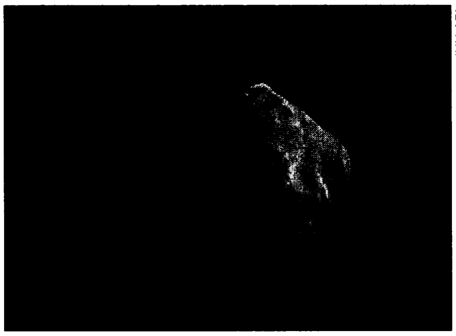
PLANETARY SCIENCE

Does Mathilde Have a Broken Heart?



Not as solid as she looks. Gravity data suggest Mathilde's interior is disrupted.

LAUREL, MARYLAND—Seen in the first images from a passing space probe, the asteroid Mathilde was stunning enough, adorned with incredibly deep, shadowed craters. But when the probe radioed back the first clues about the interior of the 52-kilometer asteroid last week, researchers were in for another surprise: They found only a third of the mass they had expected. The discovery supports the claim that most asteroids are heaps of rocks loosely held together only by their own gravity. Eons of banging about in the asteroid belt, it seems, have reduced Mathilde, and perhaps most asteroids, to piles of flying rubble.

Mathilde, the largest asteroid to date to be viewed up close, was imaged by the low-cost, Discovery-class Near Earth Asteroid Rendezvous (NEAR) spacecraft, which is on its way to an encounter with the asteroid Eros in 1999. The spacecraft carries no instrument that could directly probe an asteroid's interior, but NEAR's radio managed to do so indirectly, as researchers reported at a press conference here last week. As the spacecraft passed within 1200 kilometers of Mathilde, the asteroid's feeble gravity slightly deflected NEAR's path. By monitoring the Doppler frequency shift in the spacecraft's radio signal during the flyby, researchers inferred that Mathilde slowed down the spacecraft by 1 millimeter per second—about the speed of a sluggish ant, said NEAR team member Donald Yeomans of the Jet Propulsion Laboratory (JPL) in Pasadena, California.

From that minuscule slowing, Yeomans calculated a mass for Mathilde of 10^{17} kilograms, or a millionth the mass of Earth's moon. Assuming an average diameter of 52 kilometers (a preliminary value determined from NEAR images), Mathilde has a density of just 1.3 grams per cubic centimeter—not much more than water. But meteorites thought to have been chipped off this type of common asteroid are typically twice as dense, or 2.6 grams per cubic centimeter. "We've got an object considerably lighter than we thought," says celestial mechanicist Yeomans. "If it were any lighter, it could float."

Although Mathilde's apparent low density may rise somewhat as researchers take better account of its irregular shape, it's unlikely that the final estimate will approach the density of solid rock, notes asteroid specialist Alan Harris of JPL. The most likely explanation, he says, is that Mathilde is a conglomeration of blocks, boulders, and loosely compacted debris. There have been earlier signs that asteroids are rubble piles (*Science*, 1 January 1993, p. 28; 26 April 1996, p. 485), but this is the most direct evidence yet, says Harris. Mathilde's apparent density bears on problems such as the collision history of asteroids and strategies for protecting Earth from future asteroid collisions.

The finding could also have implications for NEAR's future if Eros, too, is a low-density body with unexpectedly weak gravity. In January 1999, when controllers aim to put NEAR into orbit around Eros, they will have to keep Mathilde's broken heart in mind.

–Richard A. Kerr

PARTICLE PHYSICS

Case for Neutrino Mass Gathers Weight

"Neutrinos, they are very small / They have no charge they have no mass / And do not interact at all," runs the poem by John Updike. Physicists have known for decades that Updike is mistaken on one count at least: Neutrinos do interact with matter, albeit very feebly. Many are now convinced, however, that he is also wrong about the mass. Three new experimental results, announced last week at a meeting on the Italian island of Capri near Naples, add to hints that neutrinos might indeed have a very small mass.

