Ghostlike particles carry a little weight

Capping 40 years of research into one of physics' most elusive particles, a team of U.S. and Japanese researchers has presented strong evidence that neutrinos possess mass.

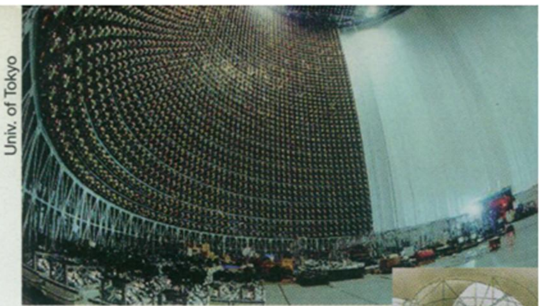
Although similar claims have appeared in recent years (SN: 5/18/96, p. 319), physicists have not generally been convinced by the evidence. The new finding comes from a wealth of data recorded at the world's biggest neutrino detector, located about 125 miles west of Tokyo, which provided more than a 10-fold leap in observational power when it began operation in April 1996.

The tiny neutrinos rarely collide with other particles, and the standard model of physics assumes they lack mass. The finding that neutrinos have mass—if confirmed—would be the first experimental evidence supporting a broader model of particle physics. Such models, including the so-called Grand Unified Theories, seek a common foundation for seemingly different forces of nature.

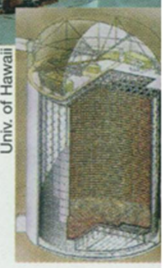
The report, presented June 5 at the Neutrino '98 Conference in Takayama, Japan, thus represents "certainly one of the most important advances in particle physics in the last couple of years," says John N. Bahcall, an astrophysicist at the Institute for Advanced Studies in Princeton, N.J.

Neutrinos are so abundant in the cosmos—billions of times more plentiful than electrons—that with even a small mass they could add up to a significant portion of the density of the universe, some astrophysicists suspect. The gravity exerted by neutrinos could mold the shape of galaxies or even reverse the expansion of the universe, they speculate.

The new findings offer no direct measurement of neutrinos, but they do provide indirect evidence of a mass on the order of one five-millionth that of an electron—itself a lightweight among particles. This puts the cumulative mass of all neutrinos "at the lower end of the range to be cosmologically important," comments particle theorist Lawrence M. Krauss of



Univ. of Tokyo



Univ. of Hawaii

Photodetectors lining the wall of the Super-Kamiokande detector record brief light flashes from neutrino collisions. Inset: Cutaway view of the 10-story detector.

Case Western Reserve University in Cleveland, Ohio, who was not on the research team.

The team of about 100 scientists from 11 U.S. and 11 Japanese institutions studied neutrinos created by cosmic rays bombarding Earth's atmosphere. Since 1985, instruments on Earth have detected fewer of one type, the muon neutrino, than theory had predicted.

Scientists suggested that this shortfall occurs because neutrinos come in three varieties that change back and forth into each other in flight, a process called oscillation. According to quantum mechanics, such switching requires neutrinos to possess mass.

Researchers searched for evidence of oscillations using the Super-Kamiokande detector, a steel cylinder 10 stories tall containing 12.5 million gallons of water. It is housed in a mine extending 3,000 feet beneath the Japanese Alps. Neutrinos entering the detector collide with water molecules, generating light patterns that are monitored by the 11,000 photomultiplier tubes in the cylinder's wall.

Compared to previous experiments, the Super-Kamiokande offered a target big enough to record a statistically significant variation in neutrino numbers, which indicates oscillation, the researchers say. The data showed that muon neutrinos coming from directly overhead reached the target at the expected rate. Those entering from below, having passed through the entire planet, showed up at only about half the predicted rate.

The researchers concluded that some of the muon neutrinos changed into another variety during their terrestrial trip. Data comparing muon neutrinos that moved through Earth at different energies and along paths of different lengths also support the presence of oscillations. "It's not consistent with anything else," Krauss says.

Researchers plan additional experiments to seek further evidence of neutrino oscillation. In Japan and the United States, they propose to use accelerators to fling neutrinos at targets several hundred kilometers away. Also, the Sudbury (Ontario) Neutrino Observatory will examine a well-known deficit of neutrinos coming from the sun. —*J. Brainard*

High-tech images shrink fossil braincase

Current theories about brain evolution in humans and prehistoric hominids may need revision, according to a new study based on computer-generated images of the inside of a fossil cranium.

Computerized reconstructions of a 2.8- to 2.6-million-year-old hominid braincase found in South Africa and attributed to *Australopithecus africanus* place its volume at about 515 cubic centimeters—much less than an earlier rough estimate of at least 600 cubic centimeters, reports a team directed by anthropologist Glenn C. Conroy of Washington University School of Medicine in St. Louis.

Cranial volume of other australopithecines may have been overestimated in previous studies as well, Conroy's group suggests in the June 12 SCIENCE.

"The implication of [the South African specimen's] surprising cranial capacity is that something is very wrong with the published record of early hominid cranial capacities," writes anthropologist Dean Falk of the State University of New York at Albany in an accompanying comment.

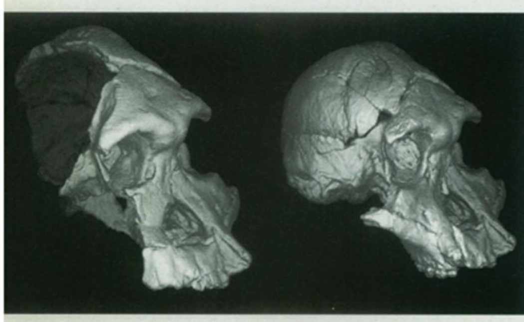
Conroy and his coworkers studied a presumably male specimen, discovered in 1989, that retains much of its face and the left side of its cranium. Using anatomical landmarks on remaining parts of the braincase, the researchers generated a complete, three-dimensional computerized tomography (CT) image of the cranium. They then used the computer to create an image of the cranium's inner surface and calculated a volume of 513 cubic centimeters.

They revised that figure to 515 cubic centimeters, based on the overall volume determined by 106 two-dimensional CT "slices" taken throughout the braincase and on the volume of water needed to fill a cast of the fossil cranium.

Preliminary water-volume results for another *A. africanus* cranium reach only about 370 cubic centimeters, down from a prior estimate of 428 cubic centimeters based on a plaster cast, the scientists add.

During the 1980s, debate raged over how to make and interpret plaster molds of the inner surfaces of fossil craniums. This controversy will not go away, says anthropologist Ralph L. Holloway of Columbia University, because CT re-creations of partial skulls still hinge on researchers' judgments about the presence and location of various anatomical landmarks.

Holloway, who conducted early analyses of cranial capacity in several australopithecine skulls, doubts that CT imaging will substantially alter his original estimates. —*B. Bower*



Conroy/SCIENCE

CT images show a partial hominid skull (left) and the same specimen with reconstructed cranial areas.