UC SANTA BARBARA

THE Current

October 19, 2018

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A Hefty WIMP Detector

There’s a big hole in our current understanding of what makes up the universe. Normal matter — the stuff in people, planets and pulsars — can account for only 16 percent of the mass in the universe. Scientists know there’s more out there because they can see its effects: Its gravity bends light from distant sources and keeps galaxies from spinning themselves apart.

Dark matter doesn’t appear to interact with normal matter via electromagnetism or through the strong nuclear force, which is known for binding particles together in the nuclei of atoms. Aside from gravity, that leaves one other force: the weak force, which is involved in radioactive decay. A leading hypothesis is that dark matter may be composed of exotic particles that have a high mass and interact with normal matter only through gravity and the weak force. Scientists call these weakly interacting massive particles, or WIMPs, and the search is on to find out if they exist.

UC Santa Barbara physics professors Harry Nelson and Michael Witherell (now the director of Lawrence Berkeley Laboratory) have researched dark matter since the 1980s. About 10 years ago, some of their collaborators proved that liquid xenon was a superb medium for detecting WIMPs. Nelson and Witherell joined to help put together the Large Underground Xenon (LUX) experiment.

The experiment was essentially a 32-gallon vat of liquid xenon that could detect when a single xenon atom was struck by a WIMP. It was located at the Sanford Underground Research Facility, roughly a mile under the Black Hills of South Dakota. This mile of rock shields the detector from the stream of particles that shower down

on Earth’s surface every day. “We led the world in sensitivity in the hunt for WIMPs,” said Nelson.

Since LUX came online in 2013, a number of similar, larger detectors in Italy and China joined the hunt. An international race was underway, and the LUX team proposed the LZ experiment, a $70 million upgrade and unification of the LUX and the UK-based ZEPLIN III teams. The LZ detector is designed to leapfrog the competition, and will contain 850 gallons of liquid xenon, about 27 times the volume of LUX.

The new experiment will be so sensitive that it has to account for false positives from solar neutrinos, explained Nelson. Neutrinos are particles so ephemeral that co-discoverer and Nobel laureate Frederick Reines called them “the most tiny quantity of reality ever imagined by a human being.” Trillions of them pass straight through your body every second.

Nelson, Witherell and a team of engineers and students designed the outer detector for the LZ experiment, starting in 2012. The outer detector consists primarily of four 12-foot-tall, clear acrylic tanks that will surround the core detector. The fabrication of these tanks proved challenging, Nelson noted, giving credit to Reynolds Polymer Technology of Grand Junction, CO, who took on the task. The scientists will fill these tanks with a liquid that produces a small flash when hit by a particle, allowing them to distinguish a WIMP event from background radiation coming from radioactive impurities in the detector or the few conventional particles that manage to penetrate the rock above.

Two of the four tanks, recently completed, will make the long journey underground later this month. “The logistics of building a large apparatus underground, accessible only by narrow tunnels, forces us to install the outer detector prior to the LZ liquid xenon detector,” Nelson said.

The LZ experiment is scheduled to turn on in 2020 and should grab the lead in the hunt for WIMPs back from the Italians, whose current Xenon1T project contains about 271 gallons of liquid xenon. The Xenon1T team has plans for an upgrade to rival LZ, however, so the race is still on.

“The incredible intellectual odyssey of the past 100,000 years, starting with modern humans questioning the nature of the element gold up to the very recent discovery of the Higgs particle, covers only one-sixth of the matter in the universe,” said

Nelson. “Should LZ see a WIMP signal, it will mark the beginning of a new era of exploration and discovery.”

Additional project collaborators at UC Santa Barbara include postdoctoral scientist Sally Shaw; engineers Susanne Kyre, Dano Pagenkopf and Dean White; and graduate students Scott Haselschwardt, Curt Nehrkorn and Melih Solmaz. The LZ group is supported by the U.S. Department of Energy’s Office of High Energy Physics, as well as the UCSB Dean of Mathematical, Life, and Physical Sciences; Office of Research; and Physics Department.

About UC Santa Barbara

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