



Seeing the unseen

Look around you. Everything you see—people, planets, stars, galaxies—makes up approximately 20 percent of all the matter in the universe. That means a lot of matter is missing. So, where is it? And, more importantly, what is it and how do we know it's there?

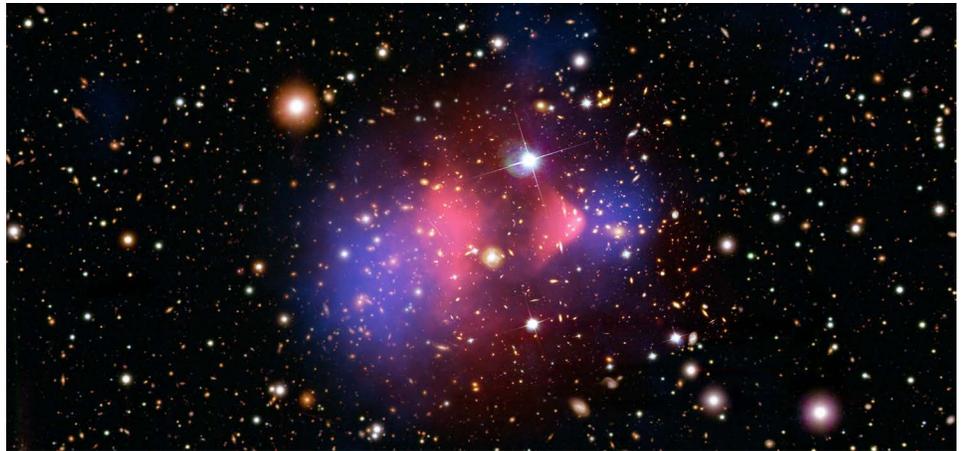
“We don't know much about dark matter yet, which is a remarkable thing because it makes up 80-85 percent of the matter in the entire universe,” said Mark Hanhardt, support scientist at Sanford Lab. “Although we've never directly detected it, we know it must exist from the way it affects the universe around us.”

Hanhardt points to several phenomena that provide strong evidence of the existence of dark matter:

The orbital velocities of stars around their galactic centers. Gravity keeps planets rotating around the sun and the solar system rotating around the galaxy. The speed at which galaxies rotate suggests there is more mass than we observe. Think of dark matter as the glue that allows galaxies to generate the extra mass and gravity required to keep it all together.

Gravitational lensing. This phenomenon occurs as light bends around massive objects such as galaxies, clusters of galaxies and even our own sun. Predicted by Einstein in his Theory of Relativity, it has been observed for more than a hundred years. “It becomes especially interesting when observed where there is nothing visible to bend the light,” Hanhardt said. This effect is especially evident in the Bullet Cluster.

The Bullet Cluster. “This is a fantastic example of how the center-of-mass of a cluster of galaxies can decouple from the regular matter, something that can only happen if dark



Credit: X-ray: NASA/CXC/CfA/M.Markevitch et al.; Optical: NASA/STScI; Magellan/U.Arizona/D.Clowe et al.; Lensing Map: NASA/STScI; ESO WFI; Magellan/U.Arizona/D.Clowe et al.

This composite image shows the galaxy cluster 1E 0657-56, also known as the “bullet cluster.” This cluster was formed after the collision of two large clusters of galaxies, the most energetic event known in the universe since the Big Bang.

matter exists,” Hanhardt said. In the distant past, these subclusters collided and the visible matter (dust and stars) slowed down while the centers of mass passed right through each other and kept going. This decoupling can only happen if there is invisible and intangible matter making up most of the mass. That matter is dark matter.

“It's an observation that very strongly supports the WIMP (weakly interacting massive particle) as a dark matter candidate,” said Markus Horn, research scientist at Sanford Lab. Both the Large Underground Xenon (LUX) and LUX-ZEPLIN experiments hope to detect these elusive particles.

Clues from the Cosmic Microwave Background. “The CMB gives us a snapshot of the universe when it was very young, just 380,000 years old,” Hanhardt said. It is now 13.8 billion years old. By studying the fluctuations and patterns in the CMB, scientists can better understand matter distribution in the early universe. Some patterns, which scientists

call “ringing,” would not appear unless there were a large amount of dark matter pulling the rest of the regular matter together at a very early stage in the life of the universe

Simulations of galaxy formations. Want to know how the universe evolved? Type the laws of gravity into a computer model and tell it to start with the conditions of the early universe. You won't see one that looks like ours unless, of course, you include a “mass field” that simulates dark matter.

“Without dark matter, we could not have gone from a somewhat uniformly distributed universe made of hydrogen and helium to a universe made up of staggeringly massive structures and formations like galaxies, clusters of galaxies, superclusters of clusters and the webs shown in the Sloan Digital Sky Survey,” Hanhardt said.

“When taken together, these phenomena lead to the inescapable conclusion that dark matter exists.”