Dark energy survey offers new view of dark matter halos, physicists report

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This artist's impression shows the Milky Way galaxy. The blue halo of material surrounding the galaxy indicates the expected distribution of the mysterious dark matter, which was first introduced by astronomers to explain the rotation properties of the galaxy and is now also an essential ingredient in current theories of the formation and evolution of galaxies. Credit: ESO/L. Calçada

Dark matter, a mysterious form of matter that makes up about 80 percent of the mass of the universe, has evaded detection for decades. Although it doesn't interact with light, scientists believe it's there because of its influence on galaxies and galaxy clusters.

It extends far beyond the reach of the furthest stars in galaxies, forming what scientists call a dark matter halo. While stars within the galaxy rotate in a neat, organized disk, these dark matter particles are like a swarm of bees, moving chaotically in random directions, which keeps them puffed up to balance the inward pull of gravity.

Previous research led by postdoctoral fellow Eric Baxter; Bhuvnesh Jain, Walter H. and Leonore C. Annenberg Professor in the Natural Sciences in the Department of Physics and Astronomy in Penn's School of Arts and Sciences; and Chihway Chang of the University of Chicago provided evidence that dark matter halos around galaxy clusters have an edge due to the "splashback effect."

"You have this big dark matter halo that surrounds every galaxy cluster," Baxter said, "and it's been accreting matter gravitationally over its entire history. As that matter gets pulled in, it goes faster and faster. When it finally falls into the halo, it turns around and starts to orbit. That turnaround is what people have started calling splashback, because stuff is splashing back in some sense."

As the matter "splashes back," it slows down. Because this effect is happening in many different directions, it leads to a buildup of matter right at the edge of the halo and a steep fall-off in the amount of matter right outside of that position.

In their initial study, the researchers used data from the Sloan Digital Sky Survey to investigate the distribution of galaxies around clusters. In a follow up study using data from the first year of the Dark Energy Survey, the researchers used a different method called gravitational lensing, which takes advantage of a phenomenon in which light coming toward an observer bends as matter exerts gravitational force on it. By looking at the slight stretching of objects behind galaxies, the researchers can directly measure the mass profile, how mass is distributed within the galaxy.

"There are many different applications of lensing," Jain said, "but this is one where something went from being undetectable to detectable, so it's particularly exciting."

In a paper to be published in the *Astrophysical Journal*, the researchers showed that this method produced an understanding of the dark matter halos that is broadly consistent with what they saw using the light of the cluster galaxies in their first study.

"We were pursuing this question of whether dark matter halos have a sharp boundary," Jain said. "The gold standard for establishing this is to look directly at the mass through gravitational lensing, which hasn't been done before now. With the latest compilation of DES data we see a picture very similar to what we saw in the distribution of galaxies."

Measuring gravitational lensing is a lot harder than simply measuring the distribution of galaxies, Jain said.

"We can see galaxies easily, we just take a picture of them," he said, "but with gravitational lensing we have to take pictures of many more faint, background galaxies and measure how those are distorted in tiny ways. It's a challenging measurement."

This leaves more room for error in the measurements, causing them to be less precise. However, the findings were only based on the first year of observations of the Dark Energy Survey. By the end of the survey, there will be four additional years of data for the researchers to analyze. This will allow them to make more precise measurements, directly probing the matter in galaxies and galaxy clusters using gravitational lensing. Tests of dark matter will then be possible, since any new physical interactions between dark matter particles could shift the location of splashback.

"We can look forward to a clearer picture of mysterious dark matter halos," Jain said.

Provided by University of Pennsylvania

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