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Vestiges of Big Bang Waves Are Reported

By KENNETH CHANG

SAN DIEGO, Jan. 11 - Astronomers reported on Tuesday that they had convincingly seen, in the patterns of galaxies scattered across the night sky, the vestiges of sound waves that rumbled through the universe after the Big Bang.

Stars and galaxies tended to form along the ripples of the sound waves where matter was slightly denser, and the pull of gravity was slightly stronger. The ripples preserve a picture of the universe when it was only about one million years old and fit well with astronomers' ideas of how the universe, which started smooth and uniform, became lumpy with stars, gas clouds and other celestial objects.

Two teams of researchers analyzing the locations of thousands of galaxies from two sections of the sky reported similar findings on the sound waves at a meeting of the American Astronomical Society here.

Earlier research had found signs of the ripples, but "we regard this as smoking-gun evidence," said Dr. Daniel Eisenstein of the University of Arizona, lead investigator of one of the teams.

"The important picture we have of the universe is hanging together amazingly well," said Dr. Martin Rees, a professor of cosmology and astrophysics at Cambridge University, who was not involved with either team. "The standard picture is firming up."

According to that picture, matter was evenly distributed in all directions for the first instant after the Big Bang. But then burbling caused by the physics of quantum mechanics created slight imperfections, clumps that were slightly denser with ordinary matter, as well as dark matter, the unknown material that accounts for most of the mass in the universe.

Just as ripples spread out from a pebble dropped in a pond, sound waves spread out from the dense clumps, traveling about half the speed of light through the hot gas made of matter, which is composed of electrons and protons, and of photons, or particles of light.

About 400,000 years after the Big Bang, the universe cooled enough that the charged electrons and protons combined to form hydrogen atoms, which allowed most of the photons to escape the hot gas. Several years ago, astronomers detected the sound waves etched by the photons.

The sound waves continued to spread for an additional 600,000 years, and when the last remaining photons escaped, the waves stopped, roughly 500,000 light-years from the dense clumps that produced them. When stars began to form, they tended to form around either the pebble-like clumps of dark matter or along the ripples.

As the universe has expanded in the 13.7 billion years since then, the typical distance between ripple and clump has stretched to 500 million light-years.

The new research shows the matter component of the early sound waves. Galaxies in the present universe are more likely to be 500 million light-years apart than other distances, Dr. Eisenstein said. One light-year is the distance light travels in one year, or 6 trillion miles.

The pictures do not show sharply delineated ripples, because the ripples were small and many overlapping ripples emanated from many different clumps.

"It’s a much more subtle effect than that," Dr. Eisenstein said. "It’s like you’ve taken a handful of gravel and thrown them in a pond."

Dr. Eisenstein and his colleagues used information from the Sloan Digital Sky Survey, which is mapping galaxies with a telescope in New Mexico.

The other team used data from a project called the 2dF Galaxy Redshift Survey that is scanning the sky with a telescope in Australia.

The research has also refined estimates on the amount of matter - 18 percent of matter is ordinary matter that makes up stars and planets, and the remaining 82 percent is dark matter. And it offers further evidence that the geometry of the universe is perfectly flat, where the angles of all triangles always add up to 180 degrees.

"It’s more than confirmation of what we already knew from the microwave background," said Dr. Richard S. Ellis, a professor of astronomy at the California Institute of Technology and a member of the 2dF team.

As the astronomers look farther away and further back in time, the size of the ripples will decrease in size. The ripples could serve as a convenient yardstick to track the history of the universe’s expansion. That could shed light on dark energy, a mysterious force discovered in the past few years that, at cosmological distances, is stronger than gravity and is causing the expansion of the universe to accelerate.