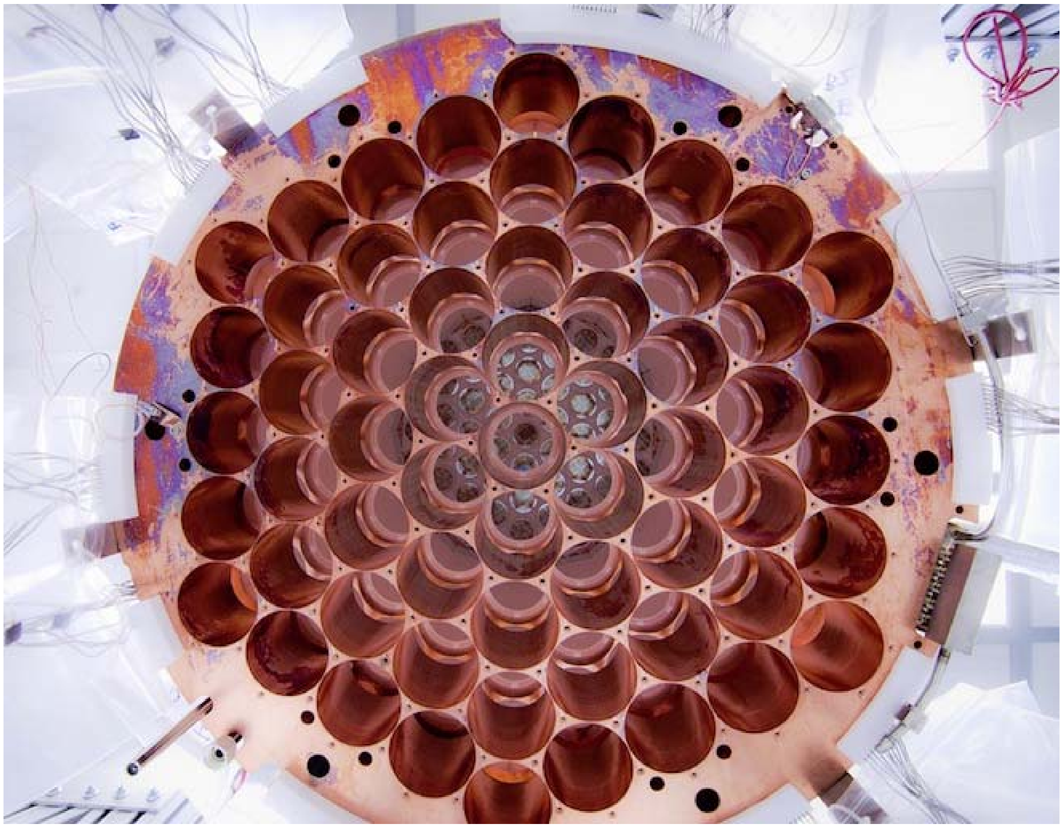
Today scientists released findings from the first three months of the Large Underground Xenon experiment, which hunts directly for the invisible particles thought to make up dark matter. Many physicists hoped that the highly anticipated results would clear up the ...

Huge Dark Matter Experiment Finds Nothing but More Mysteries

- By Adam Mann
- 10.30.13
- 12:18 PM



A view of the bottom of the LUX detector. *Image: luxdarkmatter/Flickr*

The hunt for dark matter just keeps getting more confusing. Today scientists released findings from the first three months of the Large Underground Xenon experiment, which looks directly for the invisible particles thought to make up dark matter. Many physicists hoped that the highly anticipated results would clear up the situation surrounding dark matter experiments, which have so far led to contradictory conclusions about the nature of the mysterious substance. Some thought that LUX might show them which way to go, narrowing the types of particles they might pursue. Instead, the experiment turned up empty.

“Basically, we saw nothing. But we saw nothing better than anyone else so far,” said particle physicist Daniel McKinsey of Yale, a member of the LUX collaboration.

It might appear strange to the rest of us, but a null finding is actually encouraging for physicists, who will use the results to set stringent limits on what kind of dark matter they might expect to find in the future. It also seems to rule out the results of several previous experiments, which had seen hints of what might be dark matter.

