Physics Nobel Explainer: **Why Is Expanding Universe Accelerating?**

More than a decade after prize-worthy find, dark energy still baffles. (news.nationalgeographic.com)

What goes up must come down. Few on Earth would argue with the fundamental law of gravity. But today the 2011 Nobel Prize in Physics was awarded to three scientists who uncovered a dark side of the force.

New Nobel laureates Saul Perlmutter and Adam Riess of the U.S. and Brian Schmidt of Australia contributed to the discovery that the universe is not only expanding but also speeding up.

The finding led to the now widely accepted theory of dark energy, a mysterious force that repels gravity.

Measurements show that dark energy accounts for about 74 percent of the substance of the universe.

But more than a decade after the Nobel-worthy find, scientists are still trying to pin down exactly what dark energy is and and thus solve what some experts call "the most profound problem" in modern physics.

Does Gravity Work Differently?

Until dark energy, physicists were convinced that gravity should be causing the expansion rate of the universe to slow.

"When I throw my keys up in the air, the gravity of the Earth makes them slow down and return to me," said Mario Livio, a theoretical physicist at the Space Telescope Science Institute (STScI) in Maryland, said during the Decade of Dark Energy Symposium, held in 2008.

But by studying the light from distant supernovae, astronomers saw that the supernovae's host galaxies are flying away from each other at increasing speed.

The observation that the universe's expansion rate is actually speeding up, Livio said, is as if "the keys suddenly went straight up toward the ceiling."

So far, one of the biggest challenges for dark energy researchers is marrying observations to theory.

"We have two known, totally unsatisfactory explanations," said Michael Turner, a cosmologist at Univ. of Chicago. One possibility is there is no dark energy, and gravity works differently than scientists think.

But "physicists are conservative. We don't want to throw away our theory of gravity when we might be able to patch it up," Nobel co-winner Riess, an STScI cosmologist, told National Geographic News.

"Basically it all comes down to the fact that there's one relatively simple equation we work with to describe the universe," Riess said.

"Because we see this extra effect, we can either blame it on the left-hand side of the equation and say we don't understand gravity, or we can blame it on the right-hand side and say there's this extra stuff."

Dark Energy a Product of Quantum Vacuum?

The extra stuff—and a leading contender for explaining dark energy—is quantum vacuum energy.

The idea is tied to quantum mechanics, which predicts that even in the vacuum of space, particles are constantly winking in and out of existence, generating energy.

The trick is that no one has been able to unify the math used in quantum mechanics, which describes the physics of the very small, with the equations in general relativity, which deal with large-scale interactions.

"The two theories use two different sets of rule books, [and] we've always known that these two books are incompatible," Riess said.

Unfortunately, "dark energy is one of the few cases in nature that really requires us to [somehow] use both sets of rules."

Measuring Supernovae's Stretched Light

NASA missions have already played a key role in measuring dark energy, said Michael Salamon, program

scientist for NASA's Physics of the Cosmos program.
"For one, the Hubble Space Telescope has weighed in on dark energy by virtue of the measurements of supernovae," Salamon said.
Researchers first observed accelerated expansion by studying Type Ia supernovae—the explosive deaths of white dwarf stars.
Astronomers know that each Type Ia explosion has about the same brightness.
As light from the most distant explosions travels toward Earth, it is stretched by the universe's expansion so that it appears red, a phenomenon known as redshift. The higher the redshift, the faster the star was moving away when the supernova occurred.
Examining as many supernovae as possible can help researchers measure how fast galaxies are moving away from one another.
Supernovae studies have allowed scientists to see that dark energy has been impacting galaxies since as far back as nine billion years ago.
Other groups are looking for even earlier clues in the cosmic microwave background, the leftover radiation from the big bang, believed to have occurred about 13.7 billion years ago.
In 2003 NASA's Wilkinson Microwave Anisotropy Probe produced the first full map of the early microwave sky in unprecedented detail.
Essentially looking back in time, WMAP revealed tiny ripples in density that were the seeds of today's galaxies, Licia Verde, an astrophysicist at the Institute of Space Sciences in Bellaterra, Spain, said during the 2008 symposium.
"This is a cosmic symphony. You are really seeing sound, [and] the sound can help you understand how the instrument was made," Verde said.
And in 2005 astronomers found that sound waves rippling through the primordial plasma 400,000 years after the big bang had left imprints in modern nearby galaxies.
These so-called baryon acoustic oscillations offer another yardstick for measuring the expansion rate of the universe over time and putting limits on the value of dark energy.

Dark Energy Mystery Persists

Ultimately it will take data from a combination of methods to help unravel the mystery, the experts said.
"The name of the game is to take more measurements over the expansion history of the universe, make each of them more precise, and tighten the model for understanding how dark energy works," STScI's Riess said.
A key goal of experiments is to measure the ratio of energy density to pressure in the universe, denoted by the letter *w*.
This value tells physicists "what kind of gravity a material has—whether it's repulsive or attractive—and how strong it is," Riess said.
"If [dark energy] is vacuum energy, then *w* will be -1 always and precisely," a find that would match quantum predictions with general relativity.
Otherwise, it might be time to rewrite the rules.
Lawrence Krauss, a theoretical physicist at Arizona State University, noted at the STScI symposium that most observations currently show the value for *w* as pretty close to -1.
For theorists, he quipped, "measuring *w* … is therefore not going to tell us anything we don't know already."
But "new windows show us new surprises. You have to do what you can do, because you don't know where the answer's going to come from."

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