December 17, 1998

research news

Science Magazine Names Supernova Cosmology Project 'Breakthrough of the Year'

Contacts:
Saul Perlmutter, (510) 486-5203, s_perlmutter@lbl.gov
Paul Preuss, (510) 486-6249, paul_preuss@lbl.gov
Lynn Yarris, (510) 486-5375, lcyarris@lbl.gov

BERKELEY, CA -- By observing distant, ancient exploding stars, physicists and astronomers at the U.S. Department of Energy's Lawrence Berkeley National Laboratory and elsewhere have determined that the universe is expanding at an accelerating rate -- an observation that implies the existence of a mysterious, self-repelling property of space first proposed by Albert Einstein, which he called the cosmological constant. This extraordinary finding has been named *Science* magazine's "Breakthrough of the Year for 1998."

The Supernova Cosmology Project, based at Berkeley Lab and headed by Saul Perlmutter of the Physics Division, shares the citation with the High-z Supernova Search Team led by Brian Schmidt of Australia's Mount Stromlo and Siding Spring Observatories. Both teams are international collaborations, with researchers in England, France, Germany, and Sweden among the members of the Supernova Cosmology Project.

Lawrence Berkeley National Lab's Saul Perlmutter is pictured with a view of the supernova 1987a in the background.
High-resolution versions available.

Energy Secretary Bill Richardson expressed pride in the accomplishment on behalf of the Department of Energy (DOE), which funds the country's national laboratory system.

"This brilliant example of quality research by DOE-supported scientists represents an important advance in our understanding of the universe," Richardson said. "It's impressive payback, in terms of advancing human knowledge and developing promising new technologies, for this country's investment in basic science research."

Additional Information:

Down-to-Earth Benefits from Far-Out Science

Supernova Cosmology Project Research Site

Jan 98 news release: Universe To Last Forever

Search for Omega: Will the Universe Last Forever

Fate of the Universe and the Cosmological Constant

Revolution in Telescopes: The Keck

The oldest, farthest supernova

NERSC: Computers and Cosmology

Images:

High-resolution versions of image on this page

Still images from the Supernova Cosmology

Project website

Online movie clip

Berkeley Lab Director Charles Shank concurs. "We are proud of Berkeley Lab's contributions to this dramatic accomplishment," he says. "This achievement is yet another example of how painstaking, imaginative, basic research can advance humankind's knowledge of our universe, with the promise of impacts on our lives that we can only begin to imagine." (See expanded quotes from Richardson and Shank.)

Says Perlmutter, "A DOE facility like Berkeley Lab is a unique place that brings together many different areas of expertise -- particle physicists, astrophysicists, computer scientists, and engineers were all vital to our program. Just as important, the Lab environment allows research to continue over a long time. We worked ten years before we finally got the answers to our questions."

A Special Kind of Supernova is the Key

The surprising discovery that the expansion of the universe is accelerating, and thus is likely to go on expanding forever, is based on observations of type Ia supernovae, very bright astronomical "standard candles" that all have the same intrinsic brightness. Thus how bright they appear reveals their distance.

By comparing the distance of these exploding stars with the redshifts of their home galaxies, researchers can calculate how fast the universe was expanding at different times in its history. Good results depend upon observing many type Ia supernovae, both near and far. Employing supercomputer facilities at the National Energy Research Scientific Computing Center (NERSC) located at Berkeley Lab, the Supernova Cosmology Project has fully analyzed the first 42 out of the more than 80 supernovae it has discovered, and more analysis is in progress. (More about NERSC's role.)

Type Ia supernovae are rare -- in a typical galaxy they may occur only two or three times in a thousand years -- and to be useful they must be detected while they are still brightening. Before the Supernova Cosmology Project employed search techniques developed during the first five years of its existence, finding supernovae was a haphazard proposition, which made it difficult to secure telescope time to observe them.

"It was a chicken and egg problem," says Perlmutter. "To get telescope time, you had to guarantee you were going to find a supernova. But without time on a major telescope, it was impossible to show that they were there, and that we could find them." Then, in the early 1990s, the group developed a new strategy that assured discovery of numerous supernovae "on demand."

Catch An Exploding Star -- How To Do It On Demand

Supernova Cosmology Project member Gerson Goldhaber explains how the "supernovae on demand" strategy works: "Just after a new moon, when the sky is dark, we make images of 50 to 100 patches of sky. Each contains roughly a thousand distant galaxies. Three weeks later the same patches are imaged again. Supernovae occurring anywhere in these fields show up as bright points of light -- some two dozen total, on average." In these three weeks, the supernovae typically have not yet reached their brightest moments.

