SPECIAL REPORT

THE BUBBLING UNIVERSE

Scientists in all disciplines seek patterns in nature, and astronomers are no exception. Over the past decade, as astronomy improved its ability to determine the distribution of dim, faraway galaxies, surveys revealed a texture to the cosmos: Galaxies and clusters of galaxies appeared to be strung out along lengthy chains, separated by vast regions of nothingness. The universe manifested itself as one great Swiss cheese.

These gigantic voids and gently curving filaments were very much a surprise to astronomers, who were used to thinking of the universe as blandly homogeneous. Because of that dogma, many were skeptical. But the latest evidence not only strengthens the case for large-scale structure in the universe, it also implies that the strings of galaxies sighted so far are mere stitches in a much more complicated celestial tapestry.

In recent months, a team at the Harvard-Smithsonian Center for Astrophysics (CFA) in Cambridge, Massachusetts, has concluded that the universe is better described as bubblelike, foamy as the head on a glass of beer. The data suggest that galaxies congregate on the surfaces of huge, nested bubbles. Every void is the interior of a roughly spherical shell of galaxies. Team member Margaret Geller says the cosmos resembles "a sink full of soapsuds." The change from filaments to froth distresses some people, because it could upset long-held theories concerning the origin of galaxies and the amount of dark matter in the universe.

The data that paint this foamy picture were gathered during the winter and spring of 1985 with the 60-inch reflecting telescope atop Mount Hopkins in southern Arizona. Guided by John Huchra, observers mapped the three-dimensional distribution of 600 galaxies in a 6-degree-wide strip extending across a third of the sky and out to about 450 million light-years. Each galaxy's distance was gauged by its redshift, the shifting of its spectral lines caused by its movement away from us as the universe expands. And recession speed is directly proportional to distance.

The work at Mount Hopkins is part of a 5-to-10-year program to extend a 2,400-galaxy CFA redshift survey done eight years earlier. This time, though, the probe reaches nearly two times farther into space. "Eventually," says Huchra, "we'll determine the redshifts of twelve thousand galaxies. The bigger the volume, the better chance we have at determining the true structure of the universe."

When Valerie de Lapparent, a University of Paris student studying under Geller and Huchra, plotted the first extended data last fall as part of her doctoral thesis, she thought the frothy results "could not be real." But computer glitches, she says, "would have tended to make things messy, not highly structured. We see bubbles everywhere in this survey."

The new data enabled De Lapparent, Geller and Huchra to see that filamentary strings may simply be illusions, created as astronomers mapped only particular slices of those shell-like assemblies of galaxies—much like charting the thin crust around one slice of bread. In fact, the crust is more extended and encloses an entire loaf—a void. Both large and small bubbles are present in the CFA map; the largest stretches some 240 million light-years across. That's about the size of the famous Boötes void, a large region of galaxyless space whose discovery garnered much publicity several years ago. Then, the Boötes void was the exception; now such voids appear to be quite common.

Nearly every galaxy in the survey," stresses Geller, "belongs to a structure." Even the Milky Way, our home galaxy, is likely associated with a bubble. The local supercluster, a flattened association of galaxies to which the Milky Way belongs, looks like it may be part of a bubble surface. The sharply defined surface of the bubbles and the emptiness within suggest that gravitational forces alone did not construct them—such forces could not have held the cells together over time. More likely, says Geller, the sudsy structure is a telltale relic from the dawn of creation some 10 to 20 billion years ago.

It has long been assumed that galaxies were forged as clumps of gas were pushed and squeezed by ripples emanating from the Big Bang. And theorists were encouraged when computer simulations of the process roughly reproduced some of the voids and filaments observed in the universe. But, to the dismay of cosmologists gazing at the new CFA picture, very large bubbles of galaxies have not resulted from such machinations. Many theorists are going back to their drawing boards in an attempt to accommodate the frothiness in their models.

The extragalactic suds look suspiciously like the structures called superbubbles in our own galaxy—spherical regions of

