The New York Times
nytimes.com

April 21, 1998

In the Light of Dying Stars, Astronomers See Intimations Of Cosmic Immortality

By JOHN NOBLE WILFORD

HIGH on the mountain, above the clouds and under a crescent moon, one of the world's two most powerful telescopes was aimed at stars exploding halfway across the universe. The night was not going well. At one point fog had shut down operations, and roiling winds sometimes blurred vision. An electronics glitch erased some precious data and cost time.

Scientists were hunched before computer screens in a control room at the base of the mountain, anxiously waiting for an encouraging word from telescope operators up in the dome at Keck Observatory here. "This is ulcer time," said Dr. Robert A. Knop, one of the astronomers, as he reached for another handful of corn chips. "You get the feeling the universe is trying to prevent us from discovering the truth."

There was nothing Dr. Saul Perlmutter could do but fidget and muster reserves of patience. An astrophysicist at the Lawrence Berkeley National Laboratory in California, he is the leader of one of the two rival groups racing to extract from exploding stars, or supernovas, a fundamental characteristic of the expanding universe.

"Projects like this must be the ultimate in delayed gratification," he mused. "You work 10 years developing a technique. You have to pull through problem after problem like this, and it's a year and a half after you first see a result before you can say you know something new about the universe. Then something wakes you up, and you realize that all this nitty-gritty stuff has to do with big philosophical questions."

Like the nature and fate of the universe.

For much of this century, ever since Edwin P. Hubble discovered in 1929 that the universe is expanding, scientists have not only theorized about how it all began in the Big Bang, but also how it will end: whether the universe will collapse of its own weight in a Big Crunch, slow its expansion to a state of equilibrium or keep expanding forever into an ever darker, more tenuous infinity. But their long quest to back up theories with definitive observations has until now frustrated the best astronomers.

Finally, the two teams believe that they are closing in on the answer. Recent observations by Dr. Perlmutter's team and another one, led by Dr. Brian Schmidt of the Mount Stromlo and Siding Spring Observatory in Australia, have awakened astronomers to the prospect of a cosmic surprise. The whiff of success has intensified their sense of the challenge and excitement of being on the verge of a potentially transforming discovery. Each stride forward by one group quickens the pace of the other.

Preliminary measurements strongly suggest that there must be less -- and perhaps more -- to the universe than previously imagined by cosmologists: That is, less mass in ordinary or exotic matter, which could mean the universe will expand forever. And perhaps more of something else, some mysterious force that seems to be speeding up the universe's expansion, contrary to expectations.

"This has our minds swimming," said Dr. Richard A. Muller, an astrophysicist at the University of California at Berkeley, who is not a member of either team. "This is one of the top astronomy discoveries of the century, certainly of the decade. It's worthy of a Nobel Prize."

Little wonder that competition between the two groups -- one with its roots in physics, the other in astronomy -- is so spirited.

"Hey, what's the strongest force in the universe?" asked Dr. Robert P. Kirshner of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., an influential member of the Schmidt team. "It's not gravity, it's jealousy."

Some scientists looking on raise a note of caution, saying the astronomers have not eliminated all possibilities for errors in the data and these could be yielding misleading results. "The competitive urges have driven both these groups out on a limb where they shouldn't be," said an astrophysicist who spoke on condition of anonymity. "They may be right, but they don't know it yet."

In separate three-night observing runs at Keck recently, the two teams added to their inventory of examined supernovas. It is too early to interpret the results. But they hope that the new measurements, and more to come, will enable them to deliver definitive answers in a couple of years to fateful questions about the universe's expansion and the possible existence of a pervasive force of energy, which on large scales seems to counteract gravity.

"We may have the answers by the turn of the millennium," Dr. Perlmutter said, his eyes sparkling at a whimsical thought. "Imagine the signs then: 'The End Is Not Coming!' "

The Light
Cosmic Beacons That Predate Earth

Every few seconds, a dying star explodes somewhere in the universe, shining through space like a faraway beacon. Detected at just the right moment, astronomers have discovered, these beacons seem to show the way to long-sought landfalls of knowledge. They can reveal not only the fate of stars, but also of the universe in its entirety.

Peering deep into the night sky with telescopes in Chile, Hawaii, Arizona, and outer space, the teams have learned to isolate such supernovas from the background light of faraway galaxies. They begin by taking pictures of a large section of the sky away from the light of the Milky Way and other nearby galaxies. These pictures are compared with earlier ones of the same region.

Computers scan the pictures, subtracting known galactic light, to detect any new light source, a possible supernova. Snapshots are taken 30 minutes later to make sure the light was not has not moved. If it has, it means the light probably camea cosmic ray or asteroid.