Project member Peter Nugent notes that "this guarantees that we will have supernovae to study during the best nights for observation, right before the new moon." He adds, "Type Ia supernovae are so similar, whether nearby or far away, that the time at which an explosion started can be determined just from looking at its spectrum. Type Ia supernovae which exploded when the universe was half its present age behave the same as they do today."

By 1994 the Supernova Cosmology Project had proved repeatedly that, with this search technique, a few nights on the world's best telescopes dependably resulted in many new supernova discoveries.

"While some of us are surveying distant galaxies from the Cerro Tololo Interamerican Observatory (CTIO) in the Chilean Andes, others in Berkeley are retrieving the data over the Internet and analyzing it to find supernovae," says project member Greg Aldering. "Then, with the powerful Keck Telescope in Hawaii -- designed by physicists and engineers at Berkeley Lab -- we confirm spectra and measure redshifts. We call the Hubble Space Telescope into action to study the most distant supernovae, as these require much more accurate measurements than we can get from the ground."

Among the supernovae discovered by the Supernova Cosmology Project are the most distant, and therefore the most ancient, ever seen. In the Jan. 1, 1998 issue of *Nature* magazine, Perlmutter and his colleagues announced that a supernova with a redshift of 0.83, equivalent to an age of seven billion years, had been found using the National Science Foundation's CTIO and the Keck telescopes and subsequently observed by NASA's Hubble Space Telescope. In October 1998, the team used the Keck Telescope to discover a supernova dramatically more distant still; details of this discovery will be discussed at the American Astronomical Society meetings in Austin, Texas early in January. (See sidebar.)

Enter Einstein's Cosmological Constant

As their early supernova discoveries began to accumulate in 1994, members of the Supernova Cosmology Project developed key analytic techniques that, by interpreting supernova measurements, could be used to determine the cause of the expansion rate of the universe. At the time almost everybody assumed that the universe was slowing down, due to gravity acting on the matter in the universe. The question was, how quickly is it slowing? What is the mass density of the universe? Enough to reverse expansion, and eventually end the universe in a Big Crunch?

There was also the possibility, unlikely as it seemed, that some intrinsic property of empty space was in play, something called the cosmological constant -- a term originally proposed by Einstein in 1917, in an attempt to balance the equations of General Relativity and preserve a picture of a stable universe that would neither expand nor collapse on itself. A dozen years after Einstein introduced the cosmological constant, astronomer Edwin Hubble found that the universe is indeed expanding; Einstein dismissed his cosmological constant idea as "the biggest blunder of my life."

But observations of distant type Ia supernovae place them significantly farther away than would be expected from their redshifts, suggesting that Einstein recanted too soon. Something is pushing everything farther apart faster than it did in the early universe. The cosmological constant is the best candidate.

A Startling Discovery Confirmed

Thus instead of slowing down, as everyone had expected, the expansion of the universe is in fact speeding up. In early January 1998 the Supernova Cosmology Project presented the first compelling evidence that the expansion is accelerating and that this acceleration is due to the cosmological constant, known by the Greek letter lambda, which may represent as much as 70 percent of the total mass-energy density of the universe. Subsequently, the High-z Supernova Search Team announced that they had found the same result in their data.

Says Perlmutter, "It's important to have two competing teams; it keeps us all from fooling ourselves about what we're really seeing and what it really means." He jokes that so far the two competing groups "are in remarkably violent agreement."

Barring change in the value of lambda -- whose exact nature remains a mystery -- the universe will expand forever. But that conclusion is not being taken for granted.

"We are now searching for more supernovae with high redshifts in order to get more information about the early universe," says team member Robert Knop. "But we are also looking for supernovae with low redshifts -- nearby supernovae -- to make sure that young and old type Ia supernovae are essentially the same, and make for dependable standard candles. We want to be sure we aren't being fooled by interstellar dust dimming the supernovae, or that stellar explosions weren't somehow weaker in the distant past. So far we haven't found anything to shake our confidence, but this is such an unexpected discovery that we'll keep looking for any loopholes."

Using the world's best telescopes, including the Keck Telescope and the Hubble Space Telescope, Berkeley Lab's Supernova Cosmology Project continues to pursue studies aimed at confirming these astonishing results.

Additional contacts:

Greg Aldering, (510) 495-2203, galdering@lbl.gov
Gerson Goldhaber, (510) 486-6210, g_goldhaber@lbl.gov
Rob Knop, (510) 486-5878, raknop@lbl.gov
Peter Nugent, (510) 486-6942, penugent@lbl.gov

Berkeley Lab Home Page