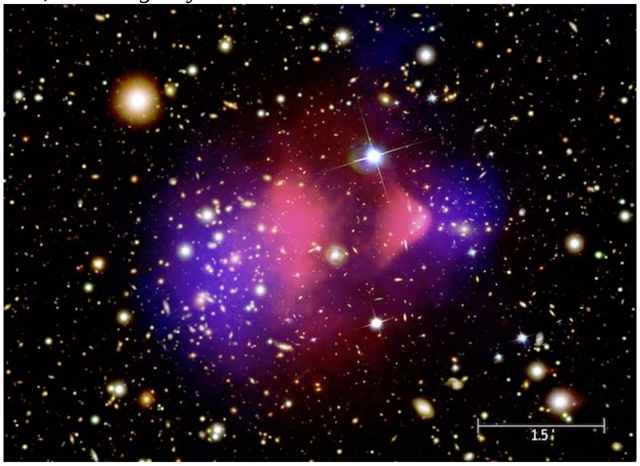
“Something that they had thought was in play is being kicked off the field,” said physicist Richard Gaitskell of Brown University, who also works on LUX.

But other scientists are not convinced that LUX has excluded their findings, and it’s likely the debate will continue.

When astronomers look out in the universe, they see dark matter everywhere. Ok, they don’t see it directly (it’s dark after all). But they know how gravity works and their equations suggest that in order for stars to spin around in galaxies at the speeds they do, there must be a whole bunch of invisible mass tugging on them. Furthermore, simulations of the universe show that dark matter is necessary for the cosmos to have the large-scale structure that it does.

Motivated by these observations, physicists calculate that for every proton, neutron, and other particle of ordinary matter in the universe, there must be more than five dark matter particles. Though that makes it the dominant mass in galaxies and galactic superclusters in the cosmos, dark matter is basically a ghost.

Physicists think dark matter is made up of what's known as Weakly Interacting Massive Particles or WIMPs. Just how weakly interacting are these particles? If you were to build a lead cube 200 light-years long on each side and send a particle of dark matter through that cube, it would have about a 50/50 chance of coming out the other side without interacting with anything. Yes, I said *light-years*.



The Bullet Cluster shows two galactic clusters crashing into one another. It provides some of the best cosmological evidence for dark matter in the universe. *Image: X-ray: NASA/CXC/CfA/M.Markevitch et al.; Optical: NASA/STScI; Magellan/U.Arizona/D.Clowe et al.*

It's really tricky for scientists to go about finding something like that. But these are clever folks and they've built an array of impressive detectors trying to sense a dark matter particle.

LUX, like most direct dark matter searching experiments, uses the wait-until-something-hits-me principle. The detector is composed of an extremely large number of atoms sitting around, increasing the probability that dark matter slams into them. In the case of LUX, these atoms are xenon, a very stable element that doesn't undergo any pesky chemical reactions that could screw with results.

The idea is that a dark matter particle might whoosh by a xenon atom, knocking off an electron, which LUX would detect as an increase in charge. Alternatively, a dark matter particle could slam right into a xenon atom, kicking up one of its electrons to a higher orbit. When that electron returned to ground state, it would release a photon, creating a tiny flash of light that one of LUX's 122 photomultiplier detectors could spot.

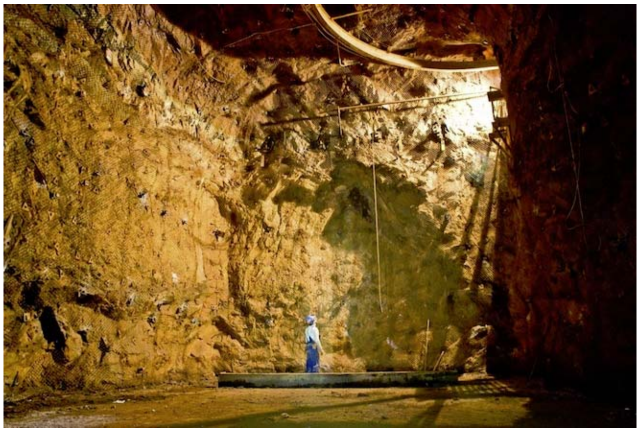
Most other direction detection methods work along similar principles, and experimentalists believe their sensors should be quite good at spotting dark matter. The problem for the last few years has been that each experiment seems to be saying something different than the others.

The major findings are more or less split into two camps: those who think the dark matter WIMP particles are relatively heavy and those who suspect they might be fairly light. Heavy in this case means a particle of around 100 gigaelectronvolts (GeV), or roughly 100 times the mass of a proton. Heavy WIMPs are predicted by a theory known as supersymmetry, which adds a host of new particles to the quarks, neutrinos, and electrons we already know about. If a detector found a 100 GeV WIMP particle, it would be momentous not only for being the first dark matter detection, but also as the first real evidence in favor of supersymmetry. Because supersymmetry is considered by many scientists to be the future of physics, a 100 GeV dark matter particle has a lot of support in the field.

