NEUTRINO MINE HITS PAY DIRT

In the subatomic particle family, the neutrino is a bit like a wayward stepson. Neutrinos were long ago detected—and even longer ago predicted to exist—but everything we know about nuclear physics says there should be a certain number of them streaming from the sun, yet there are nowhere near enough. Now an international team, including Professor of Physics Robert McKeown, has revealed that this deficit is real, and not merely an observational quirk or something unknown about the sun's interior. The team used the KamLAND detector deep in the Kamioka mine in Japan. Thus shielded from background and cosmic radiation, the detector is optimized for measuring the neutrinos from all 17 nuclear power plants in the country.

Solar neutrinos are produced when two protons fuse together to form a deuterium nucleus, a positron, and a neutrino. The positron eventually annihilates both itself and an electron, while the neutrino, being very unlikely to interact with matter, escapes into space. Therefore, neutrinos should flow from the sun like photons from a light bulb—radiating evenly in all directions, as if the surface of a sphere were being illuminated from its center. And because a sphere's surface area increases as the square of its radius, an observer standing 20 feet away would see only one-fourth the photons of an observer 10 feet away.

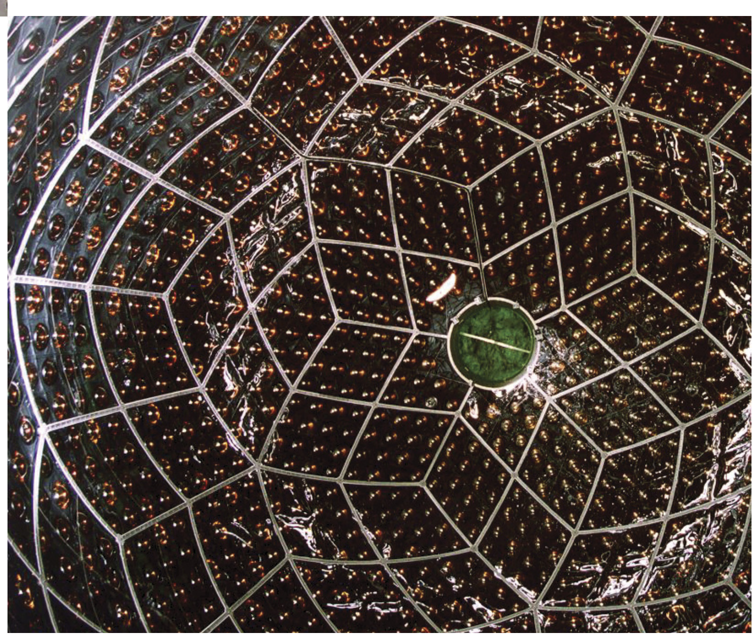
Thus, we expect to see a given number of neutrinos coming from the sun—assuming we know the proton-fusion rate—just as we can predict the luminosity of a light bulb at a given distance if we know the bulb's wattage. But carefully constructed experiments have found far fewer solar neutrinos than there should be.

One explanation is that the neutrino "flavor" oscillates between the detectable "electron" neutrino type, and the much heavier "muon" neutrino and maybe even the "tau" neutrino, neither of which can be detected. Quantum-mechanical calculations predict that the number of detectable electron neutrinos oscillates steadily, from 100 percent down to a small percentage and back again. Therefore, the theory says, we see only about half as many neutrinos as we should because about half of them are at that moment in one of the undetectable flavors.

At KamLAND, physicists can, for the first time, observe neutrino oscillations without making assumptions about the properties of the source of neutrinos. Because power plants have very precisely known amounts of material generating the particles, it is much easier to determine with certainty whether the oscillations are real. Power plants run on nuclear fission, in which an atom breaks apart to form two smaller atoms, an electron, and an antineutrino (the antimatter equivalent of a neutrino). But matter and antimatter are thought to be mirror images of each other, so power-plant antineutrinos should behave exactly like solar neutrinos.

"This is really a clear demonstration of neutrino disappearance," says McKeown. "Granted, the laboratory is pretty big—it's Japan—but at least the experiment doesn't require the observer to puzzle over the composition of astrophysical sources."

