Possible First Hints of Double Beta Decay

A new experimental result may require an extension of the standard theories of particle physics; but as always, the first question is whether the result is correct

PHYSICISTS from South Carolina and Washington State, working with an ultrasensitive detector located deep in a South Dakota gold mine, have uncovered evidence of a phenomenon known as neutrinoless double beta decay. If true—and the researchers themselves are the first to urge caution—their finding would be the first direct indication of physical principles lying outside the standard model of the strong, weak, and electromagnetic interactions.

The results were reported in Salt Lake City at the January meeting of the American Physical Society's Division of Particles and Fields. The experimenters were Frank T. Avignone III and Harry S. Miley of the University of South Carolina, and Ronald L. Brodzinski and James H. Reeves of the Pacific Northwest Laboratory in Richland, Washington.

In the conventional theory of weak interactions, explains Avignone, beta decay is well understood: a neutron simply transforms itself into a slightly less massive proton, and sheds the leftover energy by firing off an electron—historically known as a "beta" particle—and an antineutrino. In fact, this is one of the most common forms of radioactivity. The conventional theory also has a place for double beta decay, he says: very rarely, two neutrons in a large nucleus will decay simultaneously, thereby producing a pair of electrons. Isotopic analyses of billion-year-old rocks has shown that this process does indeed take place at about the rate predicted. However, conventional double beta decay also releases two antineutrinos. What Avignone and his colleagues have been looking for is double beta decay with *no* antineutrinos.

The existence of such an effect was first suggested in the early 1980s. At the time, physicists were excited by experimental hints that the supposedly massless neutrinos might actually have a small mass, perhaps a few electron volts. Astrophysicists were likewise invoking massive neutrinos to solve a number of conundrums in cosmology. Although enthusiasm for massive neutrinos has cooled since then, the theorists have nonetheless come up with a variety of mechanisms for producing neutrino mass. In particular, a model devised by European physicists in 1981 predicted that neutrinos would not only have mass, but would couple to a new, massless, and very weakly interacting particle known as a majoron. True, their model was based on some decidedly unconventional assumptions. For example, the neutrino would have to be its own antiparticle. (The mathematical framework for describing such an entity was devised in the 1930s by the late Italian physicist Ettore Majorana; thus the name "majoron.") Furthermore, a hitherto sacrosanct conservation law would have to be violated: the lepton number of the universe—that is, the total number of electrons, neutrinos, muons, and other particles in the so-called lepton family, minus the total number of antileptons—would not necessarily stay constant in particle reactions.

"We're talking about a bizarre little corner of particle physics. It's just a logical possibility."

On the other hand, this model did provide some testable predictions, including two modes for neutrinoless double beta decay. In the first, an antineutrino is emitted by one decaying neutron and is absorbed by the other before it can escape. In the second, the two decaying neutrons both produce antineutrinos, but the latter particles immediately coalesce into a majoron. It is this second decay mode that Avignone and his colleagues believe they have seen.

Their detector, one of several double beta decay experiments under way worldwide, is distinguished by its very low background, says Avignone. It essentially consists of a heavily shielded, 0.72-kilogram crystal of germanium located in South Dakota's Homestake gold mine, adjacent to the well-known solar neutrino experiment conducted by Raymond Davis of Brookhaven National Laboratory. The detector is protected from cosmic rays by some 1600 meters of overlying rock; moreover, the researchers have taken great pains to minimize naturally occurring radioactivity in the detector's own electronics and shielding material. The idea is to lower the background enough that they can observe double beta decay events in the germanium nuclei themselves; the escaping electrons would perturb the electronic structure of the crystal and thus produce a detectable signal. The result: after 401 days observing the energy distribution of the signals, Avignone and his colleagues have identified a group of some 600 counts forming a broad peak with the shape and location expected from neutrinoless double beta decay with majoron emission. (The other neutrinoless decay mode, with no majoron emission, was not observed; presumably it proceeds at a much lower rate.)

Obviously, say the researchers, such a result is far from being definitive. At a minimum they intend to improve their statistics with more running time and further refinements in sensitivity. Nonetheless, the peak is already 6 standard deviations away from being a random fluctuation, and has resisted every attempt to explain it away as background. "The main purpose in publishing the present results now is to . . . stimulate independent searches for similar effects," they write in a prepublication report that has been widely circulated in the physics community.

It must be said, however, that the community has thus far reacted with a mixture of skepticism and wait-and-see. A typical response is that of Harvard University physicist Sheldon L. Glashow, a Nobel laurate who was among the first to analyze the possibilities of neutrinoless double beta decay: "I don't believe anything until it is confirmed," he says. "Almost anything you can imagine has been discovered at least once."

One reason for being skeptical is that the majoron model was developed ad hoc, as a way of giving neutrinos a mass. "We're talking about a bizarre little corner of particle physics," Glashow says. "Nobody's pushing this as part of a beautiful unification scheme. It's just a logical possibility." Of course, if the results are true they are very important, he adds. In that case the majoron mechanism must be a part of the grander unification, and theorists will have to get busy finding the connection.

"The main question is," says Glashow, "are these guys right?"

■ M. MITCHELL WALDROP