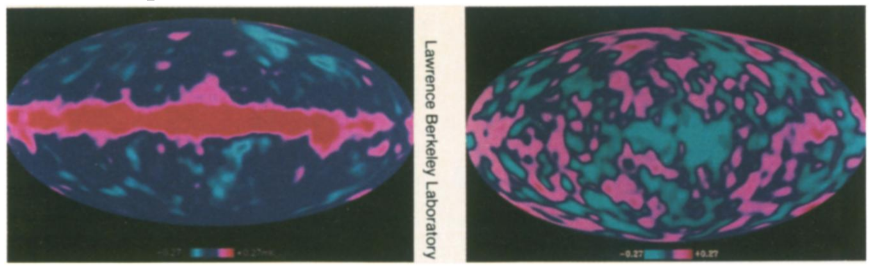
COBE Causes Big Bang in Cosmology

After searching for nearly three decades, scientists have uncovered evidence that may solve one of cosmology's oldest riddles: How did primordial matter evolve into the stars, galaxies and galactic clusters we see today?

Instruments on NASA's Cosmic Background Explorer (COBE) satellite have picked up temperature fluctuations in the cosmic microwave background, the ubiquitous energy left over from the creation of the universe. The fluctuations represent tiny gravitational ripples — variations in the density of matter. "This is like looking at the invisible man and seeing the footprints," says COBE scientist George F. Smoot of the University of California, Berkeley.

Cosmologists believe these ripples unbalanced the primordial universe enough to cause matter to begin lumping together and, after 15 billion years, evolve into the cosmic structures found today. Smoot's team announced its findings last week at an American Physical Society meeting in Washington, D.C.

"It's the missing link," says cosmologist Joseph Silk of the University of California, Berkeley. "The lack of fluctuations has been a major obstacle in having many people accept not just [theories of] galaxy formation but the basic premises of the Big Bang."



Hot (red) and cold (light blue) spots in the cosmic microwave background. To identify these tiny temperature variations, scientists had to subtract several sources of interference, such as emissions from the Milky Way, which runs across the middle of the map at left.

In its simplest form, the Big Bang theory predicts that the cosmic microwave background will have a perfectly uniform temperature. Soon after COBE's launch in 1989, the satellite's preliminary measurements indicated that the microwave background was a perfectly smooth 2.73 kelvins (SN: 1/20/90, p.36), which fit with the basic Big Bang theory. Still, this finding puzzled cosmologists because a smooth primordial universe, they believed, couldn't have evolved so quickly into the galaxies and galactic clusters visible today.

Now, after analyzing hundreds of millions of measurements taken during COBE's first year in orbit, Smoot's team has found hot and cold spots in the cosmic microwave background. These spots differ barely thirty-millionths of a kelvin from the 2.73-kelvin background. The new data support some Big Bang add-on theories, such as the inflationary model, in which galaxy formation springs from small gravitational disturbances.

But theorists still have their work cut out for them. The COBE measurements suggest that the gravitational ripples probably acted in concert with other, yet unknown mechanisms. "We've seen how strong the gravitational forces in the early universe are, and they're not strong enough to cause ordinary matter to collect in clusters of galaxies," says COBE scientist Edward L. Wright of the University of California, Los Angeles.

Some cosmologists have speculated that cold dark matter, an invisible substance that hypothetically makes up a significant chunk of the universe, provided the extra gravitational push. "The nature of dark matter is still mysterious, but it seems to be required in order to make the structures that we see today," says Wright.

While the COBE findings support the cold dark matter theory, they don't rule out other possibilities. Cosmologists have suggested more exotic models — involving cosmic strings, for example — that both fit with the new findings and seem to explain the lumpy cosmos.

COBE is still gathering data, so more concrete answers may arrive soon. "What I think we're going to see is really a breakthrough and a revolution in our understanding of the early universe," says Smoot, "because we're going to have hard facts."

— *M. Stroh*

Zeroing in on the elusive neutrino's mass

For an elementary particle that plays such crucial roles in processes ranging from radioactivity to supernova collapse, the neutrino has eluded characterization for a remarkably long time. As one step toward pinning it down, researchers have now obtained the best experimental estimate yet of a neutrino's mass.

But the relevance of this measurement, which sets an upper limit of 8 electron-volts on the mass of an electron antineutrino, remains clouded by concerns that an unknown physical effect may be interfering with the experiment. Researchers involved with this and other, related studies have detected puzzling anomalies in their data that are hard to explain using standard theory.

"Our result is correct only if there is no new physics involved," says Wolfgang Stoeffl of the Lawrence Livermore (Calif.) National Laboratory, who heads the group that established the new limit. Stoeffl reported the team's findings at last week's American Physical Society meeting in Washington, D.C.

To determine the neutrino mass, Stoeffl and his co-workers use a special apparatus to measure the energies of beta particles, or electrons, emitted by the decay of a radioactive form of hydrogen known as tritium. In such decay, one of the two neutrons in a tritium nucleus turns into a proton and sends off a particle-antiparticle pair — an electron and an electron antineutrino.

By keeping track of the numbers of electrons detected at different energies, the researchers can plot an energy spectrum for tritium beta decay. They can deduce an upper limit on the neutrino's mass from the difference between the highest electron energy detected and the theoretical prediction of what that energy would be if the neutrino had no mass. That difference now stands at 8 electron-volts.

However, this tail end of the tritium beta-decay spectrum has a puzzling feature. When all the data in this region are taken into account, statistical measures suggest that the most likely value of the neutrino mass is a negative number — something physically impossible.

"It's the opposite of what we were looking for," Stoeffl says. "We have too many counts near the endpoint."

Other teams of researchers studying beta decay have consistently found similar small deviations from the expected number of electrons in this energy range. Moreover, the extraordinarily high precision of the Livermore experiment seems to preclude explanations that invoke energy losses or known atomic processes.

"It's hard to explain," Stoeffl admits. "We have to find out exactly what it is."

— *I. Peterson*