Physicists hunt for a trace of the elusive, invisible geoneutrino

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Princeton University proclaimed this month that some of its physicists had helped discover an invisible particle known as a geoneutrino.

A geoneutrino is, it turns out, a particularly elusive type of an already elusive class of particles -- neutrinos -- most famous for inspiring John Updike to write a poem with the lines: "The earth is just a silly ball / To them, through which they simply pass."

Which is accurate, though one neutrino in billions will hit something and leave a signal. To catch just 15 of them required 300 tons of mineral oil and months of waiting.

While most neutrinos that pass through the Earth come from the sun, a few, the geoneutrinos, are said to emanate from the Earth's deep interior and could help scientists understand the power source behind volcanoes and earthquakes.

The physicists say catching geoneutrinos makes detecting the solar kind seem easy, so it's not that surprising that there's been some confusion. Back in 2005, the cover of the journal Nature proclaimed that a different international group, including two Drexel physicists, had just discovered geoneutrinos.

The scientists seem nonplussed by the duplication. Convincing the world you've caught an invisible particle is no simple matter, they say. And scientific credit can be impossible to pin down when dealing with something as slippery as a neutrino.

Neutrinos don't just go through the Earth and come out the other side -- they could, in theory, zip straight through a trillion miles of lead.

Drexel physicist Charles Lane, who worked on the 2005 geoneutrino detection, said the important thing was that science had finally offered concrete proof of a pivotal theory proposed more than 100 years ago by Ernest Rutherford, famous for discovering the atomic nucleus.

Back then, physicists were having trouble explaining how the Earth could be so hot inside and still be hundreds of millions or even billions of years old. Rutherford proposed that our planet was heated internally by radioactivity.

It wasn't until the 1980s that physicists realized they could actually measure this radioactivity through the neutrinos it would produce. "I remember giving lectures at various earth and space departments about how much you can learn about the Earth," said physicist Lawrence Krauss of Arizona State University.

"People said they didn't believe in neutrinos."

Still, there is good reason to believe in them. Neutrinos were postulated by the same people who said that if you squeezed enough uranium into a small enough space, you'd start splitting atoms and could destroy a city.

Enrico Fermi and other physicists realized back in the 1930s that energy was mysteriously disappearing during the decay of uranium and other radioactive elements. According to the principle of conservation of energy, something had to be carrying that energy away.

They dubbed those energy thieves neutrinos.

In the 1950s, two Los Alamos physicists pulled off the first neutrino detection at the Savannah River nuclear power plant in Georgia -- a finding that won them a Nobel Prize.

Various neutrino-detecting devices have sprung up since -- most of them involving swimming-pool-sized vats full of mineral oil. Neutrinos on occasion do bump into an atom or an electron in these tanks -- and when they do, it leads to either a burst of light or the release of some other particle that can be detected.

Both of the current experiments claiming geoneutrino discoveries were originally built for other reasons. The one in Japan, KamLAND (Kamioka Liquid Scintillator Antineutrino Detector), was designed to detect neutrinos from several nearby nuclear reactors.

The idea behind KamLAND, said physicist Stuart Freedman of the Lawrence Berkeley National Laboratory, was to study the basic physics of neutrinos. There are actually three known types of neutrinos (and three antineutrinos), which have different masses and can transform themselves from one type to the other.

Or maybe there are four or five. Physicists have proposed various theoretical brands of neutrinos that may or may not exist.

The other experiment, called Borexino, was built in a road tunnel in Gran Sasso, Italy, to detect neutrinos from the sun. It's also aimed at sorting out subtleties of neutrino physics.

But as time went on, physicists at both experiments realized they had a shot at finding a few of the long-sought geoneutrinos.

And that could prove useful. If you could detect enough of them, said Princeton geoscientist Thomas Duffy, geoneutrinos could tell you something about the source of heat that drives the slow drift of the geological plates, and on our time scale, brings forth earthquakes and volcanoes.

It's still not known how much of our planet's inner power comes from leftover heat of formation and how much comes from radioactivity.

You can't really sample the inside of the Earth, since it goes thousands of miles down, said Duffy. "This is really at a fundamental level trying to understand the driving force controlling all the geological activity we see," he said.

Others have suggested that geoneutrino detectors could be used to track how much plutonium is being burned in nuclear reactors -- thereby perhaps monitoring illicit activity.

The 2005 "discovery" at KamLAND not only described the finding of geoneutrinos but also used them to calculate the total energy coming from radioactive elements in the Earth.

Geologist William McDonough of the University of Maryland had used meteorites to estimate the total energy coming from Earth's radioactive elements, and he found the physicists got nearly the same answer using neutrinos.

On the downside, KamLAND's detector is subject to lots of "noise," since it's surrounded by nuclear power plants and these are constantly spewing neutrinos that might be mistaken for geoneutrinos.

They can also get false alarms from the radioactive decay of trace elements in the detector itself, said Princeton University physicist Frank Calaprice, a collaborator on the Italian experiment.

They were after a particularly rare type of neutrino from the sun, and in order to know they were really catching them, they had to purify all their equipment to get rid of radioactive elements that might emit other neutrinos.

That made it well suited to see the even rarer appearance of a geoneutrino or two. He said they can announce their find with much more certainty than the other team could back in 2005.

"Who saw them first? I'd have to say they had hint of them first but I think the clear signal was first done by our detector," said Calaprice. He said the rival team's claims were honest, however, in that they said their findings were consistent with geoneutrinos. "People should read the papers and judge for themselves."

Drexel physicist Jelena Maricic, who was part of the KamLAND team, said that when they got through with the statistical analysis, their 2005 detections were 95 percent certain to include some geoneutrinos.

That might seem like a high degree of certainty, but in particle physics, lots of 95 percent discoveries vanish with a closer look.

The Princeton/Borexino group's announcement this year had 99.73 percent certainty.

But the KamLAND group has now caught approximately 106. At a meeting this month, they just announced a new analysis with 99.997 percent certainty that they've detected the real deal.

So who discovered the geoneutrino?

"That's always hard," said Drexel's Lane. Physicists sometimes use a fixed level of confidence to allow new findings to count as discoveries, said Maricic. That's usually quite high -- at 99.999943 percent.

"So scientifically strictly speaking," she said, "geoneutrinos have not been experimentally discovered yet."

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