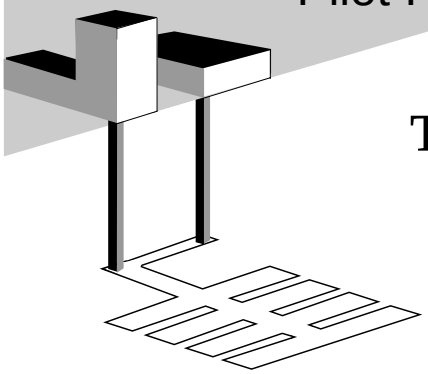

The Search for Dark Matter, WIMPs, and Neutrinos

Astrophysics experiments proposed to be sited at the Waste Isolation Pilot Plant (WIPP) presently focus on dark matter, weakly interacting massive particles (WIMPs), and neutrinos, all obscure subjects to the average U.S. citizen. Each experiment, in one way or another, tries to answer the questions, "How was the universe created?" and "What is it made of?"

How do you know they exist?

For years, astrophysicists have tried to mathematically calculate the mass of the universe. Because of the relationship between mass and gravity and the speed of the stars and other cosmological systems, scientists can estimate how much mass *should exist*. But when they calculate the mass of all the matter they *can see*, they find that about 90 percent of the mass is missing. Two astronomers are given credit for identifying this problem: Jan Oort in 1932 and Fritz Zwicky in 1933.

Dark matter

As a solution to this puzzle, scientists have theorized that a yet-unknown substance they call "dark matter" exists. But where and what is it? Astronomers believe that dark matter may be in what are called "MAssive Compact Halo Objects" (MACHOs), which are not visible through their telescopes, but which may be out there and very massive. The mass of these objects could be so great that their gravity will not allow light to be reflected back to the scientists' telescopes. These MACHOs may be red dwarfs, black holes, or some other massive object yet unidentified.

WIMPs

Physicists, though, believe that there is something more basic but unknown in the universe that may have mass but not interact with other matter. They call these basic particles WIMPs. WIMPs would have escaped detection to date because they do not interact with, but pass through, most other matter. Several experiments proposed for the WIPP will search for these WIMPs. The experiments will use detectors designed to shield out cosmic rays and yet allow some evidence of the WIMPs to be identified.

Neutrinos

Another candidate to explain the missing matter is the neutrino. Neutrinos were first theorized by Wolfgang Pauli in 1931, then later became important to Enrico Fermi in 1934. While studying a form of radioactive decay in which a neutron decays into a proton and electron, these two scientists were unable to account for all of the energy and matter released. They postulated that a new particle—the neutrino—existed, which they believed had no charge and no mass. (As noted below, the belief that the neutrino has no mass has changed in light of more recent findings.) Scientists believe that neutrinos created in a supernova, a stellar event during which the energy

released can be a billion times that of the sun, are responsible for the creation of all elements heavier than iron in the universe. When rare supernovae occur, enormous numbers of neutrinos are created and spread out through the cosmos at the speed of light. Detectors proposed for installation at the WIPP will act like a sensitive camera with its lens open to capture the elusive neutrinos as they pass through our solar system.

Since the 1930s, scientists have learned much about neutrinos. They've defined them as a fundamental particle of the universe, which has no charge (so they are not affected by electric or magnetic forces like electrons). Because they have no charge, and only interact through the weak force, they can go long distances through matter without being affected by it. Scientists also understand that neutrinos come in at least three "flavors": one related to electrons, another related to the slightly heavier and charged muon, and the third related to the heavier and charged tau. The neutrino, though, is still elusive. The last of these flavors, the tau neutrino, had been understood in theory for many years, but was finally detected this past summer. And scientists have never been able to find evidence of as many neutrinos as theoretically should come from our own nearby sun.

Finally, to be a candidate for the universe's missing mass, neutrinos must have mass. In spite of numerous experiments throughout the world, it was only in 1998 that scientists obtained the first evidence that neutrinos do have mass. No measurement of that mass, though, has been obtained to date, and many of the experiments proposed for the WIPP hope to be the first to do so.

Why should we care about dark matter?

Much is at stake, for without dark matter of some type, scientists are unsure whether such basic theories as the Big Bang Theory withstand modern scrutiny. Others believe that if neutrinos do have mass, one of the principal theories of physics, the standard model, will be called into question. At a different level, theoretical particle physics and cosmology offer gifts to our imagination: they give us a sense of ourselves and our place in the universe. But to the layperson, the strangest finding may be that a particle modern scientists still struggle to detect and understand may be responsible for more mass in the universe than all of the planets and stars combined.

For more information

For more information about experiments at the WIPP, or to be placed on the WIPP mailing list, call the WIPP Information Center at 1-800-336-WIPP (9477). Or you may review the full Environmental Assessment on the WIPP Home Page at http://www.wipp.carlsbad.nm.us/library/ea/ea.htm. If you prefer, write to:

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