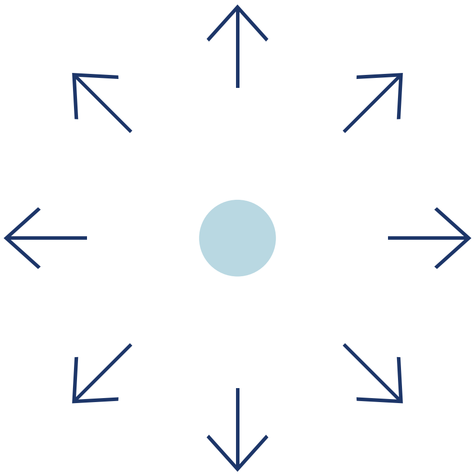
FRESH INSIGHTS

Shining a light on dark matter

To unravel this baffling space phenomenon, physicist Yonit Hochberg is studying strongly interacting massive particles **BY DAN FALK**



For almost a century, astronomers have observed that galaxies are not responding to gravity exactly as they should, leading scientists to believe that there's more matter out there than the stars, planets and nebulae that show up in our telescopes. Some additional, unseen matter is exerting a gravitational tug. This mystery material has been dubbed "dark matter."

No one knows what it is, though all manner of guesses have been put forward, from black holes to subatomic particles known as neutrinos. For several decades, the favoured theory has been that dark matter is made up of particles created shortly after the big bang, and that they barely interact with ordinary matter. These hypothetical objects have been labelled "weakly interacting massive particles," or WIMPs. Scientists have conducted sophisticated experiments in the hopes of detecting these elusive WIMPs—but so far, they have found nothing.

"The experiments are incredible—they're amazingly sensitive, and yet they haven't discovered this particle," says Yonit Hochberg, a physicist at the Hebrew University of Jerusalem. The failure to uncover this mystery particle has left Hochberg and her colleagues wondering if the search for dark matter has taken a wrong turn. "Maybe our focus has been too narrow," she says.

Traditional searches have been based on the idea that the dark matter particle has a mass of up to 1,000 times that of a proton, and that these particles interact with ordinary matter (and with each other) not only via gravity but also via the so-called weak nuclear force (the force that governs radioactive decay). Hochberg's bold idea, developed with the team she leads at the Racah Institute of Physics, is that the particles might not be so massive after all.

She proposes that the dark matter particle could be much lighter, perhaps just one-tenth of the mass of a proton. Her team's work also suggests that these lighter particles could pull on each other much more strongly—almost as strongly as a proton's quarks bind to each other, holding matter together. "So instead of a weakly interacting massive particle, it would be strongly interacting," says Hochberg, a former Azrieli Early Career Faculty Fellow. "So instead of a WIMP, we call it a SIMP."

But today's experiments are designed to identify WIMPs, not SIMPs. Most of them work by corralling lots of heavy nuclei—like the nuclei of xenon, a heavy element—and watching to see if they recoil suddenly, as though struck by some unseen particle zipping through the lab. The problem is, if the dark matter particle is as light as Hochberg suspects, it won't carry enough momentum to budge a heavy atomic nucleus. She compares the workings of traditional detectors to an array of billiard balls on a table: if a stray billiard ball comes by, it will move one of the balls on the table; you measure its recoil and work out the properties of the ball that smacked it. But now suppose the incoming object is much lighter. "Think of a ping-pong ball that's trying to give a kick to a big bowling ball," she says. "It's just not going to work."

Hochberg is keen on building new kinds of detectors, perhaps using electrons, which are about 1,800 times lighter than protons, as targets. One idea is to use superconductors, materials in which electrons, rather than orbiting around nuclei, are set free and can move unimpeded. Using electrons "opens up a whole new class of materials and sensors and targets that we could be using to search for dark matter," she says.

