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Dark Forces at Work

Ten years ago two teams discovered that the universe will expand forever at an ever faster rate, thanks to an unseen energy. The leader of one of the groups, Saul Perlmutter, expects that new observations will soon illuminate the universe's dark side

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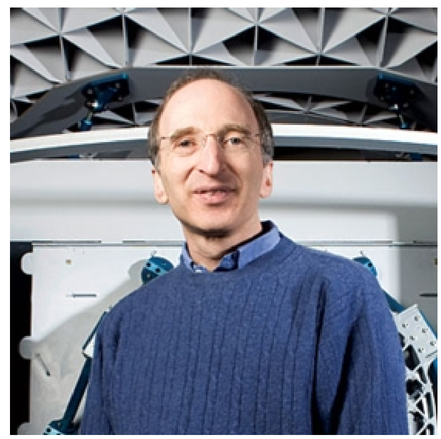

Gabriela Hasbun

One of the chief astrophysicists behind the discovery of the acceleration of the expansion of the universe, among the most startling revelations in the history of cosmology, delights in the confusion about the observation. In fact, he wonders if the acceleration will end up being the most important feature in the ultimate explanation. “It might be something unexpected that looks like acceleration,” says Saul Perlmutter, leader of the Supernova Cosmology Project (SCP), which first announced the astonishing fact in 1998. Ever the experimentalist, the 48-year-old Perlmutter is waiting, and planning, for more observations: “Until we go for a long run of more data, this just isn’t a mature field.”

Perlmutter philosophizes about the strangeness of the cosmos from his office at Lawrence Berkeley National Laboratory, high in the western hills of the San Francisco Bay Area. The room is the scientist’s amalgam of too many computer screens, too many piles of papers and an equation-filled whiteboard that would have done Einstein proud. The spectacular view of the Golden Gate Bridge in the distance cannot help but promote lofty thinking.

It has been a decade since the science community learned of the shocking discovery made by Perlmutter’s group and, independently, by the High-Z Supernova Search Team led by Brian Schmidt of the Australian National University (with analyses pioneered by Adam Riess of the Space Telescope Science Institute). The cosmos, the researchers found, is not just expanding; for unknown reasons, it is speeding up in its expansion.

The discovery took years of innovation and problem solving. The key was supernovae—specifically, those called type Ia. Such events are surprisingly invariable—the explosions have an intrinsic brightness that predictably fades over time, enabling astronomers to use them as “standard candles” and thus determine their distances from Earth. Perlmutter worked with Carl Pennypacker of the University of California, Berkeley, in the 1980s to robotically search for supernovae at relatively nearby distances. The field was then so young that their main competition came from Robert Evans, an amateur astronomer in Australia who identified supernovae with a backyard telescope.

In the beginning, the difficulty for Perlmutter's group lay in obtaining telescope time, always precious in the astronomical community. How would the researchers convince allocators to give them the chance to look for something—a supernova explosion—that had not yet taken place? So they worked out methods to predict and automatically detect supernovae in a given patch of the sky. But their goal of determining the universe's dynamics—then thought to be a decelerating expansion dominated by matter—still required additional observation to plot supernovae's brightness peaks and declines, which take place over a few weeks. Perlmutter twisted arms and begged colleagues for an hour or two on short notice, calling frantically around the world at all times of the day. Everyone knew him, he says, as half-annoying. "I was always worried about something that had to happen in the next 24 hours or sometimes the next two hours. It was a terrible way to lead an ordinary life," he recalls.

But persistence paid off. Observations of distant type Ia supernovae found them to be dimmer than expected. After eliminating the possibility of intergalactic dust and after years of painstaking data gathering and analysis at telescopes around the world (and in orbit), Perlmutter's team came to the conclusion that, incredibly, the universe is not only expanding, as Edwin Hubble discovered in 1929, but that its expansion rate is increasing. Some unknown force with negative pressure seems to be pushing the universe apart.

Subsequent balloon-borne observations of the cosmic microwave background made two years later showed that the universe is spatially flat—it was stretched out by an exponential expansion, called inflation, right after the big bang. The equations behind these experiments complemented those of the supernova teams taken a few years earlier, and together the results enabled scientists to calculate separately the density of dark energy in the universe and the density of matter.

But on the other hand, the discovery opened a mystery the size of, well, the universe. The simplest explanation is that dark energy is Einstein's famed "cosmological constant," an energy that permeates space but does not interact with any type of matter. Today astronomers have homed in on the details of this scenario; if true, then the universe consists of 72 percent antigravity dark energy, 23 percent dark matter (unseen and uncharacterized, but susceptible to gravity), and 5 percent normal matter (protons, neutrons, electrons). We would be just a small part of totality, surrounded by perplexity.

"It could well be that there's some big piece of reality that we don't fully understand," says astronomer Christopher Stubbs of Harvard University, who in a paper likened the new universe to "living in a bad episode of Star Trek." Physicist Steven Weinberg of the University of Texas at Austin calls it simply "a bone in the throat of theoretical physics."

Magic has not yet been proposed to explain the accelerating universe, but almost everything else has. In the past few years, physicists have widened their search beyond vacuum energy to include possible modifications to general relativity, spinless energy fields that vary with time and space, massive gravitons, brane worlds and extra dimensions. "All of them are so exciting, and any is going to rewrite the textbooks," says Eric Linder, a cosmologist at Lawrence Berkeley and U.C. Berkeley. The hypothetical repulsive dark energy field may well not survive in the final explanation.

"It's true the theorists right now are stuck," Perlmutter says. "But from an experimentalist's point of view, this is great: we have a mystery, and we have ways to get at it"—namely, in the form of new telescopes and satellites to look even farther across the universe (and, hence, farther back in time).

Ground-based projects are already gathering more data, looking for hundreds of type Ia events (instead of Perlmutter's and Schmidt's five dozen) to determine the relation between the pressure and density of the universe, akin to the ideal gas law. A galaxy like our Milky Way exhibits about one type Ia supernova every few hundred years, and its brightness fades in weeks, making the search for them quite a challenge. By observing the cosmic background radiation, the soon-to-launch Planck satellite will contribute more details about the universe's expansion.

Dark energy aficionados look especially to the Joint Dark Energy Mission, now in the planning stages in the U.S. for a possible launch in 2014. The probe will host a device that could find thousands of supernovae a year and provide far smaller error bars than anything done so far. One candidate is the SuperNova Acceleration Probe (SNAP), for which Perlmutter is the lead scientist and Linder the head theorist. It would host a telescope about two meters wide and have a gigapixel camera.

The discovery of cosmic acceleration will assuredly win a Nobel Prize, and over the years there has been some dispute over which team deserves priority. Perlmutter's SCP team announced the discovery first, but Schmidt's High-Z team beat the SCP group in publishing the finding. Both Perlmutter and Schmidt shared one fourth of the 2007 Gruber Cosmology Prize, with the remaining fraction going to their two teams collectively.

Gregarious and talkative, Perlmutter attributes his success to being able to convey his excitement and convince other researchers to join his team. An amateur violinist who also teaches an undergraduate physics and music course, he draws an orchestral analogy. “As a violinist, I always love the moments when a group of people are creatively tuned in together.”

ABOUT THE AUTHOR(S)

David Appell is based in Portland, Ore. A Q& A version of his interview is available here.