BERKELEY, CA - George Smoot, an astrophysicist at Lawrence Berkeley National Laboratory since 1974 and a University of California at Berkeley physics professor since 1994, has been awarded the 2006 Nobel Prize for physics. He led a team that mapped the early universe; revealing its primal form and the patterns that have shaped it.

On April 23, 1992, at a meeting of the *American Physical Society*, Smoot made an announcement that helped change the course of scientific investigations into the origin and evolution of the universe. After analyzing hundreds of millions of precision measurements in the data they gathered from an experiment aboard NASA's Cosmic Background Explorer (COBE) satellite, Smoot and his research team produced maps of the entire sky. The maps revealed vast regions of space with minuscule temperature variations. These variations are "hot" and "cold" regions with temperature differences of a hundred-thousandth of a degree, which were produced when the universe we know was so small there was not enough room for a single proton. These regions are believed to be the primordial seeds that that grew into present-day galaxies and clusters of galaxies.

The Big Bang theory on the origin of the universe was first developed in the 1940s, and theorists had since been predicting temperature variations in the ancient universe. Until Smoot and his team announced their discovery, microwaves left over from the Big Bang appeared to be persistently uniform. These microwaves have taken billions of years to reach Earth, and are called the *cosmic background radiation*. According to the Big Bang theory, the temperature variations must reveal the ripples in the fabric of space that gravity (working over the great expanse of time) magnifies into today's universe.

Since Smoot's announcement in 1992, subsequent cosmic microwave background experiments, including data from the MAXIMA and BOOMERANG balloon flights, have confirmed and refined the original maps. These provided further evidence that the Universe is flat and that Inflation-inspired models of the Big Bang are on the right track. The WMAP satellite provided dramatic confirmation of the original COBE results, and extended them substantially. With the results of this discovery, Smoot's team provided the strongest evidence that the Big Bang theory is correct. Their measurements were made using Differential Microwave Radiometers (DMR), which they designed and built. The CMB would also

be a powerful probe of the early Universe and our cosmological models. This work then inspired future experiments that confirmed and improved their results, in addition to the space missions WMAP and Planck Surveyor (scheduled for launch August 2008). In this sense, this discovery provided the foundation and inspiration for a whole field of endeavor. In attempting to scientifically measure and describe the Universe, we now have a single story on its origins and ourselves.

As Smoot has explained, “The tiny temperature variations we discovered are the imprints of tiny ripples in the fabric of space-time, originating in the primeval explosion process. Over billions of years, the smaller ripples have grown into galaxies, clusters of galaxies, and the great voids in space. In our current model, these were once very tiny quantum fluctuations made cosmically large by the tremendous expansion of the universe over the intervening history.”

Smoot was one of the first pioneering astrophysicists who devised ways to conduct experiments that produced data and information about the early universe. "People have contemplated the origin and evolution of the universe long before the time of Aristotle," he says. "Although cosmology has been around since the time of the ancients, historically it has been dominated by theory and speculation. Very recently, the era of speculation has given way to a time of science. The advance of knowledge and of scientific ingenuity means that at long last, we can actually test our theories."

To understand how our universe was created, Smoot focused on clues hidden in the extremely faint heat left over from the Big Bang, which happened some 15 billion years ago. This relic radiant energy or cosmic microwave background radiation (CMB) has been called "the message from the beginning of time."

According to theory, all space began to expand at the moment of the Big Bang and was pervaded with the physical contents produced by the leviathan explosion, including the relic CMB radiation. To this day, CMB radiation saturates all of space throughout the universe. In fact, at any given instant, every cubic meter of space is bathed in over four hundred million photons of CMB radiation zipping through at the speed of light.

In 1976, Smoot was a key member of the team that found startling evidence in the CMB that contradicted the prevailing scientific view that galaxies are

spread relatively evenly throughout the universe. Instead of a universe where galaxies are evenly dispersed, the data revealed that vast regions of space are virtually devoid of galaxies. Elsewhere, billions of galaxies are clustered together. These findings met with strong skepticism, but a second set of experiments by Smoot and colleagues confirmed that on the galactic scale, the universe has densely crowded neighborhoods and equally vast empty spaces.

