# JUNIOR ACHIEVEMENT

Caltech's Theresa (Teri) Juarez is the face of college athletics—at least on the cover of the winter issue of the NCAA's *Champion* magazine. The magazine highlights the junior mechanical engineering major's accomplishments on the basketball court and in the classroom. Making the cover is not just an honor for her, Juarez says: "It's an extension of our whole team and the athletics department." Sandra Marbut, head coach of the women's basketball team, adds, "It's great because it continues to validate that our kids are many things. Yes, they're brilliant, but they're also athletes, musicians—so many things."

Indeed. A Gates Millennium Scholar, Juarez worked at JPL last summer, where she did thermal engineering on a proposed Venus lander and contributed to the book *Thermodynamics for Dummies*.

She's also recruiting for Caltech. A Latina from El Paso, she had never heard of Caltech until she participated in the Youth Engineering and Science Scholars (YESS) program. The three-week, on-campus program is designed for exceptional, underrepresented high-school students.

Juarez says she wants to connect with underrepresented minorities and other students who otherwise might never consider going to Caltech. She has visited her high school to spread the word, and she has recently started to help recruit students from the Los Angeles area as well. —*MW* E&S



Move over Tennessee, UConn, and Louisiana Tech—Caltech women's basketball, in the person of junior Theresa Juarez, made the cover of the latest issue of the NCAA magazine. A quarterly, *Champion* gives this honor to only one Division III athlete (from any sport!) per year.

## A NEW STREAK

They did it! With a 46–45 victory over Occidental College, Caltech's men's basketball team won its first Southern California Intercollegiate Athletics Conference (SCIAC) game in more than 26 years, breaking its 310-game losing streak.

With the score tied at 45–45, Caltech had the ball for the final possession of the game. Senior Ryan Elmquist was fouled on a layup with 3.3 seconds left. Having already made 14 free throws in the game, he sank the first of two to give the Beavers a one-point lead, sending the crowd into a frenzy. After the second attempt rimmed out, Oxy rebounded and missed a desperation heave at the buzzer. Fans, players, and coaches stormed the court, embracing and high-fiving one another. Techers everywhere rejoiced.

With four nonconference wins early this season, and several nail-biters in conference play, hopes were high that this would be the year that Caltech snapped the SCIAC streak. And with this victory, coming on the last game of the season, the Beavers finally triumphed. —*MW* E&S

## HAIL FROM THE CHIEF

In his 2011 State of the Union address, "Winning the Future," President Obama pointed to Caltech as a model for innovation, saying: "We're issuing a challenge. We're telling America's scientists and engineers that if they assemble teams of the best minds in their fields, and focus on the hardest problems in clean energy, we'll fund the Apollo projects of our time.

"At the California Institute of Technology, they're developing a way to turn sunlight and water into fuel for our cars. At Oak Ridge National Laboratory, they're using supercomputers to get a lot more power out of our nuclear facilities. With more research and incentives, we can break our dependence on oil with biofuels, and become the first country to have a million electric vehicles on the road by 2015."

"It is a great honor," says Caltech president Jean-Lou Chameau, "that President Obama has recognized the Institute's game-changing solar energy research as a prime example of how America is investing in innovation to confront 'our generation's Sputnik moment.' Caltech's Jet Propulsion Laboratory designed and built the first U.S. satellite in just a few short months after Russia's launch of Sputnik 1 in 1957, leading our country into the Space Age. When America wins this new innovation arms race—developing efficient ways to cleanly power our planet—we will not only 'win the future,' we will make a better future." —*KB* E&S

Above: Head coach Oliver Eslinger hugs Elmquist after the game.

Right: President Barack Obama gave a shout-out to Caltech in his State of the Union address to a joint session of Congress on January 25. Behind him are Vice President Joe Biden (left), in his role as president of the Senate, and Speaker of the House John Boehner.

This galaxy, Messier 99, is 60 million light-years away and is home to a transient named PTF10fqs (inset). Called a luminous red nova, this oddball transient is brighter than an ordinary nova but too faint to be a supernova. Its visible light dimmed after only a few months, but it still glows in the infrared and may do so for a couple of years.

