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SCIENCE DESK

From Space, A New View Of Doomsday

By DENNIS OVERBYE (NYT) 2646 words

Once upon a time, if you wanted to talk about the end of the universe you had a choice, as Robert Frost put it, between fire and ice.

Either the universe would collapse under its own weight one day, in a fiery "big crunch," or the galaxies, now flying outward from each other, would go on coasting outward forever, forever slowing, but never stopping while the cosmos grew darker and darker, colder and colder, as the stars gradually burned out like tired bulbs.

Now there is the Big Rip.

Recent astronomical measurements, scientists say, cannot rule out the possibility that in a few billion years a mysterious force permeating space-time will be strong enough to blow everything apart, shred rocks, animals, molecules and finally even atoms in a last seemingly mad instant of cosmic self-abnegation.

"In some ways it sounds more like science fiction than fact," said Dr. Robert Caldwell, a Dartmouth physicist who described this apocalyptic possibility in a paper with Dr. Marc Kamionkowski and Dr. Nevin Weinberg, from the California Institute of Technology, last year.

The Big Rip is only one of a constellation of doomsday possibilities resulting from the discovery by two teams of astronomers six years ago that a mysterious force called dark energy seems to be wrenching the universe apart.

Instead of slowing down from cosmic gravity, as cosmologists had presumed for a century, the galaxies started speeding up about five billion years ago, like a driver hitting the gas pedal after passing a tollbooth.

Dark energy sounded crazy at the time, but in the intervening years a cascade of observations have strengthened the case that something truly weird is going on in the sky. It has a name, but that belies the fact that nobody really knows what dark energy is.

In six years it has become one of the central and apparently unavoidable features of the cosmos, the surprise question mark at the top of everybody's list, undermining what physicists presumed they understood about space, time, gravity and the future of the universe.

"In five years we've gone from saying it looks like a mistake to something that everyone is claiming evidence for," said Dr. Robert Kirshner of the Harvard-Smithsonian Center for Astrophysics, who was part of the original discovery.

Dr. Saul Perlmutter, a physicist from the Lawrence Berkeley Laboratory who was a leader of one of the 1998 teams, said he thought astronomers had even gotten comfortable with the idea -- "or as comfortable as you can be with something as bizarre as dark energy."

Now, armies of astronomers are fanning out into the night, enlisting telescopes, large and small, from Chile to Hawaii to Arizona to outer space, in a quest to take the measure of dark energy by tracing the history of the universe with unprecedented precision.

Some of them are following the trail blazed by the first two groups six years ago, searching out a kind of exploding star known as Type 1a the supernova. Those stars serve as markers in space, enabling scientists to plumb the size of the universe and how it grew over time. Where the first groups based their conclusions on observing a few dozen supernovas, the new efforts intend to harvest hundreds or thousands of them.

Others are seeking to gain leverage by investigating how the antigravitational force of dark energy has retarded the growth of conglomerations of matter like galaxies. In one ambitious project, a team led by Dr. John Carlstrom of the University of Chicago is building an array of radio telescopes at the South Pole to count and study clusters of galaxies deep in space-time. Others are already probing the internal dynamics of galaxies by the thousands, or building giant cameras that use the light-bending powers of gravity itself as lenses to map invisible dark matter in space and compile a growth chart of cosmic structures.

Dr. Anthony Tyson, now at Bell Laboratories, is head of a project to build a "dark matter telescope" known as the Large Synoptic Survey Telescope. "High energy physicists have been marching into our project," he said. "This is not just another telescope. It's a physics experiment, like a particle accelerator."

After all, the fate of the universe is at stake. If the dark energy is virulent enough, then that fate "is quite fantastic and completely different than the possibilities previously discussed," Dr. Caldwell and his colleagues wrote last year.

The Search for One Number

The idea of an antigravitational force pervading the cosmos does sound like science fiction, but theorists have long known that certain energy fields would exert negative pressure that would in turn, according to Einstein's equations, produce negative gravity. Indeed, some kind of brief and violent antigravitational boost, called inflation, is thought by theorists to have fueled the Big Bang.

As they try to figure out how this strange behavior could be happening to the universe today, astronomers say the ultimate prize from all the new observing projects could be as simple as a single number.

That number, known as w, is the ratio between the pressure and density of dark energy. Knowing this number and how it changes with time -- if it does -- might help scientists pick through different explanations of dark energy and thus the future of the universe -- "whether it's gonna lead to a Big Rip, a Big Collapse or just a Big Fizzle," as Dr. Adam Riess of the Space Telescope Science Institute in Baltimore put it in an e-mail message.

