

More bad news for controversial 20-year-old claim of dark matter detection

Enlarge / Scientists with Italy's DAMA/LIBRA collaboration have been claiming to see a seasonal shift in "dark matter wind" for over 20 years. New results don't support that, and a new hypothesis might explain what the collaboration is really seeing.

X-ray: NASA/CXO/Fabian et al.; Radio: Gendron-Marsolais et al./NRAO/AUI/NSF Optical: NASA/SDSS

reader comments

71 with 35 posters participating

Share this story

Over 20 years ago, a team running an underground experiment in Italy announced that it had detected evidence of dark matter—a claim the collaboration maintains to this day. But many physicists remain unconvinced that the signals detected were really due to dark matter, and outside experimental results have been mixed.

A new paper in *Nature* reporting on results of a different, complementary experiment found nothing to support the controversial claim. And a draft paper posted to the online arXiv proposes an alternative hypothesis for what the Italian collaboration might really be seeing in their data. But neither paper is sufficient to put the matter to rest once and for all.

Seeing the dark

Dark matter is a mysterious substance that physicists believe comprises around 27 percent of the Universe. (The ordinary matter we see everyday accounts for just four percent, with the remaining 69 percent due to the even more mysterious dark energy.) The most likely candidate for the source of dark matter is a class of particles known as weakly interacting massive particles (WIMPs), named because they rarely interact with ordinary matter.

There are numerous experiments around the world hunting for these elusive WIMPs, using several different methods. Their detectors are usually housed deep underground, the better to reduce interference from cosmic rays, which mimic a dark matter signature in the data.

The detectors house a target material (germanium, silicon crystals, or liquid xenon); whenever an incoming dark matter particle collides with the nucleus of an atom in the target material, there should be a recoil effect, producing tiny flash of light (a scintillation). If the dark matter particle manages to transfer sufficient energy in that collision, the flash will be strong enough to be detected.

A seasonal fluctuation

But WIMPs have proven to be extraordinarily difficult to detect. Despite the occasional tantalizing hint, only one of the many experiments has made the claim that it has succeeded: the DAMA/LIBRA experiment (Dark Matter/Large Sodium Iodide Bulk for Rare Process), housed deep underground in the Grand Sasso mountain in central Italy. The DAMA/LIBRA results are very much in dispute within the broader dark matter community.

The current best theoretical model posits that there is a “halo” of dark matter particles moving with the Sun around our

galaxy. The Earth orbits the Sun within that halo. That means that for half of the year, the Earth moves with the direction of the Sun's motion around the galaxy; the other half, it moves in the other direction. That should produce an effect in the data similar to running into a dark matter wind. "In the summer we're moving into the wind, so you see a slightly faster motion towards you, and in the winter we are not moving into the wind as quickly, and so you see dark matter, on average, as slower," said Rutgers University physicist Matt Buckley.

So DAMA/LIBRA looks for an annual shift in the collision events picked up by their detectors over the courses of a year. In 1997, shortly after the experiment went live, they announced they had detected just such a modulation, and interpreted this as evidence for a WIMP with a mass of around 10 GeV (giga-electron volts). Just last year, the collaboration presented similar results from a six-year data collection run, following an upgrade to the experiment in 2010. But other physicists had strong doubts—not about the signal, which was unmistakable, but about whether it was truly caused by WIMPs.

Attempts at outside confirmation have produced mixed, and therefore inconclusive, results.

Attempts at outside confirmation have produced mixed, and therefore inconclusive, results. Xenon10 (also located under the Gran Sasso mountain) and CDMSII (Cryogenic Dark Matter Search II in Soudan, Minnesota) both failed to detect a signal in that energy range, although both were sufficiently sensitive that they should have if DAMA/LIBRA really had detected dark matter.

Another experiment, CRESST (Cryogenic Rare Event Search with Superconducting Thermometers) did find a faint signal, but it wasn't entirely consistent with DAMA/LIBRA's signal. And in 2011, an experiment called CoGeNT, designed specifically to

disprove the DAMA claims, backfired when preliminary results appeared to confirm the finding instead. It was just a hint of a signal, and it disappeared with more data. But it kept the debate alive, and the arguments often got acrimonious. “You’d give a talk about dark matter and end up getting into fights with people,” Buckley told *Quanta* in 2013.

Then, in 2017, the upgraded XENON100 experiment—considered to be among the most promising for confirming or disproving the DAMA/LIBRA claims—also failed to find any evidence for that signal. But DAMA uses a sodium iodide detector, while XENON100 uses (wait for it...) xenon. It’s possible that dark matter could interact differently with different materials, so physicists have been waiting for experimental results that also use a sodium-iodide detector. That’s where COSINE-100 comes in.

Enlarge / A physicist works on the DAMA/LIBRA experiment under Grand Sasso mountain in central Italy.

DAMA/LIBRA collaboration/LNGS-INFN

Housed deep underground in South Korea, COSINE-100 also uses

detectors made of sodium iodide crystals, and is large and sensitive enough to hunt for the same dark matter signal supposedly detected by DAMA/LIBRA. The team analyzed data from the first 59.5 days of operation, and published their findings in December in *Nature*.

The results: “We didn’t find dark matter, and we discovered that the DAMA/LIBRA measurements aren’t consistent with the standard model for the dark matter halo,” said co-author Nelson Carlin Filho of the University of Sao Paulo in Brazil.

