Physicists propose new way to search for dark matter: Small-scale solution could be key to solving large-scale mystery

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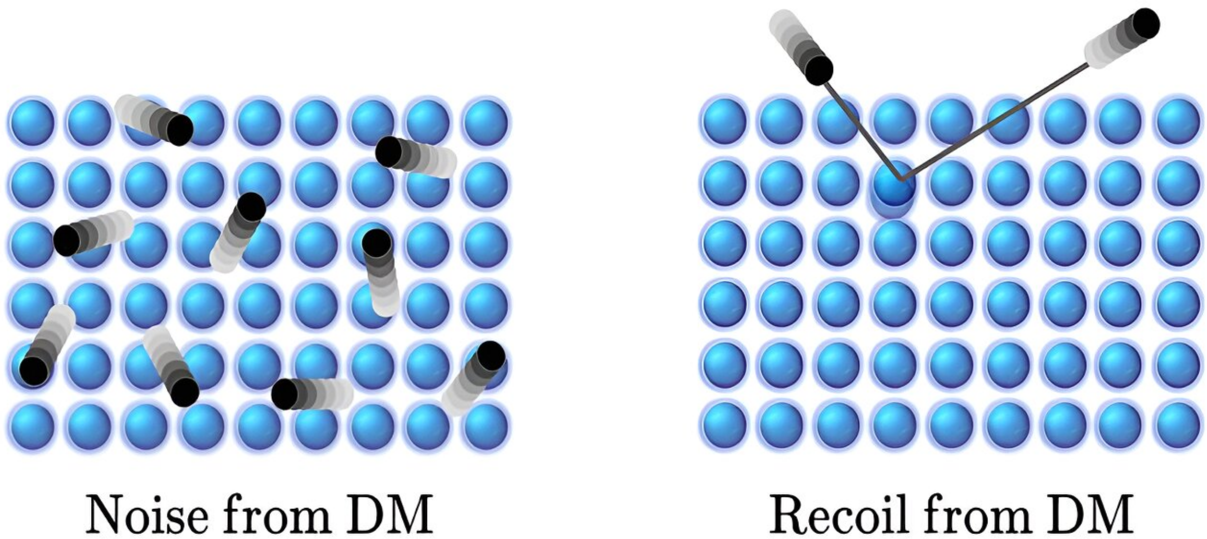

(Left) The new dark matter detection proposal looks for frequent interactions between nuclei in a detector and low-energy dark matter that may be present in and around Earth. (Right) A conventional direct detection experiment looks for occasional recoils from dark matter scattering. Credit: Anirban Das, Noah Kurinsky and Rebecca Leane

Ever since its discovery, dark matter has remained invisible to scientists despite the launch of multiple ultra-sensitive particle detector experiments around the world over several decades.

Now, physicists at the Department of Energy's (DOE) SLAC National Accelerator Laboratory are proposing a new way to look for dark matter using quantum devices, which might be naturally tuned to detect what researchers call thermalized dark matter.

Most dark matter experiments hunt for galactic dark matter, which rockets into Earth directly from space, but another kind might have been hanging around Earth for years, said SLAC physicist Rebecca Leane, who was an author of the new study.

"Dark matter goes into the Earth, bounces around a lot, and eventually just gets trapped by the gravitational field of the Earth," Leane said, bringing it into an equilibrium scientists refer to as thermalized.

Over time, this thermalized dark matter builds up to a higher density than the few loose galactic particles, meaning that it could be more likely to hit a detector. Unfortunately, thermalized dark matter moves much more slowly than galactic dark matter, meaning it would impart far less energy than galactic dark matter—likely too little for traditional detectors to see.

With that in mind, Leane and SLAC postdoctoral fellow Anirban Das reached out to Noah Kurinsky, a staff scientist at SLAC and leader of a new lab focused on detecting dark matter with quantum sensors, who had been thinking about a puzzle: Even when superconductors are cooled to absolute zero, removing all of the energy out of the system and creating a stable quantum state, somehow energy reenters and disrupts the quantum state.

Typically, scientists assume that's because of imperfect cooling systems or some source of heat in the environment, said Kurinksy. But there could be another reason; he said, "What if we actually have a perfectly cold system, and the reason we can't cool it down effectively is that it's constantly being bombarded by dark matter?"

Das, Kurinsky, and Leane wondered whether superconducting quantum devices could be redesigned as thermalized dark matter detectors. According to their calculations, the minimum energy needed to activate a quantum sensor is low enough—around one-thousandth of an electron volt—that it could detect low-energy galactic dark matter as well as thermalized dark matter particles hanging around Earth.

Of course, that doesn't mean that dark matter is to blame for disrupted quantum devices—only that it is possible. The next step, Leane and Kurinsky said, is to figure out if and how they can turn sensitive quantum devices into dark matter detectors.

With that, there are a few things to consider. For starters, maybe there is a better material to make the device out of. "We were looking at aluminum to start with, and that's just because that's probably the best-characterized material that's been used for detectors so far," said Leane. "But it could turn out that for the sort of mass range we're looking at and the sort of detector we want to use, maybe there's a better material."

There's also a possibility that thermalized dark matter wouldn't interact with a quantum device the same way galactic dark matter is suspected to interact with direct detection devices, Leane said. "In this study, we were just thinking about a simple case for dark matter coming in and bouncing straight off the detector, but it could do a lot of other things." For example, other particles could interact with dark matter, which changes the way the particles in the detector are distributed.

"This is one of the great things about being at SLAC," Leane says. "We really have quite a diverse range of groups working on a lot of different science, and I feel like this project is a really nice synergy of the research at SLAC."

The work is published in the journal *Physical Review Letters*.

More information: Anirban Das et al, Dark Matter Induced Power in Quantum Devices, *Physical Review Letters* (2024). DOI: 10.1103/PhysRevLett.132.121801

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