# A SUPERNOVA SURPRISE

Strange explosions in space keep Mansi Kasliwal (MS '07) awake at night. As a graduate student at Caltech, Kasliwal has been pointing a half dozen telescopes at the sky to catch these cosmic blasts—fleeting flashes of light that last from a few days to a few months. She's a member of the Palomar Transient Factory (PTF), a project whose automated telescopes on Mount Palomar continuously scan the heavens, looking for bright spots that weren't there just a day or two before.

Many of these fleeting flashes belong to a class of explosion called a Type II supernova, something that forms when a dying star spends the last of its fuel and collapses. Another sort of explosion, known as a Type Ia supernova, happens in a binary system consisting of a bloated red-giant star and its white-dwarf partner. About the same size as Earth, a white dwarf is a low-mass star at its last life stage. As the red giant, which has health issues of its own, sloughs off its outer layers, some of the matter accumulates on the white dwarf's surface. Under the right conditions, a nuclear explosion can ignite. A third class, the classical nova, is a calmer version of a Type Ia supernova that's 1,000 times fainter.

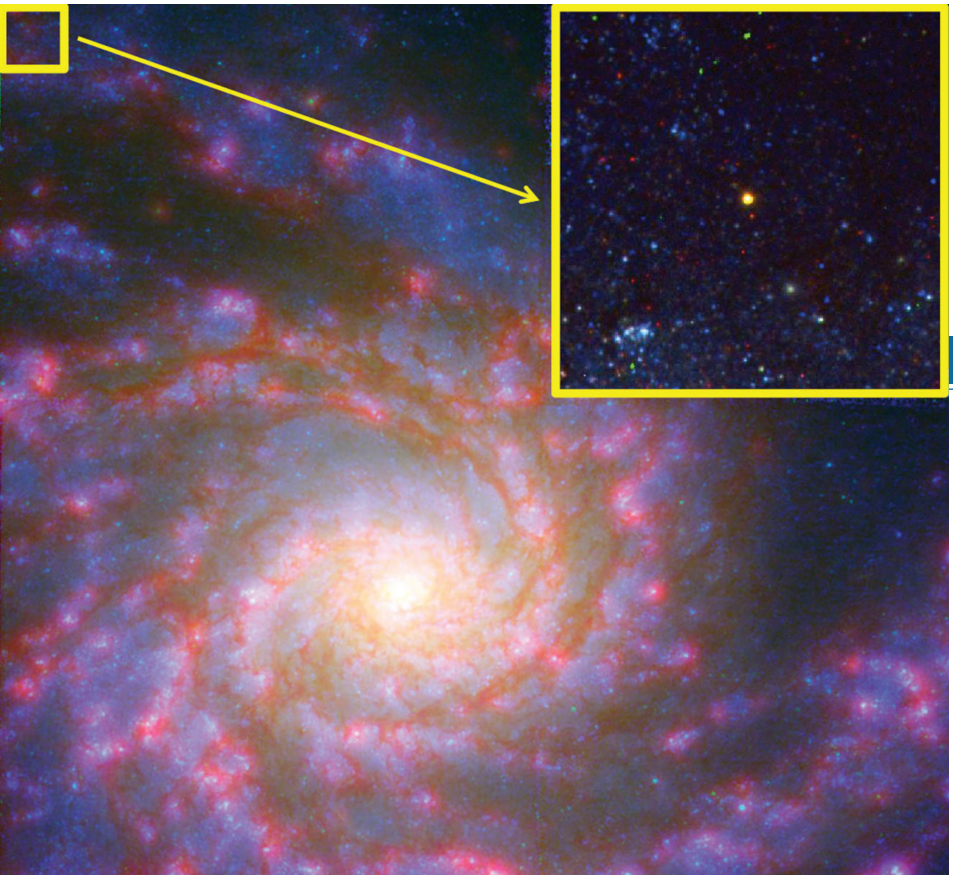
Astronomers classify supernovae by a dozen or so characteristics: their maximum brightness, the time it takes for them to dim, and the wiggles and bumps found in their spectra—which are like supernovae fingerprints, revealing the chemical composition of the explosion. Members of the PTF team measured spectra of their finds during follow-up observations using the Palomar Observatory, the MDM Observatory on Kitt Peak in Arizona, the Gemini telescopes in Hawaii and Chile, and the W. M. Keck Observatory, also in Hawaii.

