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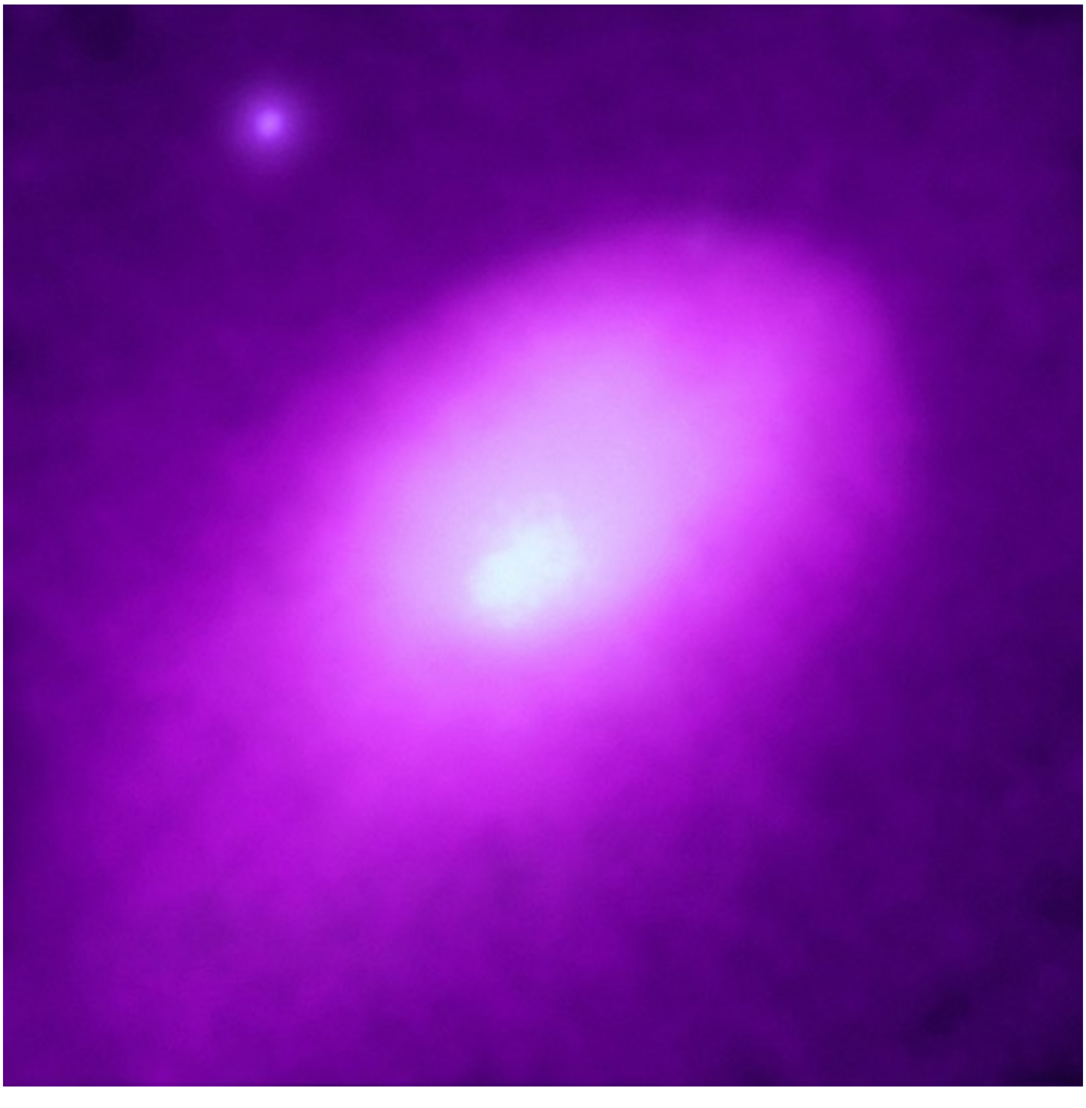
The Dark 'Fifth Force' of the Universe --“It’s Totally Beyond Anything We Understand" (Thursday's Most Popular)

May 26, 2016



Scientists have been trying to puzzle out for decades why the universe seems to weigh more than it should, and so far the answer points to dark matter—an invisible substance that they still don't clearly understand and is thought to exist in clumps throughout the universe. Dark matter, believed by physicists to outweigh all the normal matter in the universe by more than five to one, is by definition invisible. But, scientists at MIT and elsewhere have developed a new tool that could test to see if dark matter is detectable.