One possible explanation for dark energy, perhaps the sentimental favorite among astronomers, is a force known as the cosmological constant, caused by the energy residing in empty space. It was first postulated back by Einstein in 1917. A universe under its influence would accelerate forever.

While the density of energy in space would remain the same over the eons, as the universe grows there would be more space and thus more repulsion. Within a few billion years, most galaxies would be moving away from our own faster than the speed of light and so would disappear from the sky; the edge of the observable universe would shrink around our descendants like a black hole.

But attempts to calculate the cosmological constant using the most high-powered modern theories of gravity and particle physics result in numbers 1060 times as great as the dark energy astronomers have observed -- big enough, in fact, to have blown the universe apart in the first second, long before even atoms had time for form. Theorists admit they are at a loss. Perhaps, some of them now say, Einstein's theory of gravity, the general theory of relativity, needs to be modified.

Another possibility comes from string theory, the putative theory of everything, which allows that space could be laced with other energy fields, associated with particles or forces as yet undiscovered. Those fields, collectively called quintessence, could have an antigravity effect. Quintessence could change with time -- for example, getting weaker and eventually disappearing as the universe expanded and diluted the field -- or could even change from a repulsive force to an attractive one, which could set off a big crunch.

Recently, in a variation on the quintessence idea, Dr. Leonard Parker of the University of Wisconsin at Milwaukee and various colleagues, including Dr. Caldwell, have suggested that the field associated with some unknown very light particle could get tangled up with gravity and cause the universe to accelerate. That would alter Einstein's equations, said Dr. Caldwell. He added, "Our calculations show, however, that galaxies reside in a bubble of old-fashioned Einstein gravity, whereas gravity has changed outside and between galaxies."

A Weird Idea Gets Weirder

But the strangest notion is what Dr. Caldwell has called phantom energy, the dark energy that could lead to the Big Rip.

"It's weird negative pressure," said Dr. Lawrence M. Krauss, an astrophysicist at Case Western Reserve University in Cleveland.

While the density of the energy in Einstein's cosmological constant stays the same as the universe expands, the density of phantom energy would go up and up, eventually becoming infinite. Such would be the case if the parameter w turned out to be less than minus 1, say physicists, who admit they are stunned by the possibility and until recently simply refused to consider it.

"It crosses a boundary of good taste," Dr. Caldwell said, calling phantom energy "bad news stuff." Phantom energy violates physicists' intuitions about how the universe should behave. A chunk of it could be used to prop open wormholes in space and time -- and thus create time machines, for example.

"It could lead to such bizarre effects as negative kinetic energy," Dr. Krauss said. As a result, objects like atoms would be able to lose energy by speeding up.

Nevertheless, a recent analysis by Dr. Caldwell and his Dartmouth colleague Dr. Michael Doran of the supernova measurements to date, combined with other cosmological data, suggest that w could lie anywhere from minus 0.8 to minus 1.25, leaving open the possibility of phantom energy. The cosmological constant would give a value of minus 1.0, and anything higher would be a sign of quintessence.

Dr. Kirshner said phantom energy had been dismissed as "too strange" when his group was doing calculations of dark energy back in 1998. In retrospect, he said, that was not the right thing to do.

"It sounds wacky," he said, referring to phantom energy, "but I think we're in a situation where we're going to need a really new idea. We're in trouble; the way out is going to be new imaginative things. It might be our ideas are not wild enough, they don't question fundamentals enough."

Dr. Chris Pritchet of the University of Victoria, who is part of a collaboration using the Canada-France-Hawaii telescope on Mauna Kea to search for supernovas, said, "In many ways phantom energy is unphysical, but we're not ruling it out."

Counting Down to the Big Rip

This version of doomsday would start slowly. Then, billions of years from now, as phantom energy increased its push and the cosmic expansion accelerated, more and more galaxies would start to disappear from the sky as their speeds reached the speed of light.

But things would not stop there. Some billions of years from now, depending on the exact value of w, the phantom force from the phantom energy will be enough to overcome gravity and break up clusters of galaxies. That will happen about a billion years before the Big Rip itself.

After that the apocalypse speeds up. About 900 million years later, about 60 million years before the end, our own Milky Way galaxy will be torn apart. Three months before the rip, the solar system will fly apart. The Earth will explode when there is half an hour left on the cosmic clock.

