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New finding to help probe dark matter

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In a landmark discovery that bridges nearly a century of theoretical physics, a Chinese research team has successfully captured the first direct evidence of the Migdal effect, a breakthrough with profound implications for probing dark matter — the invisible substance thought to make up roughly 85 percent of the universe.

The finding, published on Thursday in the journal Nature, confirms a prediction made in 1939 by Soviet physicist Arkady Migdal: When an atomic nucleus suddenly gains energy — for instance, from a collision with a neutral particle (like a neutron or a dark matter candidate) — and recoils, the rapid shift in the atom's internal electric field can eject one of its orbiting electrons.

For nearly nine decades, this "electron ejection" process remained purely theoretical. Direct evidence proved elusive because the effect occurs on an incredibly tiny scale and is easily masked by background noise from cosmic rays and natural radiation.

To capture it, a research team led by the University of Chinese Academy of Sciences, working with several other Chinese universities, developed a specialized "atomic camera" — a high-precision gas detector integrated with a custom-designed microchip. The setup is sensitive enough to track the trajectory of a single atom and the electron it releases.

By bombarding gas molecules with neutrons and analyzing more than 800,000 candidate events, the team identified six clear signals. Each displayed the defining signature of the Migdal effect: two particle tracks — one from the recoiling nucleus and one from the ejected electron — emerging from precisely the same point. The statistical confidence of the discovery reached the five-sigma threshold, the gold standard in particle physics.

"Directly observing the Migdal effect in nuclear experiments has been a long-standing and widely recognized challenge. Several leading international research teams have attempted to detect it, without success," said Yu Haibo, a professor of physics and astronomy at the University of California, Riverside. "Therefore, the result achieved by the Chinese team is a genuine breakthrough and truly exciting."

For decades, the search for dark matter has focused on hypothetical particles called WIMPs, or weakly interacting massive particles. But after major experiments such as China's PandaX and Italy's XENON found no evidence of these heavy candidates, scientific attention has increasingly turned to so-called light dark matter — particles that are far lighter and even more difficult to detect.

The challenge is that when such a lightweight particle strikes an atom, the nuclear recoil it produces is too faint for conventional sensors to register.

This is where the Migdal effect changes the equation.

"With the Migdal effect, once an electron is ejected, our detector can, in theory, capture 100 percent of its energy," said Zheng Yangheng, a professor at the University of Chinese Academy of Sciences and a co-leader of the research. He said the process effectively converts an otherwise imperceptible low-energy jolt into a measurable electronic signal.

"This work fills a long-standing experimental gap, solidifies the theoretical foundation of the Migdal effect, and represents a crucial first step toward applying it in the search for light dark matter," said Liu Jianglai, a professor at Shanghai Jiao Tong University and lead scientist of the PandaX experiment.

Looking ahead, the team plans to study the Migdal effect using different target materials.

"Our next steps include optimizing the detector's performance and extending observations of the Migdal effect to other elements," said Liu Qian, a professor at the University of Chinese Academy of Sciences and a co-leader of the research. "This will provide essential data to support the search for even lighter dark matter particles."