Dark matter experiment finds nothing, makes news

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A US team with a highly sensitive dark matter detector has just finished its first run. It has found nothing, and that is still big news.

Physicists can explain accurately the behaviour of what makes matter made up of atoms. But that type of matter constitutes less than 5% of the universe. The rest is the mysterious "dark energy", which is purported to contribute to the accelerating expansion of the universe, and "dark matter", which may be the reason galaxies are held as they are in space.

At the Sanford Underground Laboratory in Lead, South Dakota, physicists working on the Large Underground Xenon (LUX) experiments have found nothing statistically significant in more than 100 days of data-taking. "We found absolutely no events consistent with any kind of dark matter," quoted a LUX spokesperson.

The LUX experiment is a cylinder filled with 368kg of mostly liquid xenon, which is contained within a 270,000-litre tank of water. It is located in a mine 1,500m below ground in South Dakota.

The leading theory is that dark matter may be made up of WIMPs, or Weakly Interacting Massive Particles. These WIMPs only interact with two of the four fundamental forces – gravity and nuclear weak force (which governs radioactivity among other things).

If a WIMP were to collide with the nucleus of a xenon atom, then it will emit some light. The LUX setup is so sensitive that its light detectors would be able to capture that light. (The water shield is meant to keep other cosmic stuff from creating false positive signals.)

Particle physics experiments can be compared with firing a rifle at a target. If nature has made the target sufficiently small, you can't hit it and no events are seen. Physicists measure the cross-section of their targets in cm^2. LUX results are therefore quoted as a measurement of the cross-section of the dark matter particle for target xenon nuclei.

Although physicists think that dark matter is a particle with a mass and a small cross-section for interaction with nuclei, we only have a vague idea of the mass and no idea of the cross-section.

Results of LUX are effectively saying that it is harder to see a dark matter particle of 33 GeV, a unit of measuring mass, than it is to spot something the size of a pea at the centre of the Milky Way. (A proton's mass is 0.938 GeV, and LUX is most sensitive to a 20 to 100 GeV range.)

Liquid xenon, at -100°C, fills the cylinder. luxdarkmatter

Two other experiments, one using a germanium target, have recorded a significant number of events. This led to an expectation of over a thousand events in this first LUX run with its more sensitive (bigger) xenon detector. But LUX rules them out, which is its real achievement. It has struck out some of the theories about WIMPs, which allows researchers to focus on fewer leads.

There are alternative dark matter particle scenarios that would go undetected by the LUX experiment, such as axions. Axions are bosons, a different variety from that Peter Higgs predicted, with a small mass and very low cross-section for the two nuclear forces. They are predicted to change to and from photons in the presence of strong magnetic fields, and this property allows for the design of experiments to detect them.

Other heroic experiments, such as CERN's LHC and the South Pole's IceCube, are expected to weigh in on this subject in the not too distant future. Both take rather different approaches.

As Ken Freeman, professor of the Australian National University, has said:

> *Depending on the nature of dark matter, there is a faint hope it might give off some detectable gamma rays as the dark matter particles annihilate.*

This approach is also being actively (and, some say, positively) pursued by the International Space Station.

Marc Davis, CAASTRO Visiting Professor from University of California Berkeley and co-winner of the Gruber cosmology prize for dark matter simulations of the universe, commented:

> *There is a great tradition in physics of efforts to measure smaller and smaller limits. A recent example is the 15-year effort to measure the fluctuations of the cosmic microwave background. The LUX experimentalists are hoping the detection of the dark matter particle will follow this same tradition, but nature need not give up its secrets with our efforts.*

There are alternative scenarios that avoid attributing so much influence to dark energy and dark matter. One is MOND, a modification of Newton's inverse square law of gravity. A fundamental argument for the inverse square law is the axiom that the universe is naturally understood with three dimensions and one time dimension. However, the existence of exactly three dimensions can be challenged in string theory and other radical theories.

It will take a lot more than the first run of LUX to force physicists to adopt MoND or other unconventional theories of gravity, even though theories of gravity also have the dark energy challenge to handle. More sensitive dark matter experiments are needed with a variety of targets, including a Southern Hemisphere experiment.

Although dark matter particles have random velocities in the frame of reference of the Milky Way, in the terrestrial frame of reference they have an average velocity of 220 km/sec opposite to the sun's rotational velocity in the plane of our galaxy.

This leads to a signature that varies with the latitude of the experiment (or observatory, if you prefer), with the time of the year and the time of day. A fully successful suite of experiments will need to confront the predictions in all these aspects.

As with the Higgs boson, the exact mass and nature of the particle is the greatest experimental prize and a Nobel Prize in the making. The Higgs quest teaches us to be patient with these painstaking experiments and, of course, to try harder.