In addition to McKeown's team at Caltech, other partners in the study include the Research Center for Neutrino Science at Tohuku University in Japan, the University of

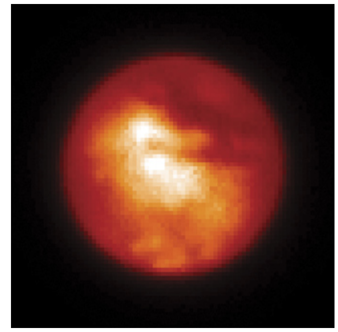


Professor of Physics Robert McKeown (above) scrubs the inside of KamLAND's neutrino detector—a stainless steel sphere (right), 18 meters in diameter and lined with about 2,000 photomultiplier tubes to catch the elusive flash of a neutrino hitting 1,000 tons of what is essentially heavily doped baby oil. So sensitive is the detector that a single speck of dust within it could emit enough natural radioactivity to queer the readings.

Alabama, the University of California at Berkeley and the Lawrence Berkeley National Laboratory, Drexel University, the University of Hawaii, the University of New Mexico, Louisiana State University, Stanford University, the University of Tennessee, Triangle Universities Nuclear Laboratory, and the Institute of High Energy Physics in Beijing.

The project is supported in part by the U.S. Department of Energy. □—*RT*

THE METHANE RAIN FALLS MAINLY ON TITAN



This Keck image of Titan shows several small, bright clouds of methane near the south pole (bottom), as well as the large, bright "continent" at the equator.

Teams of astronomers at Caltech and UC Berkeley have discovered bright clouds of methane near Titan's south pole. The observations were made using the W. M. Keck II 10-meter and the Gemini North 8-meter telescopes atop Hawaii's Mauna Kea volcano. Titan is Saturn's largest moon, larger than the planet Mercury, and is the only moon in our solar system with a thick atmosphere. Like Earth's atmosphere, Titan's is mostly nitrogen. But Titan's lack of atmospheric oxygen and its extremely cold surface temperatures (–183° C) make it inhospitable to life. Titan's atmosphere also contains a significant amount of methane.

Earlier spectroscopic observations hinted at the existence of clouds on Titan, but gave no clue as to their location. These early data were hotly debated, since Voyager spacecraft measurements of Titan appeared to show a calm and cloud-free atmosphere. Furthermore, previous images of Titan had failed to reveal clouds, finding only unchanging surface markings and very gradual seasonal changes in the haziness of the atmosphere.

The Keck and Gemini telescopes are outfitted with

SHEAR STRESS IS GOOD FOR THE HEART

In a triumph of bioengineering, an interdisciplinary team at Caltech has seen, for the first time, the blood flow inside the beating hearts of embryonic zebrafish. The results reveal that high-velocity blood flowing over cardiac tissue is important for proper heart development, which could have profound implications for future surgical techniques. The team obstructed the blood flow through the hearts, which are finer than a human hair, and followed the action on very-high-resolution videos. The reduced "shear stress," or friction imposed by the flowing fluid on its surroundings, led to serious heart defects.

Thus, says co-lead author Jay Hove, more detailed studies of shear force might illuminate human heart disease. Congestive heart failure, for example, causes the heart to enlarge due to constricted blood flow, so a precise understanding of the flow could lead to ways to counteract the enlargement. And exploring the genetic factors involved with blood flow in the heart—a future goal of the team's research—could aid in the diagnosis of prenatal heart disease. "Our research shows that the shape of the heart can be changed during the embryonic stage," says Hove. "The results invite us to consider whether this can be related to the roots of heart failure and heart disease."

Hove, a bioengineer, along with Liepmann Professor of Aeronautics and Bioengineering Morteza Gharib (PhD '83), teamed with Scott Fraser, the Rosen Professor of Biology, and co-lead author Reinhardt Köster, a postdoc in Fraser's lab. Gharib, a specialist on fluid flow, has worked on heart circulation in the past, and Fraser is an authority on the imaging of cellular development in embryos. The effort is thus a marriage of engineering, biology, and optics.

The researchers used zebrafish because their one-millimeter eggs and the embryos inside them are nearly transparent. The embryos were treated to block the formation of additional pigment, and "optically dissected" via confocal microscopy, which allows the imaging of a layer of tissue. The two-dimensional images are "stacked" to make a three-dimensional reconstruction.