In just about a year's worth of observing time, the PTF has found over 1,000 so-called transients. Most are likely to be novae and supernovae—when confirmed, they will account for nearly a fifth of the total number discovered in the past century—and 97 percent of them fit the profiles of one of the three usual suspects. Among the remaining 3 percent are half a dozen explosions that are complete mysteries. A few last for several months, like Type II supernovae do, but they are about 100 times dimmer. Others are as brief as regular novae, but as bright as supernovae. They're nothing like any cosmic explosions we've seen before, so what are they? "There are lots of stories, lots of ideas that people have thought of," Kasliwal says. But none of these theories can explain everything about each object—except for one.

In February 2010, an amateur astronomer named Douglas Rich discovered a supernova that was quickly confirmed by another amateur, Paul Burke. Soon after, the PTF made the same discovery independently. The object, dubbed PTF10bhp, was particularly short-lived, shining for only about five days before fading away—rivaling only one other supernova as the fastest ever known. It turns out that all of the characteristics of this supernova—such as its peak luminosity, decay time, and spectrum—perfectly match those of a theoretical model devised by astrophysicist Lars Bildsten at UC Santa Barbara.

In this scenario, two white dwarfs zip around each other in a tight orbit, taking less than an hour for each revolution. One white dwarf is composed of helium, while the other

The explosion is called a Type .Ia supernova—pronounced "point one A"—because it's about one-tenth as bright, lasts one-tenth as long, and has about one-tenth the amount of nickel as a Type Ia supernova.



is made of carbon and oxygen. Helium from the lower-mass star spills over to the higher-mass one. When all the mass has transferred over, the system can become unstable, and runaway reactions can lead to a thermonuclear explosion. The explosion is called a Type .Ia supernova—pronounced "point one A"—because it's about one-tenth as bright, lasts one-tenth as long, and has about one-tenth the amount of nickel as a Type Ia supernova.

Bildsten's model makes very specific predictions about the supernova's peak luminosity, how long the supernova takes to brighten and decay, and the presence of calcium and titanium lines as seen in its spectrum—the latter a weird feature not observed in ordinary supernovae. One by one, Kasliwal was able to check each prediction off the list, as PTF10bhp satisfied every requirement from the model. More work will be needed to confirm that PTF10bhp is indeed a Type .Ia, but such a perfect fit between observation and theory is a reason to rejoice. "It's very interesting because there have been very few theoretical models for these things," she says. "It's certainly very rare, and certainly exciting."

Kasliwal has discovered some other oddballs, as well. For example, she's found two supernovae about 130,000 light-years away from their host galaxies—farther than the diameter of the Milky Way. These supernovae appear to be massive stars, and their shorter lifetimes are insufficient for them to have made the long voyages from their host galaxies. They must have formed near their current locations, out in the galactic boonies surrounded by nary a wisp of gas or dust—perhaps similar to the conditions in which the first stars in the universe were born. Studying these supernovae, then, is a way to understand the evolution of the very first stars.

"I really did not think before I came to Caltech that I could actually be a part of a project where you start with some crazy brainstorm and see it happen," Kasliwal says. "Mother Nature's revealing these rare opportunities to teach you about new physics you could never have dreamed of. There's so much territory that's completely unexplored. Nature always catches you by surprise—it's fantastic."