The three experimental groups approached the question from different directions, two of them by using massive underground detectors to capture neutrinos streaming from the upper atmosphere, and one by studying neutrinos made with an accelerator. But all three believe they may be seeing signs of "neutrino oscillations," in which neutrinos—which come in three "flavors" called electron, muon, and tau—spontaneously switch from one flavor to another. Oscillations can take place only if neutrinos have mass. "We have evidence, in fact, I believe strong evidence, that oscillations are occurring," says Bill Louis, spokesperson for the accelerator experiment—the Liquid Scintillator Neutrino Detector (LSND) at Los Alamos National Laboratory in New Mexico.

Mining for mass. The 1000 tons of corrugated iron at the heart of the Soudan 2 detector in northern Minnesota.

Whether the humble neutrino has a mass is a weighty matter for physicists. Massive neutrinos could help account for the universe's "missing mass," the extra heft astronomers believe must be out there but have not been able to find; neutrino oscillations might also explain why the sun appears to produce fewer neutrinos than theorists expect; and neutrinos with mass would offer a first step outside the Standard Model—the tried-and-tested description of nature's fundamental particles and forces. "The Standard Model, as it stands, doesn't have room for massive neutrinos," says Oxford University physicist Hugh Gallagher, a member of the Soudan 2 experiment in the Soudan iron mine in northern Minnesota, one of the two groups studying atmospheric neutrinos.

Hints of oscillations had already emerged from a previous LSND experiment (*Science*, 10 May 1996, p. 812) and from earlier atmospheric neutrino studies. But the trio of new results may be more compelling. The two atmospheric neutrino experiments offer better statistics and rely on two different detector technologies, and the LSND group has devised new ways to produce and detect their neutrinos. Even so, theorists are scrutinizing the new results very carefully before rushing to rewrite their models. One reason for the skepticism is that the two sets of results seem to deliver different messages about how neutrinos oscillate. "The LSND results are apparently not consistent with atmospheric neutrino results," says Yoji Totsuka, spokesperson for Japan's Super-Kamiokande group, the other team reporting atmospheric neutrino results.

The Soudan and Super-Kamiokande claims rest on a single calculation: the relative numbers of electron and muon neutrinos created when cosmic rays collide with particles in the upper atmosphere. "This ratio is simple to calculate and is quite robust," says theorist Tom Gaisser of the University of Delaware.

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> **—Bill Louis**

Both Soudan 2 and Super-Kamiokande aim to measure this ratio to see if any of the neutrinos have oscillated to a different type en route between the upper atmosphere and the detectors deep underground. Based in the Kamioka laboratory west of Tokyo, the Super-Kamiokande detector snares neutrinos in a 50,000-ton water tank watched by 13,400 photodetectors. An electron neutrino crashing into nuclei in the water produces an electron, a muon neutrino, and a muon. The electron and muon, being charged, create distinctive flashes of light that are picked up by the detectors. Soudan 2 works on a similar principle, but relies on 1000 tons of corrugated iron sheets interspersed with sensitive charged-particle detectors.

"We have observed a smaller muon-neutrino-to-electron-neutrino ratio as compared to the expectation of the atmospheric neutrino flux calculations," says Kenzo Nakamura, reporting Super-Kamiokande's results at Capri. The Soudan result is "in line" with Super-Kamiokande's, according to Gallagher. "What we've measured is a result which is only about 60% or 65% of what we expect based on the Standard Model," he says, adding, "The fact that they measure essentially the same result in very, very different detector technologies serves as a strong indication that what we're measuring is not some artifact of our experimental apparatus."