Köster microsurgically inserted beads into the embryos' hearts to block the blood flow, nearly eliminating the shear forces. The obstructions had a profound effect—when observed two to three days later, the tiny hearts had not formed valves properly, nor did they "loop," or form an outflow track properly. Because the early development of an embryonic heart is thought to proceed through several nearly identical stages in all vertebrates, the effect should also hold true for human embryos.

The researchers will now attempt to see how slight variations in the shear force affect structural development, and explore how gene expression is involved in embryonic heart development.

The team also includes grad students Arian Forouhar and Gabriel Acevedo-Bolton (MS '99). The work appears in the January 9, 2003 issue of *Nature*. □—*RT* adaptive optics, in which a flexible mirror compensates for distortions caused by turbulence in Earth's atmosphere. (These distortions cause the stars to twinkle.) Details as small as 300 kilometers across were distinguished on Titan, a stupendous 1.3 billion kilometers away—the equivalent of reading a car's license plate from 100 kilometers, and finer than the details seen by the Voyager spacecraft at their closest approach.

"We see the intensity of the clouds varying over as little as a few hours," said postdoc Henry Roe, lead author for the Berkeley group. "The clouds are constantly changing, although some persist for as long as a few days."

Titan experiences seasons much like Earth, though its year is 30 times longer due to Saturn's great distance from the sun. Titan is currently in the midst of its southern summer and its south pole has been in continuous sunlight for over six Earth years, which may explain the clouds' location.

"These clouds appear to be similar to summer thunderstorms on Earth, but formed of methane rather than water. This is the first time we have found such a close analogy to the Earth's atmospheric water cycle in the solar system," says Caltech grad student Antonin Bouchez.

In addition to the clouds above Titan's south pole, the Keck images, like previous data, show a bright, continent-sized feature that may be a large icy highland, surrounded by linked dark regions that are possibly ethane seas or tar-covered lowlands.

"These are the most spectacular images of Titan's surface we've seen to date," says Michael Brown, associate professor of planetary astronomy and lead author of the Caltech paper. "They are so detailed that we can almost begin to speculate about Titan's geology, if only we knew for certain what the bright and dark regions represented."

In 2004, Titan will be visited by JPL's Cassini spacecraft, which will look for clouds on Titan during its multiyear mission around Saturn. Cassini carries a probe named Huygens, furnished by the European Space Agency, which will parachute into Titan's atmosphere and land near the edge of the bright continent.

The results were published by the Caltech team in the December 19 issue of *Nature* and by the Berkeley team in the December 20 issue of the *Astrophysical Journal*. The Caltech team includes Brown, Bouchez, and Caitlin Griffith of the University of Arizona. The Berkeley team consists of Roe, Imke de Pater, Bruce Macintosh of Lawrence Livermore National Laboratory, and Christopher McKay of the NASA Ames Research Center. The research was

A Letter to the Editor

It was a pleasure reading Doug Smith's profile on Charley Kohlhase, a man of remarkable and varied talents. As the former media relations representative for the Cassini mission, I will always be grateful to Charley for saying "yes" to my design idea and funding the development of Cassini's "Amazing Saturn" poster.

The inspiration was provided when JPL's former education head Phil Neuhauser gave me a color copy of an old *Amazing Stories* magazine cover. It featured a painting of ice skaters on the imagined surface of Mimas, one of Saturn's moons. The ringed planet dominated the horizon. It seemed a natural starting point for a poster to depict the Cassini mission, replacing "Amazing Stories" with "Amazing Saturn." Fortunately, Charley was enthusiastically receptive to my idea and crude sketch. He provided the resources and oversight, and we were able to adapt already-commissioned artwork to the vertical poster design.

I'm also grateful to the classroom teachers who advised the Cassini education outreach team, telling us we'd garner more student interest if we designed a poster with inspiring, mind-opening artwork. Hence, the eye-catching "Amazing Saturn" poster, with the curriculum-friendly information about the Saturn system and Cassini mission printed on the back.