Kasliwal will finish her PhD in June. Having been awarded a prestigious Hubble Fellowship and a Carnegie-Princeton Fellowship, she will begin her postdoctoral work this fall at the Carnegie Institution for Science, just up the street from Caltech. *—MW*

## BETTER THAN A POKE IN THE EYE

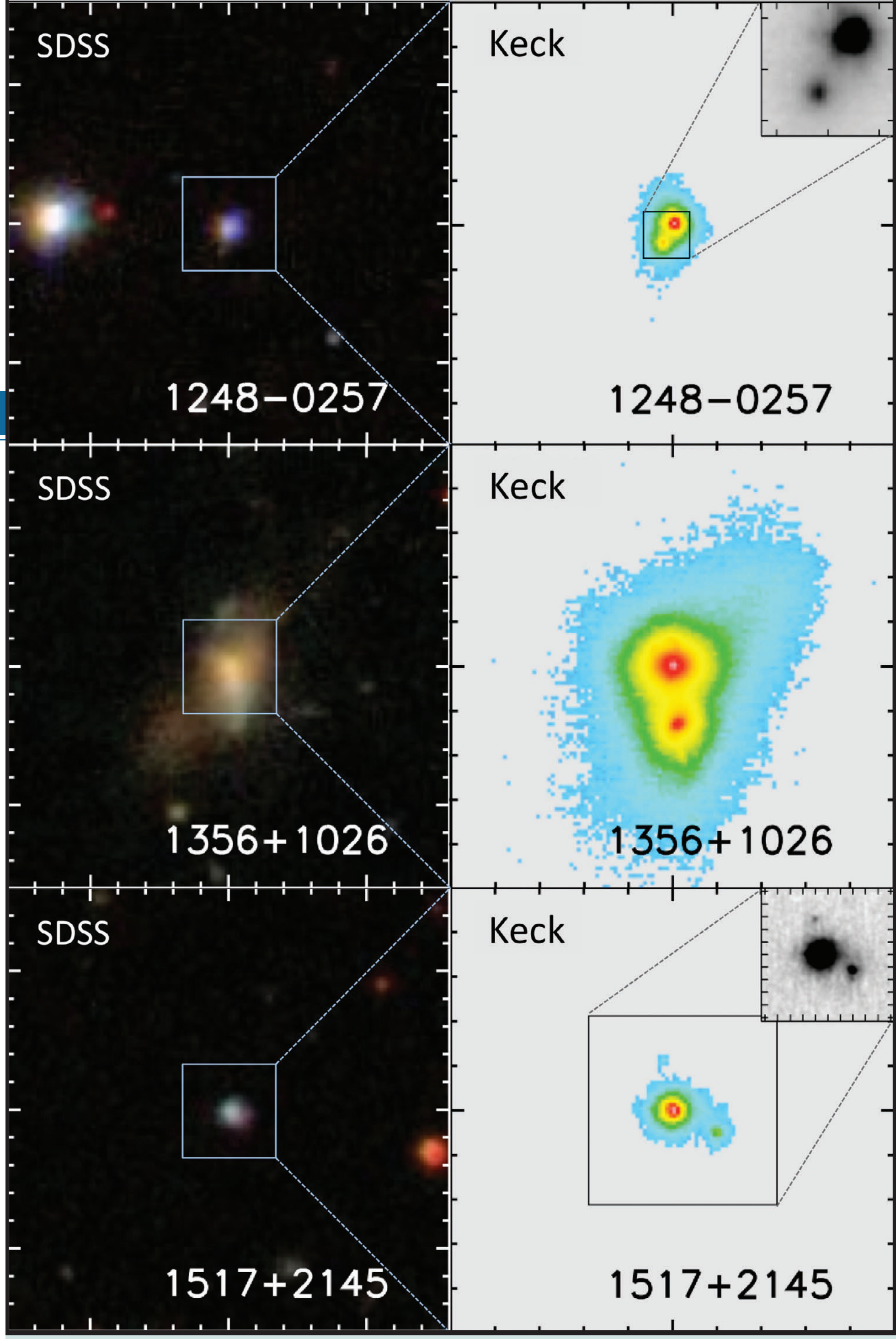
For most of human history, cataract surgery has consisted of pushing the clouded lens aside or scraping it out altogether with a needle jabbed into the patient's eyeball. A lensless eye was better than a blind one; at least the patient could make out shapes and colors. Today's techniques are slightly less cringeworthy and considerably more effective. They generally involve fragmenting the lens with ultrasound, and implanting a synthetic replacement through a tiny incision in the cornea—the clear part of the eyeball.

