COSMIC BACKGROUND BY MARCIA BARTUSIAK

Dark Matters

The search for WIMPS

Nearly half a mile beneath the surface of the Earth, within a cavern of an old iron-ore mine in northeastern Minnesota, special detectors cooled almost to absolute zero (−459.67 degrees Fahrenheit) are on the lookout. They serve the Cryogenic Dark Matter Search (CDMS), one of several projects around the world attempting to find a novel type of matter that has been long hypothesized but never seen. New particle physics theories, beyond the so-called standard model, suggest that all around us could be ghostly particles that blithely whiz through us with nary a nudge. The hope is that deep underground, far from disruptive cosmic rays, one of these exotic particles will occasionally bump into a detector and release an indisputable signal.

If and when that happens, astronomers will be jumping for joy. Along with opening up new physics, the discovery of such weakly interacting massive particles (or WIMPs) might solve a cosmic mystery that has endured for eighty years. Those particles—distinct from those in the standard model, including the recently headlined Higgs boson—could be the long-sought "dark matter" thought to permeate the universe.


NASA/ESA/HUBBLE HERITAGE TEAM (STSCI/AURA)

Hubble Space Telescope long-exposure image of Galaxy NGC 4911, at the heart of the Coma cluster of galaxies: What keeps the cluster from tearing apart?

The first person to wonder about this unseen cosmic ingredient was an irascible physicist named Fritz Zwicky (1898–1974). A Bulgarian-born Swiss national, Zwicky arrived at Caltech in 1925 to study the properties of liquids and crystals. But that was just for starters. An aggressive and stubbornly opinionated man, he regularly annoyed his physics and astronomy colleagues by studying anything he pleased. Along the way he championed some pretty wild ideas, some of which proved their worth decades later. In 1933, for example, he was the first to propose that a supernova—the total destruction of a star—left behind an extremely small and dense object that he called a "neutron star." The first such object wasn't detected until 1967.

Given his eclectic scientific style, it's not surprising that Zwicky also spied one of the first signs that the universe's ledger books were not quite balancing. He had decided to examine all the velocity information then available in the literature on the galaxies situated within the famous Coma cluster, a rich group of hundreds of galaxies some 330 million light-years distant. His statistical analysis revealed that the galaxies were moving around in the cluster at a fairly rapid clip. But adding up all the visible light being emitted by these galaxies, he realized that there was not enough luminous matter to bind the speeding objects to one another through the force of gravitation.

"It is difficult to understand why under these circumstances there are any great clusters of nebulae remaining in existence at all," he observed. The situation seemed paradoxical. With the Coma galaxies buzzing around so nimbly, the cluster should have broken apart long ago, but it was still very much intact. Zwicky reasoned that some kind of unseen matter must pervade the Coma cluster to provide additional gravitational glue. In his report to the Swiss journal *Helvetica Physica Acta* in 1933, Zwicky referred to this invisible substance as *dunkle Materie*, or dark matter.

Fritz Zwicky (1898–1974) coined the term dunkle Materie *(dark matter).*

Zwicky's suggestion was largely ignored for several decades. Astronomers at the time figured the dilemma would disappear once they could analyze the motions of galaxies in more detail. They presumed that "weighing" a cluster of galaxies would prove more complicated than Zwicky had supposed.

The issue wasn't revived until the 1970s, largely owing to Vera Rubin, an astronomer with the Carnegie Institution of Washington. Early in her career she had dabbled in quasar research, the study of those energetic young galaxies that dwell at the edge of the visible universe. Having been recently discovered, they were then the hottest topic in astronomy, but Rubin came to dislike the field's cutthroat pace. She eventually turned her attention to a problem far less controversial, even boring: the rotation of spiral galaxies. In doing this, she teamed up with W. Kent Ford, who had recently perfected a new electronic instrument that made it easier to record the spectrum of a galaxy, the data needed to measure the rotation.

At this point, astronomers just assumed that a galaxy rotated much like our solar system, following the laws of gravity set down by Isaac Newton. The stars closest to the galaxy's massive center would travel faster than those farther out in the disk, where the gravitational influence is diminished—just as the inner planets in our solar system practically race around the Sun, while the outer planets move at a far slower pace. But in spiral galaxy after spiral galaxy, Rubin, Ford, and a team of Carnegie postdocs found a far different pattern. To their surprise, they revealed that the stars and gas at a disk's edge traveled just as fast as matter closer to the galaxy's center.

If the planets in our solar system acted like this, Jupiter, Uranus, and Neptune would have careered off into interstellar space long ago. Rubin recognized that a huge reservoir of extra matter, imperceptible to her instruments, had to be tucked away somewhere to keep the stars from flying out of the galaxy. It was the Coma cluster problem all over again, but this time within an individual galaxy. Modeling this effect, theorists figured that each spiraling disk must be embedded in a large sphere of invisible matter to keep the luminous galaxy intact.

Some radio astronomers had measured a few of these fast galactic spins earlier, but by 1978 Rubin and her team had measured more than 200. This arsenal of data at last took the dark-matter problem off of the back burner and turned it into one of the most active concerns in astronomy—an effort that continues to this day. While some astronomers questioned Rubin's findings when they first came out, recent and more varied measurements have removed nearly all doubt.

Some of the best evidence to date is based on an effect known as "gravitational lensing." Astronomers, for example, have aimed the Hubble Space Telescope at massive galaxy clusters to map their dark matter. While astronomers can't directly see the dark matter, they can view its gravitational effects, especially in the way it bends light arriving from the distant galaxies behind it, much like a lens. What results is a fun-house view of the cluster, filled with myriad arcs, bands, and rings of light. The amount of light bending, using Einstein's rules of general relativity, provides the means to weigh the dark matter in the cluster and map its distribution.

On top if that, the exquisite measurements now made of the cosmic microwave background, the remnant radiation left over from the big bang, tell us that there is six times as much dark matter in the universe as there is of the ordinary elements that make up the stars, nebulae, and us. We're merely the icing on the cosmic cake. What this invisible stuff is remains one of the astronomy's greatest mysteries, and yet the answer to dark matter's composition may not come from *out there*—the farthest recesses of space-time—but possibly from instruments that stand watch deep down in the Earth.

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