Instead of relying on nature to supply their neutrinos, the LSND team at Los Alamos drives a proton beam from an accelerator into a water target to create particles called pions. These then spawn other particles, including muon neutrinos. Thirty meters away is the neutrino detector itself, consisting of 167 tons of mineral oil under the watchful gaze of 1220 photodetectors. The new LSND experiment, reported at Capri by team member Geoff Mills, detected a couple of dozen excess electron neutrinos in the beam, which originally contained only muon neutrinos. If what the group sees really is due to oscillations, then these results, together with their earlier ones, show that "roughly about a third of a percent of the muon neutrinos … will turn into electron … neutrinos," says Louis.

Weaving together the threads of evidence is not straightforward, however. "The solar neutrino deficit, atmospheric [neutrinos], and Los Alamos—they are not all consistent," says Adam Para of the Fermi National Accelerator Laboratory near Chicago. "At least one of them must be due to something else, or something that we didn't think of," he says. Louis, however, believes these are simply wrinkles that theorists will be able to iron out. "They could be seeing different aspects of oscillations," he says.

Others, such as physicist Douglas Morrison at the CERN particle physics lab near Geneva, are less sanguine. Morrison suspects that dubious assumptions behind the calculations, rather than oscillating neutrinos, might explain both the solar and atmospheric shortfalls. Although Gallagher, Nakamura, and others say the uncertainty in estimates of the ratio of electron to muon neutrinos generated by cosmic rays is about 5%, "my feeling is that the error is bigger than 5%," Morrison says. As for the LSND result, he says, "I think the majority of the community is skeptical."

But Oxford's Wade Allison, another member of the Soudan 2 team, thinks the evidence for oscillations cannot be discounted: "I am completely convinced there is a real [neutrino] problem, and I also believe that neutrino oscillations are the only show in town to explain that problem." New experiments will win the day, he says, by revealing more of the properties of neutrino oscillations than simple ratios, such as actual mass differences and identity-switching probabilities. Adds Allison: "We've really got to try and tie the thing down, and then it will be convincing."

–Andrew Watson

Andrew Watson is a science writer in Norwich, U.K.

ALZHEIMER'S RESEARCH

New Lesion Found in Diseased Brains

For years, researchers praying for clues that might lead to a new treatment for Alzheimer's disease have had two congregations to choose from: the "BAPtists," who attribute the disease mainly to the β-amyloid protein (sometimes known as BAP) found in plaques that riddle the brains of Alzheimer's patients, and the "Tauists," who suspect that the misbehavior of a neuronal protein called tau is more central. Now, with the detection of a third type of lesion that has apparently lain hidden ever since Alois Alzheimer began studying the disease 90 years ago, a new sect may be in the making.

SCHMIDT ET AL.

Invisible enemy. Antibody staining reveals AMY plaques (green), which are similar to the more familiar amyloid plaques (red) but have no amyloid core.

The new lesions are known for now as "AMY plaques," because they were initially mistaken for amyloid plaques. They appear to be nearly as widespread in the brains of Alzheimer's patients as the more familiar plaques and tangles of tau proteins, according to a team led by neuropathologist John Trojanowski and neuroscientist Virginia Lee at the University of Pennsylvania School of Medicine in Philadelphia, who report their work in the July issue of the *American Journal of Pathology*. That means the AMY plaques could represent an unrecognized cause of the dreaded memory-depleting disease, which strikes 5% of people over age 65.

"I feel very excited about it," says neuroscientist Zaven Khachaturian, director of the Alzheimer's Association's Ronald and Nancy Reagan Research Institute in Chicago. "This opens new vistas for us in terms of conceptualizing what's happening in the disease, and it may even give us new diagnostic tools and new targets for treatment." But he and others note that this promise won't be realized soon, because researchers still aren't certain how or even whether the familiar amyloid plaques and neurofibrillary tangles cause neuronal deterioration.

The Penn researchers discovered the new lesions by accident while trying to learn more about the tau protein, which is normally found inside neurons but congeals in extracellular masses in the brains of Alzheimer's patients. Two years ago, Trojanowski and Lee reported from studies of biopsied and autopsied tissue