Like contact lenses, these implants can be made of hard or flexible plastic; and like contact lenses, the prescription is "baked in" when they're manufactured and can't be altered later. Not so with the laser-adjustable lens (LAL), whose optical properties can be fine-tuned days or weeks after surgery. The LAL is the product of a multi-institute collaboration that includes Daniel Schwartz, an associate professor of ophthalmology at UC San Francisco, as well as Caltech's Robert Grubbs and Julia Kornfield (BS '83, MS '85). Grubbs, a 2005 Nobel laureate, is the Atkins Professor of Chemistry; Kornfield is a professor of chemical engineering. Kornfield studies how a polymer's microscopic structure dictates its macroscopic properties; Grubbs is an expert on making polymers to order.

Kornfield and Grubbs make their implants from photosensitive macromers (short-chain polymers), allowing the lenses' optics to be tweaked post-op. (See "Squishy Is Good," *E&S* 2002, No. 2.) Once the incision has healed, there's a follow-up eye exam. Then the ophthalmologist briefly illuminates selected regions of the lens with a pattern of near-ultraviolet light. This activates the macromers in those areas, creating a chemical imbalance that osmotically attracts free macromers from nearby regions. Over the next day, the influx of material alters the lens's shape, and thus its refractive power. A final lenswide dose of ultraviolet light locks in the new configuration.

Although the LAL isn't yet approved for use in the United States, it's taken off overseas. "Sales in Europe are doing well," Grubbs remarks. Meanwhile, recent clinical trials have confirmed the lens's ability to correct astigmatism. Says Kornfield, "It's exciting to be involved in a technology that might soon be giving people over 45—like me!—near and distance vision without glasses or contacts."

So keep an eye out—er, as it were. —*DZ* E&S




S. G. Djorgovski, H. Fu, et al., Caltech

## COSMIC COLLISIONS

Newly discovered black-hole pairs provide a rare glimpse into the later stages of how their host galaxies collide and merge. The images on the left, from the Sloan Digital Sky Survey, each show a single blurry object. Now the Keck telescope's adaptive optics have resolved each smudge into two active galactic nuclei (right), each of which is powered by a supermassive black hole. These binary black holes are a hundred to a thousand times closer to each other than most previously observed pairs—and these 16 pairs are the largest population of such objects discovered with a systematic search. Postdoc Hai Fu, Professor of Astronomy George Djorgovski, Member of the Professional Staff Lin Yan (PhD '96), and Alan Stockton of the University of Hawaii at Manoa, reported their observations at the American Astronomical Society meeting in January. E&S

# AUTOMATA IN OUR MIDST

Pity the poor service robot. It has its marching orders; it knows where to go, but to get there, it must thread its way through a mob of humans. We all face that same problem daily, in malls and museums, on boardwalks and boulevards: navigating a living, jostling obstacle course. Only this purposeful pedestrian is electronic.

"I see crowds as swarms of massive particles with random trajectories," explains Caltech graduate student in control and dynamical systems Pete Trautman. "Picture a hapless robot wading into the melee. It takes baby steps. It backpedals frantically." And one stubborn human, motivated by obstinacy, curiosity, or simple obtuseness, can detain it indefinitely.

Not that most of us flesh-and-blooders wish our mechanical friends ill. Adults frequently try to engage them in conversation, no doubt having been conned into thinking they are sentient by the melodious bleeps and burbles of R2D2 and WALL•E. And University of Washington researchers have observed infants responding to social cues from robots. But crowds are chaotic, and even a mind-reading android capable of predicting each person's every move might never find a clear path. All the obvious strategies have limitations. "Make an aggressive beeline? That's obnoxious," Trautman cautions, "and potentially dangerous. Wide, evasive detours? Inefficient or impossible." What about simply waiting for the seas to part, then making a dash for it? "And if they never part?" he shrugs. "You'd wait forever. We call that the Freezing Robot Problem."

