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From Distant Galaxies, News of a 'Stop-and-Go Universe'

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NASHVILLE, May 30 -- New observations of exploding stars far deeper in space, astronomers say, have produced strong evidence that the proportions of the mysterious forces dominating the universe have undergone radical change over cosmic history.

The findings, reported here at a meeting of the American Astronomical Society, which ended Thursday, supported the idea that once the universe was expanding at a decelerating rate but then began accelerating within the last seven billion years, scientists concluded.

''We are now seeing hints that way back then the universe was slowing down,'' said Dr. John Tonry, an astronomer at the University of Hawaii who is a member of one team studying exploding stars, or supernovas, for signs of cosmic expansion rates.

The new research by Dr. Tonry's group and another, led by Dr. Saul Perlmutter of Lawrence Berkeley National Laboratory in California, confirmed the earlier surprising discovery that the universe is indeed expanding at an accelerating rate and has been for at least the last 1.2 billion years. But four supernovas, almost 7 billion light-years away, appeared to exist at a time the universe was slowing down, Dr. Tonry said.

''A stop-and-go universe'' is the way Dr. Robert P. Kirshner of the Harvard-Smithsonian Center for Astrophysics characterized the phenomenon. Well, the expansion never really stopped, he conceded, but it has certainly revved up.

''Right now, the universe is speeding up, with galaxies zooming away from each other like Indy 500 racers hitting the gas when the green flag drops,'' said Dr. Kirshner, a member of the Tonry team. ''But we suspect that it wasn't always this way.''

The changing pace of cosmic expansion, combined with recently announced measurements of the cosmic microwave background, revealing conditions soon after the Big Bang, encourages theorists in thinking that a tug-of-war has been going on between dark forces of matter and energy no one yet understands.

The combined gravitational pull from all matter in the universe, most of which is beyond detection, has acted as a brake on cosmic expansion. The so-called dark matter apparently had the advantage when the universe was younger, smaller and denser. Now the ever-increasing pace of expansion suggests that something else even more mysterious is at work. Theorists are not sure what the antigravity force is, but they call it dark energy. It has apparently gained the upper hand.

This is the latest turn of events in the unfolding story of cosmic history. Once scientists believed the universe was everlastingly static. Along came Edwin P. Hubble, who discovered seven decades ago that the galaxies of stars are rushing away from one another in all directions. The universe, Hubble announced, is expanding.

Five years ago, astronomers were in for a surprise. They had assumed that after an initial burst of rapid expansion from the originating Big Bang the gravity of matter was gradually slowing things down. Then the two supernova survey teams found that the universe was accelerating instead. This pointed to the existence of some kind of dark energy permeating all of space.

For the current research, astronomers observe what are called Type Ia supernovas, stellar explosions that at their peak are brighter than a billion stars like the Sun. They are thus visible across billions of light-years of space, and a close examination of their light reveals the distances, motions and other evidence of conditions. As the light travels to Earth, the wavelengths are stretched by an amount that reflects the universe's expansion when the star exploded.

Dr. Kirshner said the four extremely distant supernovas indicated that the universe seven billion years ago was ''in fact winning this sort of cosmic tug-of-war,'' but now dark energy is more dominant.

Scientists said they assumed that with the stretching out of space the proportion of dark energy to dark matter had been reversed. In the earlier and denser universe, matter of all kinds, the invisible dark matter and the visible ordinary matter of stars and planets, predominated.

The team of Dr. Tonry and Dr. Kirshner estimates that about 60 percent of the universe is filled with dark energy and 30 percent of the mass is dark matter. The remaining 10 percent consists of ordinary matter, only 1 percent of which is visible in the galaxies. Theorists offer roughly the same estimates and surmise that the changeover from dark matter to dark energy domination probably occurred before 6.3 billion years ago.

Dr. Perlmutter said that much more research would be necessary to determine whether the changing density of the expanding universe was the only reason dark energy came to rule cosmic dynamics. Or have the physical properties of dark energy, whatever it is, changed?

Dr. Perlmutter said that in the words of Dr. Edward Witten, a theoretical astrophysicist at the Institute for Advanced Study at Princeton, the true nature of dark energy ''would be No. 1 on my list of things to figure out.''

The research teams are planning new observations of more distant supernovas to determine when cosmic acceleration began and to gather clues about the properties of dark energy. Some observations will be conducted with ground-based telescopes, others with the Hubble Space Telescope. Dr. Perlmutter's group has proposed putting a spacecraft in orbit with telescopes especially designed for supernova hunting and pinning down the nature of dark energy.

In ''The Extravagant Universe,'' published last fall by Princeton University Press, Dr. Kirshner wrote: ''We are not made of the type of particles that make up most of the matter in the universe, and we have no idea yet how to sense directly the dark energy that determines the fate of the universe. If Copernicus taught us the lesson that we are not at the center of things, our present picture of the universe rubs it in.''