SCIENCE NEWS OF THE WEEK

The Neutrino Flies as Fast as a Photon

In the 1930s the phenomenon of nuclear beta decay presented a mystery that threatened to overthrow one of the cherished laws of physics, the law of conservation of energy. In beta decay a neutron turns into a proton by emitting an electron. So much had been experimentally recorded thousands of times. But the energy didn't add up; energy was leaking out in some unseen way.

Considering the question, Enrico Fermi postulated the existence of an electrically neutral, massless particle to take away the energy. Using his native language, he named it neutrino, little neutral thing. Since the rules of special relativity require that a particle with no rest mass travel at the speed of light, it was assumed that neutrinos traveled that fast.

Now, 45 years after Fermi put the neutrino into physical theory, an experiment at the laboratory named for him, the Enrico Fermi National Accelerator Laboratory, indicates that the supposition that neutrinos travel at the speed of light is correct to within a fairly narrow margin of error. The report is in the April 12 PHYSICAL REVIEW LETTERS. The experiment was a collaboration of 14 physicists from Brookhaven National Laboratory, Purdue University, California Institute of Technology, Fermilab and Rockefeller University (Joshua Alspector et al.).

It may seem odd that it took 45 years to verify such a supposition, but the history of neutrinos is as elusive as the particles themselves. It was apparent from the very first that neutrinos must have little or no interaction with other matter because they were never detected in the beta-decay experiments. Nevertheless, physicists believed in them for lack of a better explanation of how the missing energy leaks away. It was not until 1956 that neutrinos were first detected.

Today we know that there are at least two kinds of neutrinos. When the second was discovered, the richness of the Italian language in diminutive suffixes led some physicists to suggest differentiating it with the name "neutretto," but that didn't go over. The two are now called electron neutrino and muon neutrino. We also know that in ordinary beta decay it is actually an antineutrino that is emitted. But all of this makes no difference to the current experiment because all four, the two neutrinos and the two antineutrinos that match them, should go at the same speed.

The course over which the neutrino speed was measured consisted of 1,800 feet of earth and steel in Fermilab's neutrino line. At one end of the line protons from the laboratory's big synchrotron struck a target to produce secondary particles, among them neutrinos. The purpose of the earth and steel was to screen out secondary particles that interact more readily with matter than neutrinos. At moderate energies only neutrinos could get through the shield; at high energies both neutrinos and muons could. At the other end was a 150-ton detector made of electronic counters and steel plates.

At high energies muons travel for all practical purposes at the speed of light. Since they have a small rest mass, they can never quite reach the speed of light (so long as special relativity is correct), but at Fermilab energies they get extremely close. The experiment compared the pattern of neutrinos arriving at the detector at different energies with that of muons at high energies. The patterns reproduced the timing of the pulses of protons that had created the muons and neutrinos, thus indicating that all the particles had traveled at the same speed. Since the high energy muons go at (very nearly) the speed of light, that means that all the neutrinos did, too.

The result is a support for the principle that massless particles go at the speed of light or that the neutrino is massless or both. The neutrinos at different energies all travel at the same speed. Under the assumptions of special relativity, that means a massless particle going at the speed of light.

The precision of the experiment is about five parts in 10,000. Further work will attempt to increase the precision. The error limit still allows the possibility that the neutrino has an extremely tiny rest mass, and that is important to some theorists. For example, the nuclear processes in the sun should produce a flow of neutrinos. Fifteen years of experiment have not recorded the expected amount. Some theorists have proposed that that is because the neutrinos decay into something else on the way from the sun to the earth. (In eight minutes flight time they have plenty of opportunity.) But they can do that only if they have some rest mass. Particles without rest mass must remain themselves. So it would be nice if experiment could narrow the possible limit of a neutrino rest mass below the amount required by this and other suggestions of decaying neutrinos. ☐

Complicating the law of gravity

One of the oldest and most important tenets of classical physics is the inverse-square law of gravitation, the principle that the gravitational force between two bodies is inversely proportional to the square of the distance between them. Isaac Newton deduced it by comparing the acceleration of the moon with the acceleration of a small body near the earth's surface and then strengthened it by pointing out that it made a plausible explanation for the planetary orbits that Johannes Kepler had worked out from observations.

The inverse-square law makes the calculation of gravitational fields fairly simple and straightforward compared to other possible choices. It contributes to the unity of classical physics because the other great fundamental class of force in classical physics, electrostatics, shares the inverse-square character. Coulomb's law says that the electrostatic force between two charged bodies is inversely proportional to the square of the distance between them.

The latest news is that although electrostatics comes through with still flying colors, there appears to be a discrepancy in the inverse-square law for gravity at close, but still classical, distances, say tens of centimeters. The report, representing more than a year's work by Daniel R. Long of Eastern Washington State College in Cheney, Wash., and some of his students, appears in the April 1 NATURE.

Astronomers have verified the inverse-square law for planetary motions (more specifically those of Mercury) to high precision. Long does not contest this, but he points out that the distances involved in the case of Mercury are 11 orders of magnitude greater than the ones at which he worked. In view of the things that have been happening lately in physics, he says, it is not implausible that what is valid astronomically may fail in the laboratory.

There have been a number of laboratory measurements of gravitational force; everyone who has studied physics can probably remember the names of the most famous ones. Long contends that most of these experiments did not really test the accuracy of the inverse-square law itself. The few that did, he points out, all recorded seeming divergences. Long stresses that his work is consistent with past tests, saying that he has had a hard time convincing the scientific community of this.

What Long adds is evidence for a systematic trend in the deviation from the inverse-square law as the distance changes. He presents a graph that shows an apparent variation of Newton's universal gravitational constant, the constant of proportionality in the inverse-square law. The constant varies from slightly less than