“We’re not saying the researchers at DAMA/LIBRA were wrong. They may have captured a periodic modulation in actual signals. However, unless the dark matter model is significantly modified, the signals are highly unlikely to be attributed to interactions with WIMPs.” The collaboration will need several more years of data before COSINE-100 can fully confirm or refute DAMA/LIBRA’s claims.

The two experiments aren’t entirely identical, however. While both experiments use the same target material, the crystals used by COSINE are a bit “dirtier,” according to Buckley—that is, they weren’t purified of radioactive isotopes to quite the same extent as the crystals used by DAMA/LIBRA. “It’s not like COSINE has some really crappy crystal—it’s just that it’s very hard to make them pure,” he said. “The levels here are incredibly small”—so small that if the equipment used in such experiments flies on an airplane, thus being exposed to more cosmic rays, the target will have measurably more radioactivity, even after five years.

In addition, DAMA is measuring a modulation in the dark matter wind, but COSINE is looking for an absolute rate for how fast it’s moving—mostly because their “dirtier” crystals makes it more difficult to accurately measure the modulation. That’s an important distinction. “To directly compare the two you need to know how fast the dark matter is moving,” said Buckley. “If you make the standard assumption about [the conventional dark matter halo model], then these results rule out DAMA. But you

could imagine that the dark matter is moving in a fundamentally different way.”

Enlarge / The COSINE-100 detector is housed within a nested arrangement of shielding components, as indicated by different colors.

COSINE-100 collaboration

University of Chicago physicist Juan Collar wasn't particularly impressed with the new paper from the COSINE-100 experiment and thinks it has limited relevance, mostly because he believes it is premature. “I think it is a bit of a publicity stunt on their side,” he said. For instance, “The uncertainty they are assigning to their background models is very small. As someone who does these simulations for a living, I do not buy it.”

That said, he does think this new paper is a harbinger of something much more interesting down the line. “What is really impressive is that they have almost matched DAMA's level of background at low energy,” said Collar. “That is a first, and

a remarkable achievement. What it means is that they will soon have, with certainty, the ability to put this mystery to rest, by seeing or not seeing that pesky modulation, while using the same target material. So the best from COSINE is still to come.”

Blame it on helium

So if DAMA/LIBRA’s signal isn’t due to the dark matter wind, what could be producing it? Daniel Ferenc, a physicist at University of California, Davis, has proposed an intriguing new hypothesis: helium that has seeped into the photomultiplier tubes used in the experiment’s detectors. As explained by University College London physicist Jon Butterworth at the Cosmic Shambles blog, “It is well-established that there are seasonal changes in the underground density of helium, connected to changes in temperature and the water table. Helium is a tiny atom, horribly penetrative, and could get into the DAMA detectors and cause this effect.” It’s a draft paper posted to the arXiv, and not yet peer-reviewed, but it’s piqued the interest of people like Butterworth.

Ferenc stumbled upon the seeds for this new hypothesis while designing new prototype detectors for a next generation of physics experiments. Most dark matter experiments use photomultiplier tubes, a technology that is around 80 years old. Great care is taken to ensure these tubes are protected from outside contamination, but Ferenc and his colleagues realized that helium was still leaking into the tubes over time.

“Every photomultiplier tube in the world has helium in it,” he said. “This is something you cannot eliminate.” And that’s bad news for sensitive detection experiments like DAMA/LIBRA that only pick up a few weak events per year. Effects from trace amounts of helium must be accounted for in the analysis to make sure what’s being detected is a genuine dark matter

particle. Hunting for dark matter is often compared to looking for a needle in a field of haystacks. “All of a sudden you realize you have much more hay in your haystacks than you thought before,” said Ferenc.

“It is precisely the sort of thinking that we should be doing about finding alternative explanations to the DAMA modulation.”

When Ferenc *et al.* searched for the term “helium” in all of the DAMA/LIBRA collaboration’s papers, they got zero hits—another red flag. Nor did they find any mention of how the experiment might have protected itself from helium. Because DAMA/LIBRA is housed in a mine, and hence prone to trace amounts of radon, the collaboration did include protection from radon contamination in their design. But radon is a much heavier gas than helium, with an atomic mass of 222, compared to helium’s 4. [corrected] “The bottom line is, what works for radon, doesn’t work for helium,” said Ferenc. He also found out that there is a helium liquefying facility quite close to the experiment, adding more circumstantial evidence for his hypothesis.

Ferenc is a leading expert on photomultiplier tubes, so physicists like Collar are taking his hypothesis seriously—at least the argument concerning the signal creation mechanisms for DAMA/LIBRA. “I think the paper could be improved, but it is precisely representative of the sort of thinking that we should be doing about finding alternative explanations to the DAMA modulation,” said Collar.

Plenty of other scientists have offered theoretical explanations for the DAMA/LIBRA signal, suggesting they are detecting neutrons or cosmic rays. But Ferenc points out that none of these alternative explanations can really be tested. He and his colleagues think the collaboration can test this latest hypothesis for themselves, simply by unplugging their 25 pairs of photomultiplier tubes and replugging them back

into different places. If the detectors still pick up the same signal, that would be conclusive evidence that the signal is due to helium, not dark matter particles, according to Ferenc.

“They just have to replugin 25 cables,” he said. “In about half a year, they will know the answer. If they see the same variation like they are seeing now, then it means it is not dark matter.”

DOI: *Nature*, 2019. 10.1038/s41586-018-0739-1 (About DOIs).

<https://arstechnica.com/?p=1448269>