The last item on Dr. Caldwell's doomsday agenda is the dissolution of atoms, 10-19 , a tenth of a billionth of a billionth of a second before the Big Rip ends everything.

"After the rip is like before the Big Bang," Dr. Caldwell said. "General relativity says: "The end. Time can't evolve."

The cosmos probably still has a lot of life in it, according to recent calculations by Dr. Krauss. Based on the current age of the universe, some 14 billion years, and other data, w cannot be less than about minus 1.2, he said, putting the Big Rip about 55 billion years in the future.

"It can't be very phantom," Dr. Krauss said.

The dark energy surveys now under way hope to be able to measure w to an accuracy of 5 percent, but even if that can be done, it may not be sufficient to eliminate the nightmare of phantom energy.

"It's hard to measure anything in astronomy to a few percent," said Dr. Sandra Faber of the University of California at Santa Cruz, who directs one of the dark energy surveys. Variations in the atmosphere and gaps in astronomers' understanding of supernova explosions add uncertainty to the dark energy measurements.

As a result some astronomers fear that the results may leave us on the razor's edge unable to decide between a cosmological constant and the other possibilities -- quintessence or a Big Rip. Cosmologists could then be stuck with a "standard model" of the universe that fits all the data, but which they have no hope of understanding.

If the parameter w comes out to be something other than minus 1, Dr. Krauss said, it will at least give some direction to physicists.

One encouraging sign -- "a tantalizing bit of hope," in Dr. Krauss's words -- that the data will distinguish between a cosmological constant and the other possibilities came last fall when Dr. Riess, of Baltimore, reported, based on new observations of distant supernovas, that the "cosmic jerk" when dark energy took over the universe happened only five billion years ago.

In the standard cosmological constant model, said Dr. Riess, the turnaround should have come one or two billion years earlier.

Dr. Tyson was more sanguine. "Dark energy is crazy, right?" he said. "It's going to be exciting no matter what we find."

Dark Future for Dark Energy?

The work of the dark energy hunters has been complicated by the impending loss of the Hubble Space Telescope, which can see far enough out in space and time to measure how and if the dark energy parameter w is changing over the eons.

Last month, citing safety, NASA canceled all future shuttle maintenance missions to the telescope, dooming it to die in orbit, probably within three years, according to astronomers. "The Hubble shutdown will slow us all down," Dr. Perlmutter said.

At the same time, as a result of the agency's presidentially ordered shift toward the Moon and Mars, plans for a special satellite that was to have been jointly sponsored by NASA and the Department of Energy have at least temporarily disappeared from NASA's five-year budget plan.

Dr. Perlmutter, who has devoted much of his time in the last six years to the proposed satellite experiment, said he hoped that a way would be found to keep the project on track to be launched in the next decade.

"When you have the most exciting scientific problem of the day, you don't want to wait around," he said.

CAPTIONS: Photos: Dr. Robert Kirshner of the Harvard-Smithsonian Center for Astrophysics helped discover that a mysterious force seems to be wrenching the universe apart. (Photo by Rick Friedman for The New York Times); Dr. Saul Perlmutter, top, a physicist, and Dr. Adam Riess, an astronomer. (Photo by Marty Katz for The New York Times); (Photo by Peter DaSilva for The New York Times)(pg. F4); (Photo by Bill Marsh/The New York Times); (Photo by Milky Way image by Dr. Edward L. Wright and NASA)(pg. F1)

Chart: "The Big Rip"
After the instant when protons and neutrons are pulled apart, only elemental particles would remain, probably electrons and a soup of quarks. Time, according to Einstein's theory, ends.

Four Paths to Oblivion
The universe is in a period of moderate acceleration compared with its probable swelling after the Big Bang.

Scientists are trying to calculate how powerful dark energy is and how it will affect the universe.

Stronger dark energy rips the universe apart sooner.

If dark energy is weak, a "big chill" sets in as the universe expands indefinitely. Or dark energy could reverse, collapsing the cosmos.

A MORE IMMEDIATE PROBLEM
The Sun swells up and destroys the Earth in about five billion years,
well before the Big Rip.

PHANTOM FORCE
Dark energy speeds the universe's expansion. Distant galaxies disappear from view as they approach light speed.

MILKY WAY SPINS APART
Stars and planets remain intact, but the galaxy does not.

(Sources by Dr. Robert Caldwell, Dartmouth College; Dr. Lawrence Krauss, Case Western Reserve University)(pg. F1)