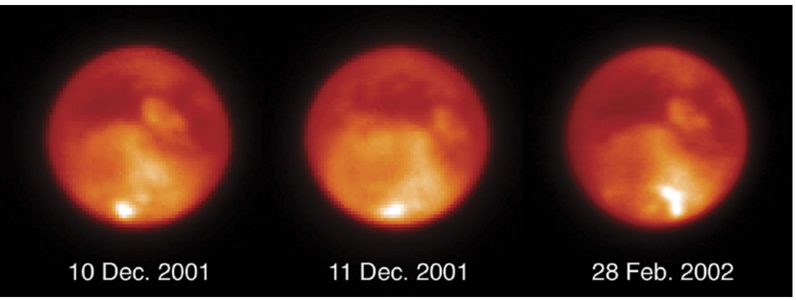
Sincerely,
Mary Beth Murrill

Interfering RNA Keeps the HIV at Bay

Caltech and UCLA researchers have developed a new gene therapy that is highly effective in preventing the HIV virus from infecting individual cells in the immune system. While not curative, the method could reduce the number of HIV-infected cells in the bodies of people who have the virus. Reporting in the January 7, 2003 issue of the *Proceedings of the National Academy of Sciences*, Caltech president and professor of biology David Baltimore and collaborators used a disabled version of the virus as a "Trojan horse" to smuggle a disruptive agent into human T-cells, thereby reducing the likelihood that a potent HIV virus will be able to successfully invade the cell. Early laboratory results show that more than 80 percent of the T-cells may be protected.

"To penetrate a cell, HIV needs two receptors that operate like doorknobs and allow the virus inside," says Baltimore. "HIV grabs the receptor and forces itself into the cell. If we can knock out one of these receptors, we hope to prevent HIV from infecting the cell." The receptors are called the CCR5 and the CD4. The human immune system can't get along without the CD4, but about 1 percent of the Caucasian population is born without the CCR5. These people are known to have a natural immunity to AIDS. Therefore, the researchers disrupted the CCR5 receptor with a special double-stranded RNA known as "small interfering RNA," or siRNA, engineering a disabled HIV virus to carry it into the T-cell. (The disabled funded in part by grants from the National Science Foundation and NASA. □

These Keck images of Titan show essentially the same face in all three shots. The bright storm cloud in the February 28 image is over 1,400 kilometers long.



virus has no disease-causing ability.) Once inside the T-cell, the siRNA knocked out the CCR5 receptor. When the T-cells were put in a petri dish and exposed to HIV, less than 20 percent of them became infected.

"Synthetic siRNAs are powerful tools," says Irvin Chen, an author of the paper and director of the UCLA AIDS Institute. "But scientists have been baffled at how to insert them into the immune system in stable form. You can't just sprinkle them on the cells."

"Our findings raise the hope that we can use this approach or combine it with drugs to treat HIV in people—particularly in persons who have not experienced good results with other forms of treatment," says Baltimore. The technique can also potentially be used for other diseases when a specific gene needs to be knocked out, such as the malfunctioning genes associated with cancer, Chen says. "We can easily make siRNAs and use the carrier to deliver them into different cell types to turn off a gene malfunction." It could also be used to prevent certain microorganisms from invading the body, Baltimore adds.

The paper's other two authors are Caltech postdoc Xiao-Feng Qin and UCLA postdoc Dong Sung An. The two contributed equally to the work.

The research is supported by the National Institute of Allergy and Infectious Diseases and the Damon Runyon–Walter Winchell Fellowship. □

Image credits: NASA, Jayanne English (U. of Manitoba), Sally Hunsberger (Penn State), Zolt Levay (STScI), Sarah Gallagher (Penn State), and Jane Charlton

The Hubble Space Telescope's Wide Field and Planetary Camera 2, designed and built at JPL, caught this close-up of a galaxy cluster known as Stephan's Quintet. It reveals that the upper two galaxies collided violently, bedecking themselves with a diamond necklace of star-forming regions. A gentler side of the quintet is seen in the opening scenes in Frank Capra's *It's a Wonderful Life*, in which they play the heavenly bureaucrats who dispatch the bumbling Clarence to George Bailey's aid. Caltech is honoring Capra, who graduated in 1918, with a film festival that includes four of his movies (although not this one). Details can be found at http://events.caltech.edu.