are secured to a carbon-fiber truss. A network of sensors and actuators will keep the surface smooth to within ten micrometers—between the width of a red blood cell and a white blood cell. "CCAT is a really tough technical challenge," says lead telescope designer Steve Padin, whose work with Woody is supported by a five-year gift from John B. and Nelly Kilroy.

Astronomers will use CCAT to test the prevailing wisdom about the evolution of galaxies, stars, and black holes. Here's the gist of the story. After the Big Bang, the universe—most of which is dark matter—varied slightly in density. Over billions of years, gravity emptied material from less dense areas into denser ones, which, in turn, merged into larger structures. As the dense regions merged, galaxies that had coalesced inside of them also gravitated toward each other, often colliding and merging. These smash-ups roiled the gas clouds within the galaxies, triggering bursts of star formation and causing much of the gas to sink toward the merged galaxies' cores, fueling the growth of supermasssive black holes.

Everything we can see fits this story, but the problem is that, at most wavelengths, the picture dims at the height of the action. In the universe's first few billion years, when all those

This false-color composite image of the Antennae galaxies uses infrared data from the Spitzer Space Telescope and visible data from the Kitt Peak National Observatory to show what we can expect from CCAT. The image sharpness is comparable, with the red dot in the lower left corner representing CCAT's 3.5-arc-second resolving power at 350 micrometers. The red box outlines CCAT's five-arc-minute-by-five-arc-minute field of view with the proposed ATACamera. By contrast, the red dot in the lower right corner shows ALMA's entire seven-arc-second field of view at 350 micrometers.

galactic collisions and mergers were making new stars hand over fist, those stars were born enshrouded by gas and dust, making them invisible. But the copious ultraviolet light from the new stars heated that dust, which reradiated the heat at longer wavelengths that penetrate the dust and are visible to CCAT, enabling astronomers to tell what happened behind the curtain.

Recent submillimeter observations have turned up hundreds of distant galaxies that give off most of their light in the submillimeter and far-infrared bands. These are the ancient, colliding galaxies that astronomers want to see. Big, fast, and sensitive, CCAT will find hundreds of thousands of such objects. CCAT will survey the submillimeter sky from the earliest era of galaxy formation forward, measuring luminosity, redshift, and color.

Astronomers will sift through this wealth of newly discovered galaxies for those with the most potential to refine the story, and will follow up with closer observations at narrowly focused instruments like the Thirty-Meter Telescope and the Atacama Large Millimeter / Submillimeter Array (ALMA), an interferometer under construction on a plateau 2,000 feet below CCAT.

At the other end of the cosmological scale, CCAT will turn its dust-vision on our own sun's remnant disk—the Kuiper Belt beyond Neptune—to catalog and analyze hundreds of objects dating back to the birth of our solar system. This and CCAT studies of other stellar disks, from protoplanetary systems to old debris, will offer new insights into how planetary systems form.

As planning for CCAT advances, the community of interested astronomers swells. CCAT, initially the Cornell Caltech Atacama Telescope, got its new working title in recognition of the consortia of British, German, and Canadian astronomers, plus American partners, including the University of Colorado and Associated Universities Inc., that have signed on.

"The worldwide community is excited about CCAT, and there is no shortage of potential partners. It is wonderful for Caltech and JPL to be in the position of playing a leading role in the development of this unique and powerful new telescope," says Andrew Lange, Goldberger Professor of Physics, who has made CCAT the Division of Physics, Mathematics and Astronomy's number-one priority since becoming division chair one year ago. —*AW* e&s

Spitzer: NASA/JPL-Caltech/Z.Wang (Harvard-Smithsonian CfA); Kitt Peak: Mary Jo Rushing and Jim Lawler/Adam Block/NOAO/AURA/NSF