Starring role. A new laser system sharpens the Keck II Telescope's view of faint objects.

Laser Points to Bright New Era For Ground-Based Astronomy

Many dark nights at the W. M. Keck Observatory atop Mauna Kea, Hawaii, now feature a startling source of light: a laser beam emerging from one of the twin domes. Rather than swamping faint signals from the heavens, however, the photons have quite the opposite effect.

The long-awaited advance, called laser guide star adaptive optics, trumps the standard adaptive optics now used at most major telescopes. Light from a star jitters rapidly as it passes through Earth's shifting atmosphere. In the current systems, computers analyze that pattern, then flex a thin mirror within the telescope's optical path to correct the distortion. The result is steady vision rivaling that of the Hubble Space Telescope. But this technology requires light from a bright star or planet, limiting its application to about 1% of the sky.

In contrast, astronomers can aim the Keck laser nearly anywhere. The beam illuminates a layer of sodium atoms about 90 kilometers high, left there by incoming meteoroids. The flexible mirror sharpens the telescope's vision of this "star"—and, along with it, faint objects in the adjacent field of view. After years of tinkering, this system became available last year for routine scientific use on the 10-meter Keck II Telescope.

The first results delighted a packed session of observers at the meeting. "It's very clear that it has moved beyond an experimental development to mature science observations," says R. Mark Wagner, an instrument scientist for the Large Binocular Telescope at Mount Graham, Arizona. "They've made laser adaptive optics into a turnkey system," adds Jeremy Mould, director of the National Optical Astronomy Observatory in Tucson, Arizona. "You just use it to do astronomy, and you don't worry about whether it's going to work."

For example, astronomer Michael Liu of the University of Hawaii, Manoa, used laser-honed vision to study close pairs of the failed stars called brown dwarfs. Liu's team resolved one binary pair with distinct reddish and bluish colors, even though the dwarfs probably formed together in the same gaseous nursery. Liu believes the difference arises from the ebb and flow of iron-rich clouds in their gradually cooling atmospheres. "Binaries like this will be our Rosetta stones for understanding how clouds vanish at this critical transition," comments modeler Mark Marley of NASA's Ames Research Center in Mountain View, California.

In another laser-guided project, astronomer Judith Cohen of the California Institute of Technology in Pasadena short-circuited a dispute about tight clusters of stars orbiting the nearby Andromeda galaxy. Some researchers had claimed that a few of Andromeda's stellar clusters are as young as 1 billion years, even though all such clusters in our Milky Way are at least 9 billion years old. But with Keck's newly piercing view, Cohen found that most of the supposed clusters were much looser groupings of stars or even flaws in previous images.

Other targets have included satellites of bodies in our solar system's remote Kuiper belt; stars on swooping orbits around the

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Pulsar Sets a Dizzying Standard

Astronomers have broken a long-standing record by finding the fastest spinning object in space. The new champ is a neutron star—the ultradense remnant of a supernova explosion—rotating 716 times each second. If the star is about 20 kilometers wide, as assumed, its equator would whirl at 15% the speed of light.

The object is among dozens of newfound millisecond pulsars, so named for their clocklike pulses of radiation at hundreds of hertz (cycles per second). Astronomers led by Scott Ransom of the National Radio Astronomy Observatory (NRAO) in Charlottesville, Virginia, detected the pulsars in several of our galaxy's rich clusters of stars. Old pulsars in these tightly packed swarms get resuscitated when they interact with other stars and acquire binary partners. When such a companion star evolves into a bloated giant, intense gravity pulls its gas toward the pulsar. The infalling matter spirals onto the pulsar and whips up its spin. The previous standard-bearer of 642 hertz was the first millisecond pulsar found, in 1982. The long wait made some theorists doubt that the spin-up process could go much faster.