Yet humans navigate crowds routinely—how? "First," Trautman says, "I collected mountains of data by filming pedestrians negotiating a crowded sidewalk." Their motions revealed details of the hidden logic known as cooperative collision avoidance: the subconscious twists and turns we all execute to keep from continually bumping into one another. Next, he constructed a mini-robot of intentionally disarming cuteness (a laptop computer on wheels, with stereo camera "eyes") and turned it loose among the lunchtime crowds in Caltech's Chandler Dining Hall. Some days he hovered nearby, maneuvering it remotely; other times, the WALL•E wannabe moved autonomously. Hearteningly, the seething mass of humanity accepted the newcomer. Far from running interference, they simply flowed around it as if it were any other (very short) chow seeker on a mission. Some even professed not to have noticed it.

These observations led Trautman to a key insight. "We all expect cooperative collision avoidance from robots," he says. "It turns out they can also expect it from us." People are surprisingly predictable creatures, he explains. "We want to get where we're going, we can only change direction so fast, we don't like touching strangers. Some metal gizmo whizzes up. Maybe we noticed someone with a joystick nearby—whatever. We're busy, we're distracted, we make way and move on." The only exception is when the robot dawdles or appears lost. "Then folks notice it and crowd around. Certain individuals even try to prevent it from moving off again."

Trautman presented his crowd-navigating algorithm at January's TEDxCaltech conference. Using probability theory to predict the behavior of others, it charts assertive courses. "In fact," he notes, "the algorithm generally selects shorter, smoother paths than most humans do." So next time you hear "Last orders!" or "Look, it's Brad Pitt!" or "70 percent off in housewares!" . . . follow the nearest robot. *—DZ* E&S

In this overhead view of part of Chandler's food-service area, a small crowd gathers around Trautman's robot (green circle) the moment it stops moving. For videos, see http://www.cds.caltech.edu/~trautman.

# THE PHYSICIST WHO CAME TO DINNER

Top: Every year since 1992, famed physicist Stephen Hawking has spent about a month at Caltech. And every year since 2000, a group of Caltech students have cooked dinner for him. This year, on January 25, the students—led by Rosemary Macedo (BS '87) as part of a cooking class taught by Tom Mannion, senior director for student activities and programs—prepared an Indian feast.

Left: From left: Anguel Alexiev ('11), Wesley Chen ('12), and Laura Decker ('11) prepare Goan-style seafood curry in Mannion's backyard.

Below: From left: Pengsu Jiang ('12), Jenny Xiong ('11), and Skylar Cook ('12) stir up beef in black-cardamom tomato sauce and pork vindaloo in Mannion's backyard. Afterward, the students carried the steaming pots and trays to Chandler Dining Hall, where dinner was served.

# DUNE THE MATH

Despite its name, the Arroyo Seco (Spanish for "dry streambed") meandering past Caltech's Jet Propulsion Laboratory does actually contain water. But even if it were bone-dry, perpetually so, you wouldn't need a planetary scientist like JPL's Serina Diniega (BS '03) to deduce that at one time something liquid this way came.