The new view of the universe created by this body of work required that science rethink its theory of the origin of the universe. Cosmologists had believed that in the early universe, matter had been evenly distributed. The virtually uniform temperature of the CMB -- 2.7 degrees above absolute zero -- is consistent with this notion. But in finding that the universe is "lumpy," scientists came to believe that similarly, there should be minute variations in the CMB radiation.

Smoot began a search for these tiny fluctuations in 1974, submitting a satellite proposal to NASA to measure and map the cosmic microwave background. Fifteen years later, the COBE satellite was launched joining a competitive quest that at that stage involved many scientific teams. In April 1992, Smoot's team was ready to announce that they had found what had evaded scientists for decades. The team included over forty people - some at Berkeley, many at Goddard Space Flight Center, and a few at other institutions. The COBE satellite project had an estimated 1000 individuals.
At an *American Physical Society* meeting in Washington, D.C., Smoot made his historic announcement of the discovery of fossil relics from the primeval explosion that began the universe. The relics were colossal hot and cold regions of differing densities in the infant universe. Smoot said these fifteen billion-year-old fossils are the primordial seeds that grew into the galaxies and superclusters of galaxies evident today.

One newspaper in Europe published the map developed by the COBE team, labeling it a "baby photo" of the universe. Smoot says that technically, this is an accurate description. In fact, the maps show the universe as it looked when it was about one ten-thousandth of its current age, or about 300,000 years after its birth. As Joseph Silk of Oxford University described the image, "We are viewing the birth of the universe."

Smoot was born in Yukon, Florida in 1945. His father was a hydrologist for the U.S. Geological survey and his mother was a science teacher and school

principal. His mother is now deceased. His sister, her family, and father live in New England. Smoot says his parents instilled in him a joy for learning and an interest in science and math. He received his Ph.D. in physics at MIT in 1970 and decided to enter the field of cosmology, a frontier of fundamental science that was ripe for exploration.

Smoot recalls that when he first started his career, cosmology wasn't even considered a real science. "It was a fringe field," he says. "Back then, you could get all of us into a single room. I remember the teasing from my particle physics colleagues that real physics is done at accelerators. Today, opinions have changed. We have begun to explore the early universe, the original accelerator. The fields of particle physics and cosmology have been joined."

The COBE team that Smoot headed was a large collaboration involving participants from Berkeley Lab, UC Berkeley, the NASA Goddard Space Flight Center, JPL, UCLA, MIT, and Princeton. In addition to Smoot, team members at Berkeley Lab included astrophysicist Giovanni De Amici, data analyst Jon Aymon, and Berkeley graduate students at that time: Al Kogut, Charley Lineweaver, Steve Levin, and Luis Tenorio.

Their findings support Big Bang cosmology, the theory that predicts the existence of CMB radiation, which was first detected in 1964 by Nobel Prize winners Arno Penzias and Robert Wilson. Since that time, there had been a gradual awareness among a few scientists that the CMB is laden with clues as to the evolution of the universe. After the COBE results proved the CMB fluctuations were real, many papers attempted to explain how the fluctuations could be used to describe the early universe and cosmology. We went from having a few measured quantities to explain the universe to potentially having a thousand. Smoot says that is because the evolution of the universe is effectively synonymous with the change in spatial distribution of matter and energy through time. Starting from virtually equal distribution in the early universe, and evolving to the very lumpy one of today - with matter clustered as galaxies, clusters of galaxies, superclusters, and even larger groupings. Imprinted within the CMB is the pattern of the distribution of matter created shortly after the beginning of time. It is a pattern that reveals the newborn shape of the universe and a blueprint that dictates its future.

"Human beings have had the audacity to conceive a theory of creation and now, we are able to test that theory. I believe we have discovered the fossil remnants of the progenitors of present day structure in the universe. They tell us that we have a viable theory of the universe back to about 10^{-30} *seconds. At that time the currently observable universe was smaller than the smallest dot on your TV screen, and less time had passed than it takes for light to cross that dot."* George Smoot