The new find explains part of the delay: The speediest millisecond pulsars appear screened by matter blasted off their companions, making them tough to spot. Graduate student Jason Hessels of McGill University in Montreal, Canada, and others worked with Ransom to tease out the pulsar's 716-hertz flashes, which vanish 40% of the time. An ongoing search of star clusters with a sensitive radio processor at NRAO's 100-meter Green Bank Telescope in West Virginia should unveil ever-faster spinners, Ransom says. The group reported its discovery at the meeting and in the 12 January online edition of *Science* (www.sciencemag.org/cgi/content/abstract/1123430).

In principle, pulsars could accelerate to 1500 to 2000 hertz before shattering from centrifugal force, says astrophysicist Deepto Chakrabarty of the Massachusetts Institute of Technology in Cambridge. "But it's quite striking that they are nowhere near that," he says. The new pulsar may have surpassed 1000 hertz at its peak. But Chakrabarty believes some physical mechanism—perhaps shedding of energy by gravitational waves—applied the brakes to the pulsar and its cousins soon after their rebirth.

–R.I.

CREDIT: SARAH ANDERSON/W. M. KECK OBSERVATORY

black hole at the center of our galaxy; and the physical properties of galaxies where supernovae exploded more than 8 billion years ago. "These are the big leaps we were looking for," says Keck Director Frederic Chaffee.

Chaffee says Keck went to school on a prototype laser system at the University of California's Lick Observatory near San Jose. Several 8-meter telescopes are now catching up with planned laser-guided science runs later this year, including the U.S.-led Gemini North and Japan's Subaru Telescope at Mauna Kea, and the European Southern Observatory's Very Large Telescope at Cerro Paranal, Chile.

Pesky Companions Warp the Milky Way

Our galaxy wins no prize for symmetry. Its disk of gas and stars bends upward and downward, like the brim of a trampled hat. Astronomers have long suspected that dwarf galaxies orbiting the Milky Way perturb the disk, especially the Magellanic Clouds—two smudges of stars visible from the Southern Hemisphere. At the meeting, researchers laid out fresh details of how that warping might occur. "It's a careful explanation for what's going on in the outer galaxy," comments astrophysicist David Spergel of Princeton University in New Jersey.

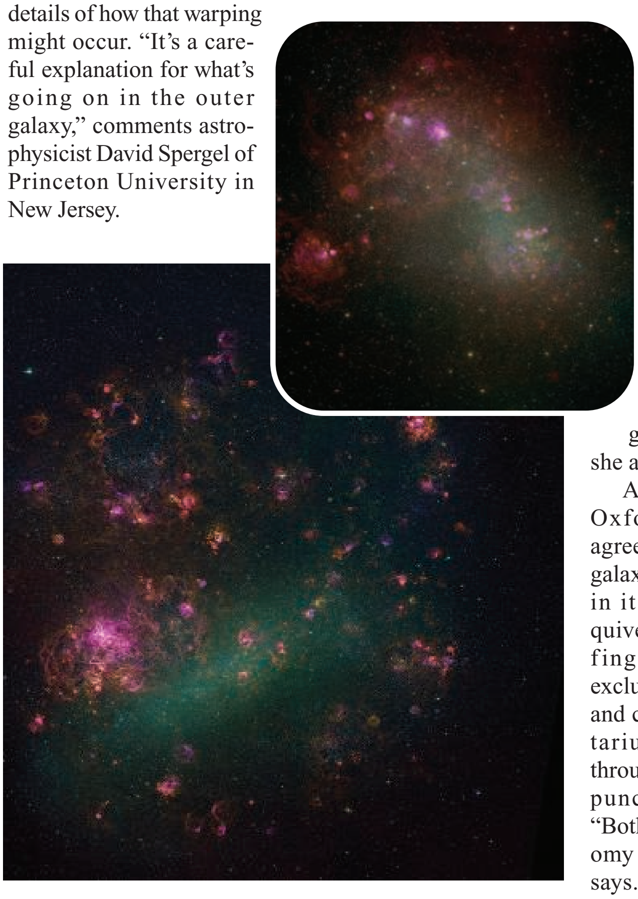
Important clues came from detailed radio images of neutral hydrogen gas in the Milky Way's disk, assembled by scientists in the Netherlands, Argentina, and Germany. Astronomer Leo Blitz of the University of California, Berkeley, and colleagues used the data to chart the asymmetric ebbs and flows of hydrogen above and below the disk. The team found that it could describe the warped shape as a mathematical superposition of three simple modes of vibration. Effectively, the Milky Way behaves like a vast cymbal anchored at its center.

