Delving the Hole in Space

This void between the galaxies is five times the size of any other; cosmologists wonder what it means

The recently announced "hole in space," a 300-million-light-year gap in the distribution of galaxies, has taken cosmologists by surprise—not because it exists, but because it is so big.

Smaller gaps are well known: when distant galaxies are plotted on a map of the sky the result is a striking tangle of clumps and filaments and voids. Explaining how this structure arose out of the well-blended uniformity of the early universe is in fact one of the major unsolved problems of cosmology. The hope is that this new cavity in space, five times the size of any previously known hole, will provide some insight.

The new hole was found by Robert P. Kirshner of the University of Michigan, Augustus Oemler, Jr., of Yale, Paul L. Schechter of the Center for Astrophysics and Kitt Peak National Observatory, and Stephen A. Shectman of the Mount Wilson and Las Campanas Observatories.* In effect, they took very deep core samples of the sky, measuring the red shifts of all the galaxies down to magnitude 17 in six regions about 1 degree across. Three samples in the Southern Celestial Hemisphere showed nothing unexpected. But three in the Northern Hemisphere, lying in the general direction of the constellation Bootes, showed striking gaps in the red shift distribution. In each, the gaps extended from roughly 360 million to 540 million light-years; moreover, each showed a marked enhancement of galaxies on the inner and outer edges of the void.

"This doesn't show that the whole area is empty," cautions Kirshner. The original three areas formed the points of a triangle some 35 degrees on a side, and it is possible that the existence and alignment of the gaps were just coincidences. To verify the extent of the hole, the team has spent the last year sampling Bootes over a much finer grid of points, and are now preparing their results for publication.

"I think it most likely that the matter density contrast is not nearly as great as the galaxy contrast," adds Schechter. "Perhaps it just has fewer 'typical' galaxies like M31 [the Andromeda galaxy]." For example, if there were some threshold density for the formation of brighter galaxies, the matter in the hole might be just below that density. The group is also asking for telescope time to look for dimmer dwarf galaxies within the hole.

If the hole is real, are there any more of that size? Obviously, the only way to know for sure is to go out and look for them. But in the meantime, Princeton's James Peebles, one of the foremost authorities on the large-scale structure of the universe, points out that holes are just the obverse of density enhancements. The largest previously known structure in the universe is the Serpens-Virgo supercluster, he says. It is about half the size of the recently found hole, and its excess of galaxies is of about the same magnitude as the apparent deficit in the hole. But Serpens-Virgo is also unique in the observable universe, he says, so it would be extraordinary if holes of such magnitude are common.

There are at least two theoretical models of the large-scale structure that could produce holes of this magnitude. Both emphasize the role of hydrodynamics and dissipation. In the first, Ya. B. Zel'dovich and his colleagues in the Soviet Union have calculated that certain types of density fluctuations in the early universe could cause gaseous matter to accumulate in randomly oriented sheets, or "pancakes," with gaps in between. Dissipation and viscosity within the pancakes would keep the gas from reexpanding, and eventually gravity would force it to collapse into galaxies and clusters of galaxies. The result would be a kind of cellular universe, with clusters and superclusters arrayed in diaphanous membranes around gaping voids.

In the second theory,† Jeremiah P. Ostriker and Lennox L. Cowie of Princeton University postulate that small-scale density fluctuations in the early universe would result in the formation of massive stars, each of which would quickly run through its cycle of stellar evolution and erupt as a supernova. Shock waves from the blast would propagate through the surrounding gas, piling up material in a shell. Within this shell would form galaxies and new massive stars. More explosions would ensue, and the process would proceed exponentially. The end result would be a universe much like Zel'dovich's: galaxies arrayed in immense flattened superclusters (the remains of the massive shells) surrounding empty holes. In fact, says Ostriker, computer simulations and analysis of the gas dynamics predict holes up to 300 million light-years across—just what Kirshner and his colleagues observed.

Unfortunately, neither of these theories really stands on first principles. The pancake model requires that the initially homogeneous universe give rise to fluctuations that are just so. (The "spectrum" of fluctuations, the frequency of their occurrence as a function of their size, must be postulated ad hoc.) Ostriker and Cowie must assume that massive stars would somehow form very quickly in the early universe.

"The problem is always that we don't understand the initial values for the density fluctuations and the velocity distributions," says Peebles. In fact, even the evidence for the cellular model of the universe is quite shakey. Galaxy maps do show a remarkable tangle of filamentary structure, and the filaments may indeed be cell walls seen edge on. "But I'm a conservative," he says. "The human eye can see 'patterns' in random dots. We've worked hard and we've never yet found a statistical measure that could ferret out the filaments and prove that they really exist."

Peebles himself has chosen to pursue the gravitational clumping model of the large-scale structure. In this model the galaxies came first, gravitationally condensing out of primeval matter in a random distribution and only later falling together into clusters and superclusters. (This is sometimes called the "dissipationless" model, since hydrodynamics and viscosity play a subordinate role.) Such an approach can reproduce the observed structure of the universe—but again only at the cost of ad hoc assumptions about the initial conditions.

"All we can do is try out scenarios," says Peebles. He subscribes to the Sherlock Holmes approach: "As we see what the models predict, we'll be able to eliminate all but one—and that one has to be right."—M. MITCHELL WALDROP

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†*Astrophys. J.* 243, L127 (1 February 1981).

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