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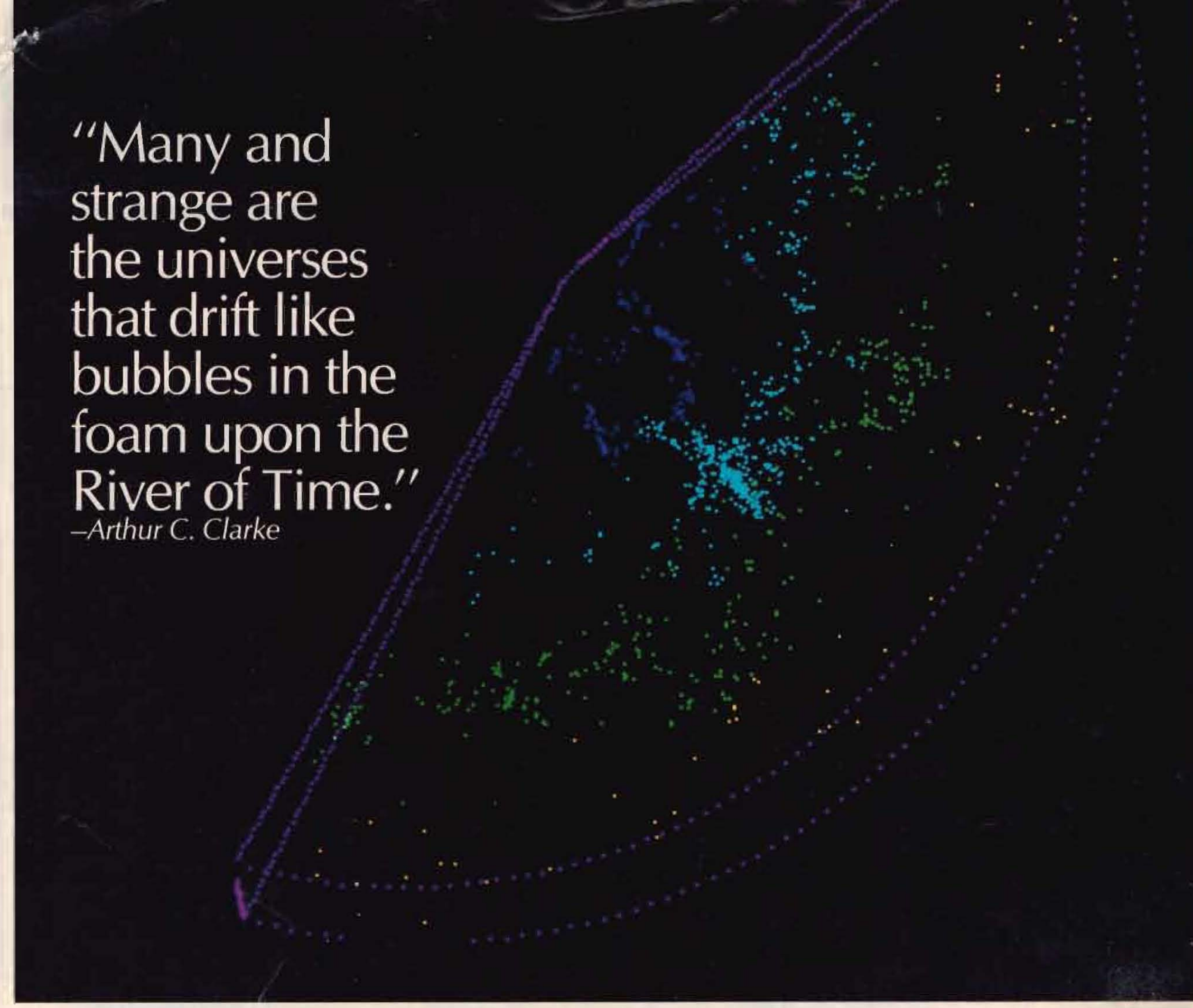

GRAPHICS BY MICHAEL KURTZ AND MATTHEW SCHNEPS/HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS

space swept clean by a series of supernova explosions. Geller ponders whether a similar hydrodynamic process—albeit on a much bigger scale—rather than the Big Bang alone, could have generated a bubbly universe. Several years ago, in fact, Princeton astrophysicist Jeremiah Ostriker and Lennox Cowie of Johns Hopkins University imagined the early universe giving birth to massive first-generation stars, which raced through their nuclear cycles, releasing tremendous amounts of energy as they burned and explosively died. "The question is," says Ostriker, "what happened to that energy? It's likely to have sent a shock wave propagating outward, like a bomb explosion."

All matter in the path of this cosmic shock wave would be swept up into a thin shell, which would then fragment into new stars and galaxies. From there, the process could continue ever more rapidly. After several cycles, the galaxies end up arranged along the surfaces of shells that enclose vast regions of cleared-out space. This scenario, though, still has trouble generating lots of voids as big as the Boötes "hole." Whatever the mechanism, the bubbles themselves will be a road map through time, back to when galaxies were born.

Meanwhile, the CFA map may shed new light on the formation of rich, dense clusters. The Coma cluster, a collection of thousands of galaxies located in the direction of the constellation Coma Berenices, sits right at the intersection of several bubbles. This setup could force astronomers to throw out their models of cluster development. If a pattern is found in further surveys—a cluster at each bubble junction—there should be a rich cluster every 120 million light-years or so. Intriguingly, that's the average distance between rich clusters listed in astronomical catalogs.

Geller, the theorist in the CFA group, speculates that the Coma cluster's position could also bear on the dark-matter debate. The motions of galaxies within clusters have persuaded astronomers that unseen matter is present, acting as gravitational glue that keeps the clusters from flying apart. The candidates for this substance range from elementary particles to stars and planetoids too faint to see. But the odd dynamics of galaxies may merely be a consequence of the bubbles. If so, estimates of the amounts of dark matter in the clusters could plummet. In fact, if too much dark matter were housed in the shells, their structures would have been disrupted by now. "We still can't put a limit," says Geller, "on the amount of dark matter that might be uniformly distributed through the universe. But at the very least, the new data serve as a warning."

This picture raises more questions than it answers: Are the bubbles expanding? Is there much matter in the voids? How much and in what form? Could it be enough to recollapse the universe in a Big Crunch many eons from now? Then, too, the map includes only a tiny fraction of the observable universe. Geller likes to remind colleagues that if the visible universe is compared to the surface of Earth, they have fully mapped an area only the size of Massachusetts. For now, extragalactic mapmakers are akin to the first surveyors of the New World, only guessing at the magnificent expanse lying beyond what they have seen. ■

The dots in this slice of universe are galaxies; blank areas are empty "bubbles." Colors represent distances from Earth.