Then, Blitz and dynamicist Martin Weinberg of the University of Massachusetts, Amherst, constructed a model of how the Magellanic Clouds might excite those vibrational modes. Although the two galaxies contain perhaps 2% of the Milky Way's mass, they exert an outsized influence thanks to one factor: dark matter. The dwarfs loop around our galaxy on lazy orbits lasting 1.5 billion years, slogging through the Milky Way's extended halo of hidden dark matter. Those motions raise persistent gravitational "wakes" that tug on the disk, Blitz says. The forces resonate strongly around the disk's edges, where gas is most loosely bound.

When Weinberg and Blitz ran their model, they were surprised to see the disk's outermost portions constantly flapping as the Magellanic Clouds trundled along. That impressed astronomer Linda Sparke of the University of Wisconsin, Madison, who notes that at least half of all galaxies have distorted disks. "This will help convince people that there are ways to get warps to live a long time," Sparke says. Thorough studies of the Milky Way's warp should let astronomers trace the extent and impacts of the galaxy's shroud of dark matter, she adds.

Astronomer James Binney of Oxford University in the U.K. agrees that "junk" falling onto our galaxy creates lumpy irregularities in its halo and makes the disk quiver. But he thinks it's hasty to finger the Magellanic Clouds exclusively. In particular, a smaller and closer galaxy called the Sagittarius dwarf is now plunging through the Milky Way's disk, so its punch may contribute as well. "Both the dynamics and the astronomy are a bit of a mess," Binney says. "I don't think this story will close off any time soon."

–ROBERT IRION



Warped. The Magellanic Clouds, both large and small (*inset*), bend our galaxy's disk of gas and stars.

CREDIT: NASA/ESA/A. SCHALLER (FOR STSCI); C. SMITH/S. POINTS/MCELS TEAM/NOAO/AURA/NSF; F. WINKLER, MIDDLEBURY COLLEGE/MCELS TEAM/NOAO/AURA/NSF (INSET)

Snapshots From The Meeting >>

Bulging waist. Vega, a bright star in the northern sky, barely holds itself together. The combined light from six widely spaced 1-meter telescopes at Mount Wilson, California, resolved fine details on Vega's surface. Interferometry patterns showed that gas at Vega's equator is a whopping 2300 kelvin cooler than at its pole, caused by the star's grossly distorted shape as it rotates once every 12.5 hours. Modeling led by astronomer Jason Aufdenberg of the National Optical Astronomy Observatory in Tucson, Arizona, suggests that Vega would break apart if it spun only 9% faster.

Doomed giants. Infrared telescopes have exposed the heftiest group of the biggest stars. Of about 200 known red supergiants in our Milky Way, 14 reside in a tight cluster previously hidden behind dust toward the galaxy's center (artist's conception, above). Each unstable supergiant is roughly 1000 times as large as our sun. On average, one star should explode in a supernova every 20,000 to 60,000 years, says astronomer Donald Figer of the Rochester Institute of Technology in New York. Recent blasts in the cluster explain a distinct buzz of gamma rays and radio waves from that part of the sky.

Nearly perfect. Those who enjoy geometric beauty in nature will gravitate to PSR J1909-3744, a rapidly spinning pulsar 3700 light-years away. For nearly 2 years, astronomer Bryan Jacoby of the Naval Research Laboratory in Washington, D.C., and colleagues clocked the arrival times of about 19 billion of the pulsar's blips. The accurate timing revealed that the pulsar's orbit, around a tiny companion star, tracks the most circular path yet seen in space. The orbit spans more than 1 million kilometers, but its major axis is just 11 *micrometers* wider than its minor axis.

–R.I.

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