Then the two teams take turns here at one of the twin 32-foot-diameter Keck telescopes and with observations by the Hubble Space Telescope in Earth orbit, examining these light sources in greater detail. Out of dozens of candidates, a few are identified at each viewing opportunity as a particular kind of exploding star, type Ia supernovas, useful in measuring changes in the expansion rate of the universe over time.

The type Ia's begin as white dwarfs. These are old stars that have converted most of their hydrogen and helium to carbon and oxygen and have collapsed to an incredibly dense sphere, with nearly the mass of the Sun compressed into a volume no larger than that of the Earth. If the white dwarf has a large companion star, which is not uncommon, the dwarf's powerful gravitational pull steadily robs matter from the giant. Once the dwarf reaches a critical mass of 1.4 solar masses, a thermonuclear explosion rips it apart.

Because all white dwarfs have about the same mass at the time they explode, all the supernovas should have much the same intrinsic brightness, astronomers reason. Thus, if their light is carefully analyzed, these explosions should make ideal "standard candles" for measuring cosmic distances. But astronomers must work fast.

As Dr. Gerson Goldhaber, a University of California physicist on the Perlmutter team, explained, "A type Ia supernova can shine brighter than an entire galaxy, but only for a month or so before it becomes too faint for even the largest telescopes to observe at these distances."

Astronomers compare the light from supernovas near and far to estimate the distance of each from Earth. The farther away the supernova, the dimmer its light. The most distant ones discovered so far appear to have occurred more than seven billion years ago, about halfway back to the supposed moment of cosmic creation in the Big Bang. The nearer ones signal explosions some five billion years ago, a little before the Sun and its planets were created.

So far away and long ago are these supernovas that although their ancient light is only now coming into view, their remains have long been scattered beyond recognition as so much stardust.

Next, the astronomers plot the supernova distances against the "redshift" of the objects' light, a measure of how fast cosmic expansion was carrying the galaxies outward at the time of each explosion. This motion displaces the light of an object toward the long-wavelength, or red, end of the spectrum -- the optical equivalent of the drop in pitch of a receding train's whistle. It was Hubble's study of the redshifts and distances of galaxies that led to the discovery that the universe is not static, as Albert Einstein and other scientists had always assumed, but expanding.

An initial goal of the supernova observations was to determine the deceleration of the cosmic expansion, a presumed consequence of the braking effect from the gravitational force of all matter in the universe. Astronomers had expected to see the nearer supernovas expanding more slowly than earlier, more distant ones.

But if they are reading the supernova distances and lights correctly, as the two teams announced in separate reports in January, at best the universe's expansion rate has slowed so little that gravity will never be able to stop it. This appeared to confirm earlier intimations of a universe with a mass density too low to fit many theories. The most likely interpretation, the scientists concluded, is that the universe will expand forever, galaxies continuing to drift apart and everything becoming darker and more tenuous.

Two possible cosmic futures may thus be ruled out. The universe seems to lack sufficient mass to halt expansion and bring about a cosmic collapse in a final Big Crunch, or to slow expansion to a point of equilibrium, a state between contraction and infinite expansion. Most cosmologists have favored the latter prospect because it accords more comfortably with their models amplifying on the Big Bang theory.

While theorists were digesting this, the Schmidt team grew bold and reported even more stunning results, which both teams had been hinting at for months. At a meeting of astrophysicists in February, Dr. Alexei V. Filippenko, an astronomer at the University of California at Berkeley, announced that supernova data strongly suggested that the universe's expansion is not slowing down at all, but speeding up.

The announcement rankled members of the Perlmutter group, who said they had the same results from a larger store of data but felt it premature to go public yet. They also considered their rivals johnny-come-latelies to the research. The Schmidt group had joined the effort in 1995, they noted, after Dr. Perlmutter's work had already demonstrated the feasibility of the strategy and many of the analytical techniques.

"Basically, they have confirmed our results," Dr. Goldhaber, said, referring to the accelerating-expansion findings. "They only had 14 supernovas, and we had 40. But they won the first point in the publicity game."

Even more important, the announcement forced cosmologists to reconsider ideas once considered unthinkable. Perhaps, after all, there is another force, in addition to gravity, playing a dominant role in the universe's expansion. This could be a pervasive repulsive force, known as the cosmological constant, that presumably is a quantum phenomenon of energy in empty space.

As both the cosmic and career implications of their research sink in, differences between the two teams have grown more apparent, though each insists this is not a rancorous contest. "We get irritated at each other," Dr. Perlmutter said, "but we're not feuding."