But there is another contingent that believes dark matter is much lighter. Though not predicted by any particular theory, light WIMPs have one thing that makes them quite appealing: Several experiments may have already seen evidence for them. A collaboration called Coherent Germanium Neutrino Technology (CoGeNT) that uses germanium crystals in its detector found a signal that could be interpreted as dark matter with a mass of between 7 and 11 GeV. Another team, the Cryogenic Dark Matter Search (CDMS), released results in April showing what might be three dark matter particles in the same mass range. These findings are tantalizing hints, but mere hints nonetheless. An even more controversial collaboration, DAMA/LIBRA, has claimed to see dark matter signals for the last decade or so.

LUX was supposed to help bring some order into this puzzling situation. It manages to be more sensitive than previous experiments by being bigger, meaning there are more xenon atoms and therefore a higher probability of getting hit, and better shielded. There are a zillion other things zipping around in the subatomic world – cosmic rays, charged particles, radiation – that could be mistaken for a dark matter direct hit.

The LUX detector avoids all these other potential false positives by "creating what is essentially the quietest place on Earth" at the range of energies it's looking at, said Gaitskell.



The cavern in South Dakota where the LUX detector sits. It happens to be the same cave where neutrinos streaming from the sun were first detected in the 1960s. *Image: luxdarkmatter/Flickr*

LUX is situated nearly 1 mile underground in a South Dakota mineshaft named the Sanford Underground Research Facility. That keeps out any weird charged particles and cosmic rays that might be coming in from the universe. A water tank surrounding the liquid xenon further shields it. The detector itself is made of materials that naturally don't emit much radiation, such as titanium and Teflon. And, just for good measure, the experiment only looks at the xenon atoms at the very center of the detector, because the outer xenon atoms should catch any stray subatomic morsel that managed to penetrate all the other safeguards.

Because they were so careful, the LUX team has a good reputation in the physics community and their findings will be taken seriously. The collaboration calculates that their detector is twice as sensitive to heavy WIMP dark matter particles and nearly 20 times more sensitive to light WIMPs than the next large collaboration, XENON 100. LUX's null result suggests that the idea of finding light WIMP dark matter could be at an end.

"It's difficult to reconcile our complete non-observation of a signal with other results," said Gaitskell. If the three hits seen in the CDMS experiment had been real dark matter particles, the much larger LUX should have detected about 1,600 events, he added.

But scientists searching for light WIMPs aren't entirely certain the team's conclusions spell doom for them. The LUX findings have only just been submitted to a peer-reviewed journal, so other physicists haven't had a good look at them yet.

It's possible that LUX's liquid xenon detector is not as sensitive to light WIMPs as the team believes, said physicist Juan Collar from the University of Chicago, who leads the CoGENT experiment. A xenon atom has a mass roughly 131 times that of a proton, making it more attuned to heavier particles than lighter ones. The LUX team has to extrapolate their findings using models that predict how many low-mass WIMPs they might see and those models might have many assumptions built into them.

"My understanding is that they have not performed any of the low-energy calibrations we are waiting for," Collar said in an email.

Theoretical physicist Jonathan Feng from the University of California, Irvine also isn't sure that the light WIMP scenario is now ruled out. Comparing the expected rate of particle detections between germanium crystals, like those in CoGENT and CDMS, and liquid xenon is a bit like apples and oranges.

"To compare the rate of germanium with xenon, you have to make a theoretical assumption" that dark matter interacts with all particles the same way, said Feng.

But scientists have no idea what dark matter is nor what possible exotic properties it might have. It could simply be that assumption is wrong and nature is more complex than the simplest models would suggest. Still, Feng acknowledges that the LUX results are starting to eat away at the predictions of some theories.

"It's getting uncomfortable," he said. "One of my favorite models [of supersymmetry] is getting excluded. There's a little wiggle room left, but it's getting very close."

As is nearly always the case, more data will be needed to figure out the dark matter situation. CDMS is still running, as is CoGENT, which is expected to release new results in the near future. LUX will continue taking data and possibly seeing a few hits one day. Two larger detectors, XENON 1T in Europe and the successor to LUX, called LZ, should come online in a few years.

"This is still round one of a 15-round heavyweight battle," said Feng. But the situation will hopefully get cleared up within the next five to 10 years, he added.

- Related
- You Might Like
- Story Resources
- Related Links by Contextly
-