However, an exotic particle -a "dark photon"- that resembles a photon, but with mass, has been proposed by some theorists to explain dark matter — whose nature is unknown but whose existence can be inferred from the gravitational attraction it exerts on ordinary matter, such as in the way galaxies rotate and clump together.

“We're looking for a massive photon,” explains MIT physics professor Richard Milner. That may seem like a contradiction in terms: Photons, or particles of light, are known to be massless. If it does exist, that would represent a major discovery, Milner says. “It's totally beyond anything we understand about the physical world. A massive photon would be totally different” from anything allowed by the Standard Model, the bedrock of modern particle physics. "It's a tiny effect,” Milner adds, but “it can have enormous consequences for our theories and our understanding. It would be absolutely groundbreaking in physics.”

The experiment known as DarkLight, developed by MIT physics professor Peter Fisher and Milner in collaboration with researchers at the Jefferson National Accelerator Laboratory in Virginia and others, will look for evidence a massive dark photon with a specific energy postulated in one particular theory about dark matter, Milner says. If the planned experiment detects the A' particle, says Roy Holt, a distinguished fellow in the physics division at Argonne National Laboratory says, “it would signal that dark matter could actually be studied in a laboratory setting.”

Meanwhile, team of physicists at the University of California have uploaded on Arvix (the e-print archive with over 100,000 articles in physics) work done by a team in Hungary in 2015 that might have revealed the existence of this fifth force of nature. The Hungarian team, led by Attila Krasznahorkay, examined the possible existence of dark photons that work with dark matter. The Berkeley team has challenged the findings, suggesting that the new particle found by the Hungarian team was not a dark photon, but possibly a protophobic X boson, which might carry a super-short force which acts over just the width of an atomic nucleus.

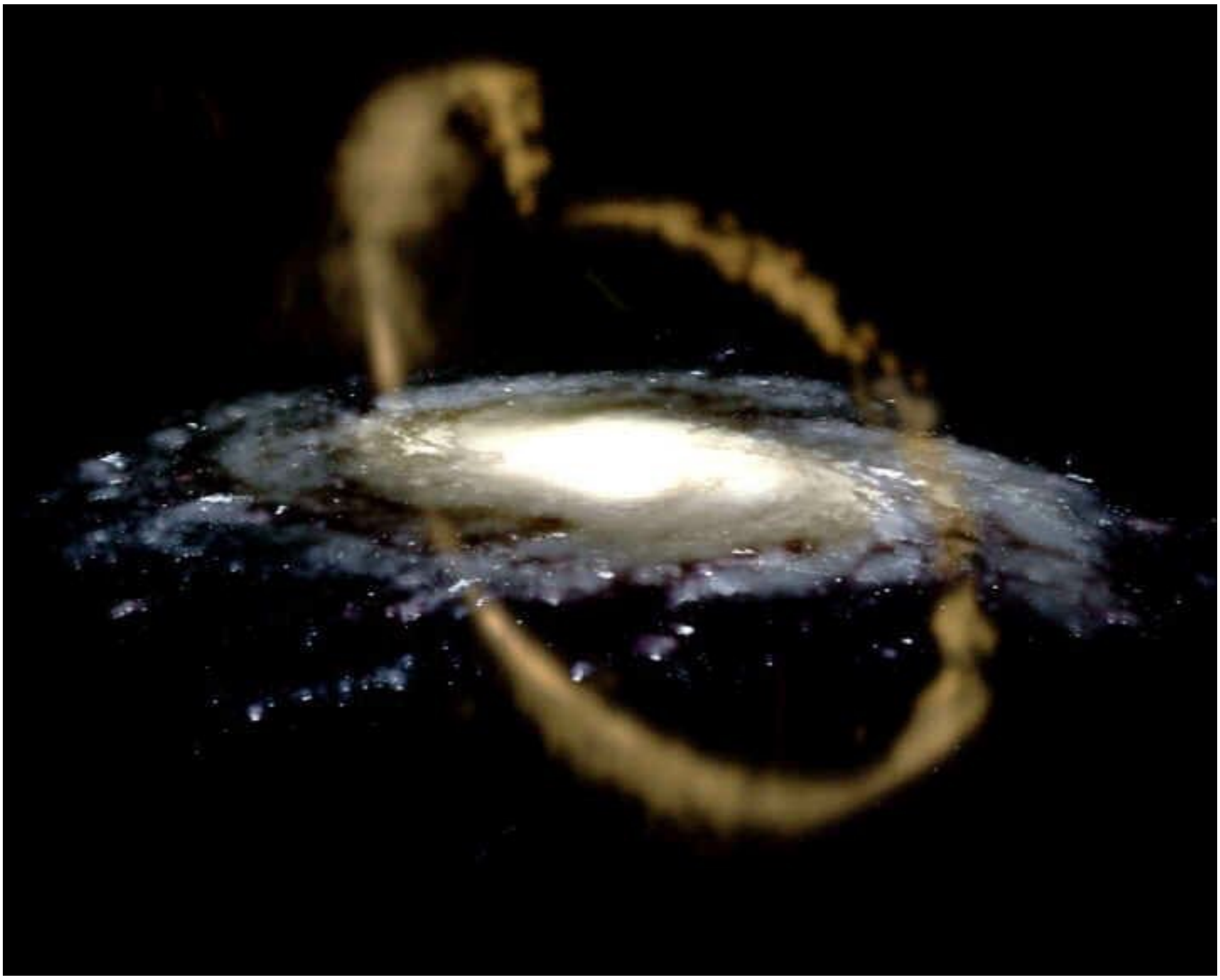
To prove the existence of the theorized particle, dubbed A' (“A prime”), the Darklight experiment will use a particle accelerator at the Jefferson Lab that has been tuned to produce a very narrow beam of electrons with a megawatt of power. That's a lot of power, Milner says: “You could not put any material in that path,” he says, without having it obliterated by the beam. For comparison, he explains that a hot oven represents a kilowatt of power. “This is a thousand times that,” he says, concentrated into mere millionths of a meter.

