Dark matter sleuths to design world's largest WIMP catcher

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A team of researchers led by a Case Western Reserve University physicist is planning the world's largest, most sensitive experiment to catch the stuff of dark matter, stuff that's proved way beyond invisible.

The researchers are seeking WIMPs, short for weakly interacting massive particles, which aren't and don't act like atoms that comprise regular matter.

Scientists believe that WIMPs could have been born of the Big Bang, stream through us by the billion every second and provide the mass needed to keep galaxies, including our Milky Way, from flying apart.

"We know there's dark matter, we just don't know what it is," said Tom Shutt, who holds the Agnar Pytte Chair of Physics at Case Western Reserve and is the principal investigator for the project.

Shutt's group, which merged with the group led by Physics Department Chairman Dan Akerib, has received a three-year, $3.2 million National Science Foundation grant to design a 20-ton liquid xenon WIMP detector, called LZD.

The group has proposed LZD as a major experiment for the Deep Underground Science and Engineering Laboratory, a national lab planned for the abandoned Homestake Gold Mine, nearly a mile beneath Lead, S.D.

The WIMP detector would be 2,000 times larger than the XENON 10 detector, a 10-kilogram prototype experiment in Gran Sasso, Italy, and 70 times larger than the 300 kilogram Large Underground Experiment, or LUX. The LUX project, led by Shutt and Brown University physicist Rick Gaitskell, will begin operating next year in South Dakota's Sanford Underground Science and Engineering Laboratory, also in the former Homestake mine.

Why build bigger?

"It's like using a larger light collector in a telescope," Akerib said. "It increases your chances of seeing what you want to see."

The 20-ton experiment would increase the chance of seeing a WIMP by more than 30,000 times over XENON 10, and more than 150 times over LUX because of increased size and sensitivity and longevity, Shutt explained.

WIMPs are hard to detect because they don't give off radiation. They don't interact with regular matter through electromagnetic forces, but pass through regular matter unimpeded, researchers believe.

That theory was bolstered by NASA's observations of two distant galaxies colliding in 2006. While a cloud of galactic gas dragged out from the friction of striking other regular matter, changes in gravity showed that dark matter had already passed through.

Shutt and Akerib say liquid xenon is the right stuff to catch a WIMP. The element is nearly completely inert, unpolarized and hard to polarize. Only dark matter particles can permeate into the inner region of the xenon liquid without being detected elsewhere, Shutt said.

What each experiment looks for is a chance strike: a WIMP knocking into a Xenon atom, something on the scale of a neutron colliding with the atom. The collision would produce a minute flash of light that supersensitive detectors would locate, amplify and analyze. In tests, LUX has detected the collision of single neutrons with liquid xenon atoms. LZD would be even more sensitive, by three orders of magnitude, giving the experiment an acuity akin to seeing an ant in the span of the Milky Way, Akerib said.

When LUX is lowered underground in 2010, the researchers will seek WIMPs. They will also field test their equipment and the underground lab and master the technology they expect to use in the 20-ton model.

Before attempting to build LZD, however, the research group wants an interim step. They are seeking funding for a 1.5 ton detector, called LZS.

The experiments are buried deep in the Earth for the same reason the Hubble Space Telescope was launched into orbit: to avoid interference. In orbit, Hubble is freed of Earth's obscuring atmosphere. Underground, WIMP experiments are shielded from hundreds of billions of charged particles that strike the surface of the earth annually, leaving the detector with a clear view should a WIMP strike.

What do we get out of this?

Detecting a WIMP would go a long way toward understanding how the universe works and confirm the dark matter theory that unseen matter must exist or galaxies would lack the mass to form, cluster and rotate as they do, Shutt said.

But the work goes beyond that.

"This is very much connected to big philosophical questions: What are we made of? What did we come from?" Akerib said.

Scientists expect the new technology could lead to another class of super-sensitive detectors for medicine and global security, including particle detectors that can tell what's happening in a distant nuclear facility and whether a country has or is building nuclear weapons.

The LUX and LZ projects compete with technologies that use germanium crystals frozen to nearly absolute zero or liquid argon detectors, in the race to find WIMPs. The groups will compete for funding to build their largest and best experiments.

Masahiro Morii, a physics professor at Harvard who helped build electronics for LUX, is among a growing number of researchers joining the xenon group. "Liquid xenon has a distinct advantage: it's straight forward to scale up," Morii said. And, "It's ahead of the other technologies by 3 to 5 years."

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