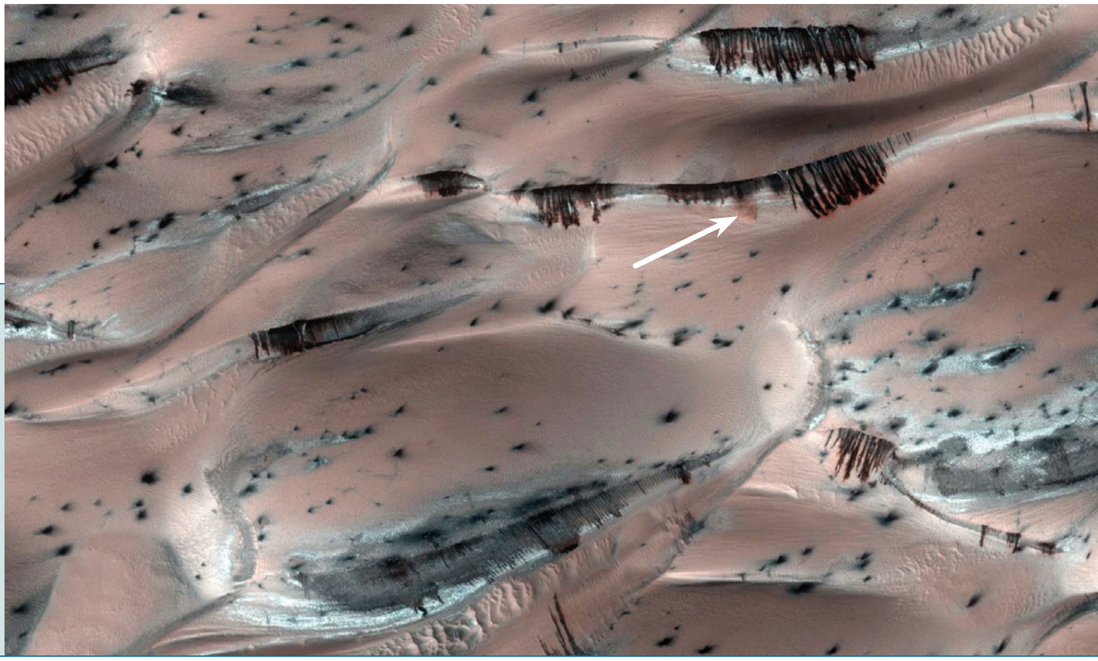
Shift now to Mars. Its empty riverbeds mark where water once flowed; its towering sand dunes don't. Yet, observes Diniega, the dunes' faces are scarred by deep channels—elongated hourglass-shaped gullies sluicing from crest to base. The wind eventually smoothes everything over; a decade's worth of orbiter images confirms that. But eerily, new gouges keep appearing.

What's flowing up there? Groundwater? Snowmelt? Condensation? All physically improbable, Diniega says: though those processes are common on Earth, "Mars is a different planet with its own mysteries." The most likely culprit, she's concluded, is carbon dioxide: the layer of dry-ice frost that blankets the planet's vast dune fields through the Martian winter.

In recent papers in *Science* and *Geology*, Diniega and her collaborators postulate that as the spring thaws approach, the warming sands heat the frost layer from beneath, causing its underside to vaporize before its surface does. Trapped, the newly liberated carbon dioxide gas rushes sideways, picking up sand particles as it accelerates, until it reaches a crack—such as the ones typically found along the crests of dunes. There the sand squirts out like feathers from a ruptured mattress; falling back, it triggers miniature landslides that gash the dune's face.

Diniega's current focus is on the dynamics of lava flows here on Earth—quite a shift from Martian dunes. Diniega is fascinated by the dynamics of everything from lava flows to river channels. "My interdisciplinary research path has been an interesting one," she acknowledges. At Caltech she was a math major—unusual for a planetary scientist. "I knew from my undergraduate experiences that I wanted to study how landforms evolve on different planets, and that I wanted to use mathematical techniques to do it. During my first year at the University of Arizona, I attended a math colloquium about 'coalescence dynamics,' in which you start with a large number of small things, but end up with a small number of large things—the way droplets of water collect, for example. That same week we discussed sand dunes in my planetary geomorphology class. Small sand dunes move faster than larger sand dunes, as there's less sand to move, so the small ones catch up to the big ones and sometimes get absorbed. I decided I wanted to know more, and fortunately Karl Glasner, the applied mathematician who'd given the colloquium, was also intrigued. He ended up serving as my PhD advisor."

So for the native Hawai`ian (whose interests include hula and who once captained Caltech's fencing team, specializing in saber), the transition from Galois fields to lava fields wasn't much of a lunge. "I've always enjoyed showing how I use math," she explains, "in studies of more 'real' questions about how the world works." *—DZ* e&s



This Mars Reconnaissance Orbiter view of a dune field in early spring caught a dust cloud (arrow) kicked up by a mini-avalanche down a dune face some 40 meters tall. The dark streaks are believed to be landslides triggered by sand squirting from the dunes' crests. The bright patches are carbon-dioxide ice remaining from winter.