The dark matter mystery has flummoxed physicists for so long that any promising new line of research is worth pursuing, Hochberg says. "We want to know what the world is made of," she says. "And on the way to answering that question, who knows what we'll discover." ●

PHOTOGRAPH BY BOAZ PERLSTEIN

There is roughly five times more dark matter than ordinary matter in our universe

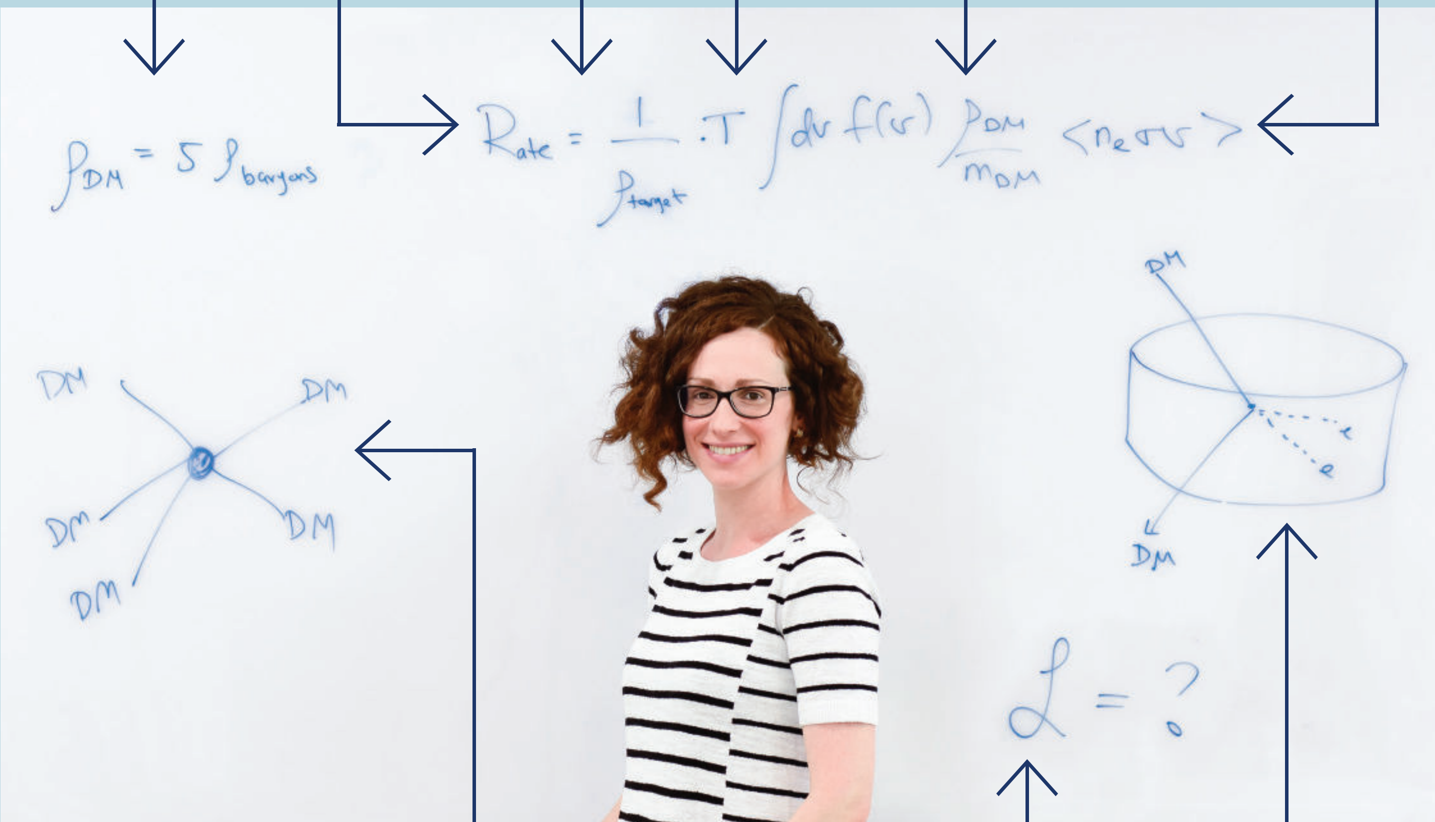
How many dark matter events you see in your detector

The size of the target volume you are evaluating

How long you measure

The flux of dark matter particles coming in

Interaction strength of dark matter with the target



SIMPs in a nutshell: three dark matter particles meet in the early universe and out come two dark matter particles

Particle physics is all about trying to find the basic equation that describes nature

How to detect? Dark matter hits electrons in a target, and we measure the system's reaction to the kick

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Hebrew University of Jerusalem physicist Yonit Hochberg is investigating new methods to study how dark matter particles interact with each other.