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LZ sees surprising result in search for dark matter

For the better part of a century, people have been trying to understand dark matter. This invisible substance makes up roughly 85% of the mass in the universe but has never been directly detected. Determining exactly what it is remains one of the biggest open questions in science.

Now, a new analysis from the LUX-ZEPLIN (LZ) experiment has recorded a single particle interaction, known as LZ.230616 for the date it occurred, that researchers have great difficulty explaining with known background signals from regular matter. The result does not yet meet the statistical threshold required to claim a discovery, but is the most compelling hint of dark matter reported by the LZ experiment to date.

"We can't explain LZ.230616 with the backgrounds we know about," said UC Santa Barbara physics professor Hugh Lippincott, who led the internal review of the analysis. "The work of young LZ researchers held up to intense scrutiny during our review. No matter what happens, I'm extremely proud of this team."

Lippincott also led construction of a skin-like layer of liquid xenon that surrounds the main dark-matter sensitive cylinder of liquid xenon. The xenon skin detector has proved critical in rejecting dark matter imposters that could have faked LZ230616.

Co-founded by UCSB physics professor Harry Nelson, LZ is an international collaboration of 250 scientists and engineers from 39 institutions. LZ held its first collaboration meeting on the 5th floor of Broida Hall on the UCSB campus in 2012. Operating nearly one mile below ground at the Sanford Underground Research Facility (SURF) in South Dakota, the experiment uses 10 tonnes of ultrapure liquid xenon to search for dark matter and is optimized to look for WIMPs, or weakly interacting massive particles.

The results were presented in a scientific talk at the 2026 TeV Particle Astrophysics conference in Japan. The paper will be released on the online repository arXiv and submitted to the journal *Physical Review Letters*.

The LZ collaboration studies experimental data in batches. In the new result, researchers analyzed 220 live days of data collected between March 2023 and April 2024. The collaboration previously searched this dataset for faint signals from the simplest kinds of WIMP interactions. The new analysis searched for a broader range of possible WIMP interactions that could deposit more energy in the detector. LZ is particularly sensitive to such signals while also minimizing false positives.

"This was a detailed study in a region we hadn't explored within this dataset, and we spent months of additional effort to understand all the possible causes of background events," said Sam Eriksen, a senior research associate at the University of Bristol in the U.K. and lead author of the study. "We understand our detector and the backgrounds so well that even a single outstanding event, like the one we found, is important. We expect dark matter events to be extremely rare, so only a handful could mark the first detection of WIMP dark matter."

If the anomalous event was caused by dark matter, the WIMP that generated it would likely have a mass of at least 200 GeV/c^2 (gigaelectronvolts), or more than 200 times the mass of a proton. It would also suggest a specific type of interaction between WIMPs and ordinary matter beyond the simplest model. The LZ results have not reached "5-sigma" significance, the statistical threshold considered a discovery in physics. The new analysis is 2.6 sigma, meaning there is approximately a 0.5% chance that the event could be explained by known backgrounds.

"To me, the most interesting thing about this event is its rather high energy. It is inconsistent not only with known backgrounds, but also with the simplest dark matter model that LZ was designed to search for," said UCSB postdoc Chami Amarasinghe, the co-deputy physics coordinator of LZ. "If more unexplainable high-energy events turn up as we look at more data, we might be able to learn a lot about the nature of the dark matter particle. While the simplest dark matter events would be described by basic quantum physics, high-energy events need ideas from the frontiers of quantum field theory."

LZ has a large data set, roughly twice the size of that used to find LZ.230616, that is in the process of careful calibration and analysis. Those data will either confirm LZ.230616 as dark matter, or not.

LZ searches for dark matter by looking for signature flashes of light from energy deposited in the detector. The collaboration leverages multiple methods to prevent or account for particle interactions caused by normal matter. This includes the mile of rock that shields the detector from cosmic rays from space, a water tank and outer detectors that protect the central detector from background neutrons, and a suite of computational tools that disentangle particle interactions and reject dark matter mimics.

UCSB graduate student Jeonghwa Kim did key cross checks of a troubling background late in the review process. "As a graduate student, you spend years building up tools and expertise, but most of the time, our results are about quantifying how successfully we haven't found anything," he said. "Seeing an event, even if we're not sure about it, is a completely different feeling. I'm looking forward to analyzing all the LZ data."

Dark matter research like LZ has been a specialty of the UCSB Physics Department since the 1980s. The department and the university administration have long supported LZ and its predecessor experiments in many forms.

LZ is supported by the U.S. Department of Energy, Office of Science, Office of High Energy and Nuclear Physics, and the National Energy Research Scientific Computing Center, a DOE Office of Science user facility. Additional support for LZ comes from the Science & Technology Facilities Council of the United Kingdom; the Portuguese Foundation for Science and Technology; the Swiss National Science Foundation; the Australian Research Council Centre of Excellence for Dark Matter Particle Physics; and the Institute for Basic Science, Korea.

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