Indeed, the two groups -- Dr. Perlmutter's Supernova Cosmology Project and Dr. Schmidt's High-Z (meaning high redshift, or extremely distant) Supernova Search -- exchange information, use some of the same instruments and on occasion yield telescope time to the other.

One morning at his Berkeley office, Dr. Perlmutter was on the telephone with rival astronomers at the Cerro Tololo Interamerican Observatory in northern Chile. Bad weather there the night before had disrupted observations by his team. If the weather did not improve, he asked, would the rivals give up their telescope time later in the week for a couple of hours? He would, of course, repay the time. No problem, the rival astronomers said.

The competition may even be productive. Cosmologists are taking the findings much more seriously because the two teams, checking each other, are getting the same results.

"Science goes more quickly with competition," said Dr. Filippenko, who started with the Perlmutter team and switched sides two years ago. "There's more attention to detail because you don't want to be embarrassed by some oversight, as can happen in science."

Another University of California astronomer on the Schmidt team, Dr. Adam G. Reiss, said: "The competition has heightened the quality of work by both teams. They had to make mistakes in the beginning that helped both of us. It's part of the learning curve. We benefited, and they have benefited from some of the trails we have blazed in correcting for possible errors in the data."

But the competition is not without tensions and clashes of ego. Members of the Perlmutter group say that Dr. Filippenko, a specialist in the spectroscopic analysis of supernova light, defected to the other side because he felt he was not receiving sufficient recognition for his work. Dr. Filippenko said he thought he "could make a greater contribution to science on the Schmidt team."

The Perlmutter group complains that the others often fail to credit their pioneering work and seem to dwell on a few of their early mistakes. When Dr. Filippenko noted such shortcomings at a recent meeting, Dr. Perlmutter bristled.

Nor can the Perlmutter forces seem to forget or forgive Dr. Kirshner's criticism of their initial efforts. It threatened the struggling project's very existence. As a leading expert on supernovas, he served on committees reviewing the research for its financial backers, the Department of Energy and the National Science Foundation.

"Bob Kirshner was pooh-poohing our research every step of the way; he said the approach would never work," Dr. Goldhaber recalled.

"In 1995, we started to get results, and he decided he also wanted to try it."

Looking on the positive side, Dr. Muller said, "Jumping in like that is the greatest compliment a former critic can pay."

In the beginning, as Dr. Kirshner sees it, the rate of supernova discoveries by the Perlmutter team was discouragingly low, and the margin for error in interpreting their brightness was unacceptably high. By the middle of the decade, though, prospects for success soared with a better understanding of type Ia supernovas, reduced error margins, greater computer power and new telescopes like the Keck and the Hubble.

Besides, Dr. Kirshner and fellow supernova astronomers felt confident that their expertise could make a difference, even though their competitors had a head start. So why let the physicists win uncontested?

"Everything is in the details," Dr. Kirshner said. "Which filters to use, how to do calibration, how to take light-curves and interpret them. We invented how to do most of that."

Good scientists are like that, Dr. Perlmutter pointed out in a generous interpretation of his rivals' motivations. "Scientists have to be a little arrogant just to have the confidence necessary to try to do unusual things," he said. "You tend to think that, if it's that difficult a task, I had better do it myself to be sure it gets done. Also, there are probably selfish reasons: They had done a lot of work on supernovas and wanted to have the fun of being in on the big action."

The Cultures
Two Disciplines, Two Temperaments

Some of the strains between the teams stem from differences in organization, background and temperament.

The small, tightly-knit Perlmutter group grew out of research at the Lawrence Berkeley laboratory, which remains the center of operations. Dr. Perlmutter is clearly the dominant leader. Like him, many of the team's early participants were physicists being drawn to astronomy. Experimental physicists, onlookers have noted, tend to work in such centralized laboratory settings. In recent years, though, more astronomers and theoretical astrophysicists have been added to the team.

Because Dr. Perlmutter developed most of the methods for finding and analyzing supernovas in numbers sufficient for cosmological research, often in the face of skepticism, his group came to feel a proprietary claim on the field. And Dr. Perlmutter has been extremely cautious in issuing formal reports on the latest findings.

The other group, by contrast, is much more loosely organized, with team members scattered at universities and observatories in several countries. Dr. Schmidt of Australia gets them all together for a meeting only once a year. No one person is the team spokesman; whoever is responsible for a particular aspect of the research takes the lead in announcing the results.

"We work in a spirit of cheerful anarchy," Dr. Kirshner said.

Nearly all of the members are astronomers with considerable supernova experience, notably Dr. Kirshner, who discovered his first supernova in 1972. This could explain their willingness in February to plunge in by announcing an accelerating cosmic expansion and explicitly invoking the cosmological constant as a likely interpretation.