The Jefferson Lab's Free Electron Laser, in Virginia, will bombard an oxygen target with a stream of electrons with one megawatt of power. This will be able to test for these massive photons at a mass-energy of up to 100 MeV. It is hoped that this hugely powerful beam of electrons will hit the target and create this theorized form of dark matter (A' particles). The dark matter, if it's created, will then immediately decay into two other particles that can be easily detected.

The MIT paper confirms that the new facility's beam meets the characteristics needed to definitively detect the hypothetical particle — or rather, to detect the two particles that it decays into, in precise proportions that would reveal its existence. Doing so, however, will require up to two years of further preparations and testing of the equipment, followed by another two years to collect data on millions of electron collisions in the search for a tiny statistical anomaly.

While DarkLight's main purpose is to search for the dark photon A' particle, it also happens to be well suited to addressing other major puzzles in physics, Milner says. It can probe the nature of a reaction, inside stars, in which carbon and helium fuse to form oxygen — a process that accounts for all of the oxygen that now exists in the universe.

"This is the stuff we're all made of," Milner says, and the rate of this reaction determines how much oxygen exists. While that reaction rate is very hard to measure, Milner says, the DarkLight experiment could illuminate the process in a novel way: "The idea is to do the inverse." Instead of fusing atoms to form oxygen, the experiment would direct the powerful beam at an oxygen target, causing it to split into carbon and helium. That, Milner says, would provide an indirect way of determining the stellar production rate.



In 2012, Simona Vegetti, a physics fellow at MIT, discovered an entire galaxy made of dark matter just outside the Milky Way. The dark galaxy may host a luminous galaxy made invisible by the dark matter. "The thing people like about dark matter is that it's been able to explain so many observations," Vegetti said.

Because dark matter reflects no light, the galaxy is elusive. Vegetti worked with an international team of scientists including three from the U.S. and two from the Netherlands. Using the Keck

Telescope in Hawaii, they detected the galaxy by studying ripples in the patterns of light rays from the Milky Way, a method known as gravitational lensing.

“It’s a dark matter-dominated object,” Vegetti said, “So there might be stars but very little.”

There are thought to be more than 10,000 satellite galaxies attached to our Milky Way galaxy, but only 30 of them are visible, she said. The image above shows the Sagittarius Dwarf Galaxy, named for the constellation in which it is seen from the earth, in the process of colliding and merging with our own Milky Way. “The question becomes are these satellites missing because they don’t exist or because they are purely dark? And that’s one question we’re trying to answer,” she said.

In the image at the top of the page, the bright source in the upper left is an active galaxy in the cluster, Abell 2142, six million light years across that contains hundreds of galaxies and enough gas to make a thousand more. It is one of the most massive objects in the universe.

The Daily Galaxy via MIT, Arvix, Northwestern, and Physical Review Letters