Cold Dark Matter Builds a Great Wall

As Mark Twain might have remarked, reports of the death of the cold-dark-matter model of the universe are greatly exaggerated.

A new computer simulation, following the evolution of matter over billions of years, clearly demonstrates that gravity by itself could have magnified tiny, random fluctuations in the distribution of cold dark matter during the first moments of the Big Bang into the huge agglomerations of galaxies now visible in the sky. Although the identity of the elementary particles that constitute cold dark matter remains a mystery, the simulation focuses on features of the model that are largely independent of the particle physics involved.

"This is the first time anyone has done simulations [of the evolution of the universe] this large," says astrophysicist J. Richard Gott of Princeton (N.J.) University. "The pictures we get look just like the observations." Gott and graduate student Changbom Park describe their model in the Feb. 1 MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY.

The recent discovery of large voids and a "Great Wall" of galaxies 500 million light-years long (SN: 11/25/89, p.340) called into question theoretical models that depend on gravity to produce such gigantic structures within the limited time available for the universe to evolve to its present state. Earlier, smaller computer simulations had shown evidence for bubbles and other structures but nothing on the scale of the Great Wall.

"Park's work, more than anyone else's, makes it look plausible that the cold-dark-matter theory can make structures as big and well defined as the Great Wall," says Edmund Bertschinger of MIT. "One thing that's clear from Park's simulation is that with enough dynamic range, gravity is capable of great intricacy."

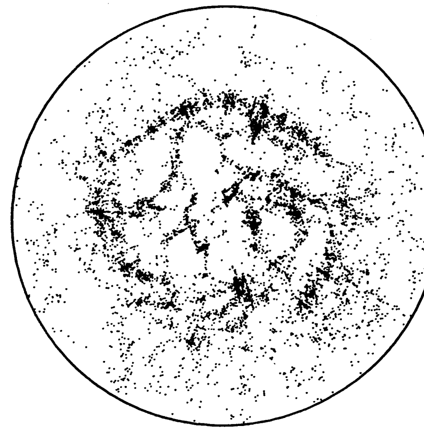
But, he cautions, "this is the first calculation of this scope to really show such massive structures, so I think all of us ought to take it as a tentative result that needs theoretical confirmation."

Park and Gott base their simulation on the so-called standard cold-dark-matter model of the universe, in which cold dark matter makes up most of the universe's mass. According to this theory, random quantum fluctuations stir up the material and then freeze just a fraction of a second after the Big Bang, during a period in which the universe is rapidly expanding in size.

Theorists can readily calculate what these fluctuations look like and where to put particles of cold dark matter, tracing their course until the universe is about 110 million years old. At that point, the effects become too large for anyone to calculate directly and the computer takes over to approximate the subsequent evolution of these particles under the influence of gravity.

Park and Gott's simulation tracks 4 million particles—2 million representing cold dark matter and 2 million representing matter in luminous galaxies — in a cube 2 billion light-years across. Galaxies of luminous material tend to form at high-density peaks in the distribution of cold dark matter.

The cold-dark-matter theory predicts that the initial fluctuations in density would have only a small effect on the microwave background radiation that fills the universe — a notion consistent with preliminary results from the Cosmic Background Explorer (COBE) spacecraft (SN: 1/20/90, p.36). "Gravity moves things around without leaving an imprint on the spectrum of the background radiation," Gott says. "People shouldn't forget that the cold-dark-matter model predicted successfully what COBE was going to see."



Park & Gott

This illustration, which shows many galaxies clustered as long walls, represents the distribution of visible matter in a simulated universe from the viewpoint of an observer at the circle's center.

At the same time, the force of gravity seems sufficient for gathering matter into large clumps to produce a universe with a sponge-like texture. By changing the simulation's viewpoint to that of an observer inside this hypothetical universe, researchers can obtain pictures with features such as voids and walls that resemble those in maps produced from Earth-based observations, Gott says.

"If this is all true, it means that the superclusters of galaxies we see today may be the fossil remains of small, random quantum fluctuations that happened only 10^{-35} second after the Big Bang," Gott says.

The simulation isn't quite as successful, however, at reproducing the distribution of velocities that galaxies have in addition to the rate at which they are receding from one another because of the expansion of the universe (SN: 1/27/90, p.60). "Surprisingly, the numbers we get are not as bad as one would have thought before doing the simulation," Gott says. "The simulation shows a reasonable amount of variation from place to place. There are spots where the streaming velocity is as large as what we observe."

Some aspects of the model are bound to change as theorists refine their ideas about the nature of cold dark matter and how the universe expanded. Large computer simulations may also provide useful insights into the role of gravity in forming large structures.

"In my opinion, even Park's simulation is not big enough," Bertschinger says. "We'd like to have 1,000 times as many particles as Park used . . . in order to understand structures like the Great Wall and how they arise." — *I. Peterson*

Sickle mice turn anemic

The race to develop an animal model for sickle cell anemia headed into the final stretch this week as researchers reported genetically engineering the first laboratory animals displaying symptoms of the hereditary disease. Previous experiments had yielded mice whose red blood cells contained the human gene for sickle cell anemia but who failed to show any signs of the disease (SN: 1/20/90, p.45).

Thomas M. Ryan of the University of Alabama Schools of Medicine and Dentistry at Birmingham and his colleagues started by adding the human gene for sickle cell anemia to mouse embryos. As in previous efforts, the mice expressed the abnormal hemoglobin that is the hallmark of the disease, but they also produced moderate amounts of normal mouse hemoglobin, staving off the illness. Ryan's group overcame this obstacle by breeding these mice with others harboring a genetic disease called thalassemia, which prevents production of normal hemoglobin.

Offspring from these crosses have clinical profiles resembling those of humans with sickle cell anemia. They exhibit mild anemia and enlarged spleens, and their red blood cells sickle under low-oxygen conditions. The hybrid mice may prove useful in tests of new anti-sickling drugs and gene therapies, the researchers assert in the Feb. 2 SCIENCE. □