Dr. Reiss of the Schmidt group acknowledged that both teams arrived at the result at about the same time. But just because their data agree does not mean the teams or other scientists are ready to accept the accelerating universe as a fact. They are particularly troubled that galactic dust may be confusing astronomers on how far away the supernovas are. Dust between here and the objects could seriously dim the light and make them appear to be more distant than they actually are.

Dust, Dr. Reiss noted, has been the cause of many blunders in astronomy. For a long time, dust obscuring much of the visible light of Milky Way stars misled astronomers into thinking that Earth was at the center of the galaxy, not off in a spiral arm. His study of supernova light in several colors is credited with largely eliminating uncertainties about the effects of dust on distance estimates for supernovas.

Many theoretical astrophysicists are still reserving judgment and want more assurances that dust or other basic oddities in the supernova data, known as systematic errors, are not leading observers astray again. Besides dust distortions, these include the possibility that type Ia supernovas are somewhat different in different epochs, causing misleading light variations.

"That's a real concern," said Dr. Michael S. Turner, an astrophysicist at the University of Chicago. "Extraordinary claims require extraordinary evidence, and all the systematics have not been cleared to everyone's satisfaction."

Dr. Perlmutter said his team "had closed more loopholes since January." Dr. Filippenko said, "We have done enough to satisfy ourselves that at least there is nothing obviously wrong with the results."

But the hunt for any systematic errors remains a priority in the new observations and analysis by both groups. Eventually, they hope to extend supernova observations even deeper in time, to about 10 billion years ago.

The Future
Figuring Distances, And Ramifications

For three successive nights, when the fog dissipated and the electronics behaved, the Keck telescope swung from target to target, its spectrograph examining supernova candidates identified the previous week by the Perlmutter group. A spectrograph breaks down light into parallel rays, each one characteristic of chemical elements that are ejected from the exploding star.

It was the job of Dr. Isabel M. Hook, an astronomer with the European Southern Observatory near Munich, to analyze the blue-and-green graphs with sharp peaks and valleys, like plots of stock prices in a volatile year.

Looking intently at her computer screen, Dr. Hook studied the first spectral patterns to confirm that the bright object in Keck's gaze really was a type Ia supernova and then estimate its redshift. Her judgment was crucial in deciding whether to continue observing the object for more detailed exposures or to move on to others.

Each promising supernova discovery is followed up with additional observations at other telescopes. One purpose is to plot a graph of each supernova's brightness over time, its so-called light curve. If the astronomers have caught the supernova on the rise, its light brightens to a peak a few days after it is first detected. Then it dims in a slow, downward curve for about two months at most.

It is from these data that the all-important determination of the supernova's distance will be made. The intrinsic brightness of the Ia type is almost but not quite invariably the same, but a group of astronomers led by Dr. Mark M. Phillips of the Cerro Tololo telescope in Chile developed a technique for analyzing these light curves to recognize and correct for slight differences. The more slowly the light curve declines, they found, the brighter the supernova was.

"I happen to think that these are the best standard candles we've ever had," said Dr. Turner of Chicago.

By now, the Perlmutter team has discovered about 130 type Ia supernovas, mostly in the last three years; critical follow-up research has been conducted on 78.

The team's most recent conclusions are based on 41 supernovas. The Schmidt team is still behind in numbers, but catching up. It has detected 70 supernovas and has a significant amount of data on more than 30. A detailed study of 16, Dr. Kirshner said, is being prepared now for publication.

During his last observing night at Keck, Dr. Perlmutter spent long stretches on the telephone with a colleague in Berkeley preparing an application for more telescope time this fall.

Both teams express confidence in their findings, but are looking for more evidence that what they are seeing -- an accelerating expansion and something like the cosmological constant -- is really there.

"Nobody is compelled to believe our evidence so far," Dr. Kirshner said, though confirmation could come early in the next century.

Two spacecraft, the American Microwave Anisotropy Probe in 2000 and the European Planck satellite in 2005, are expected to provide independent and definitive tests of the supernova results. They are to chart with greater accuracy than ever the cosmic background radiation, the pervasive echo from the Big Bang.

Encoded in the radiation's tiny temperature variations are strong clues to the density of the universe, the value of any cosmological constant and other characteristics of cosmic evolution. In the beginning, it seems, was an imprint of cosmic destiny.

But cosmologists are not waiting.

"They are already maneuvering around the data," Dr. Turner said, as they look for shortcomings in the supernova findings or ways to preserve their theories, if it should be true that strange energy forces are speeding up the universe's expansion into an infinite future.