calculations by himself, White and Carlos Frenk have demonstrated[3] that the hot-dark-matter theories are inconsistent with the empirical correlation functions of short-range galactic clustering compiled by James Peebles and his colleagues at Princeton. Such local clustering is characterized by correlation lengths on the order of 5 Mpc. The Peebles correlation lengths would have to be much longer than this if the pancakes were indeed formed *before* the galaxies, as implied by the Zel'dovich theory. The creation of large-scale structure by way of Zel'dovich pancakes is consistent with the observed correlation functions only if the pancakes are much younger than the first epoch of galaxy formation.

Unlike the hydrodynamic theory of Zel'dovich, the recent simulations by Davis and White are purely gravitational—until one gets to the actual formation of galaxies. Because they take the underlying dark matter to be cold, Davis and White cannot invoke the free streaming of relativistic particles in the early universe to get rid of small-scale fluctuations. Therefore the underlying mass distribution of the cosmos would presumably not exhibit the long-range coherence observed in the new redshift surveys of the galaxies. But the formation of galaxies, they assume, is "biased." Because one doesn't really know how galaxies are created, they take the liberty of assuming that galaxy formation may involve density thresholds that greatly exaggerate the underlying dark-matter distribution. In this way, the simulations of Davis and White have in recent weeks succeeded in creating void diameters as large as 50 Mpc. Whether these simulations can reproduce the very thin, sharp, spherical shells Huchra and company seem to see depends sensitively on the details of the unknown galaxy-formation mechanism.

"**These large bubbles** were not anticipated by any of the standard theories," Ostriker told us. Nor did the original Ostriker–Cowie–Ikeuchi theory envision bubble diameters greater than 5 Mpc. In the "standard" theories, he explained, everything is determined by growth from the initial spectrum of fluctuations. "What goes in is what comes out. There is no amplification mechanism." The essentially new feature introduced by Ostriker, Cowie and Ikeuchi is amplification by a kind of chain reaction. The seed explosion generates a spherical shock wave. The formation of galaxies on the expanding shock front provides a feedback mechanism, a chain reaction of galaxy formation that constitutes a source of nonlinear amplification. "You get an enormous output from a small input."

The efficiency of such a chain reaction of detonations depends on when it started. Ostriker's student, Edmund Bertchinger, has recently calculated[4] that if a seed explosion occurred in the era of "Compton cooling," when the radiation background that has now cooled to a 3-K whisper in the microwave spectrum was still very intense, Compton scattering would have provided a cooling mechanism so efficient that the chain reaction could amplify through many successive generations of detonations. Starting with a single supernova, Bertchinger calculates, one could sweep out a bubble diameter of 50 Mpc. However, Joseph Silk (Berkeley) raises the objection that the 3-K microwave background would be much less smooth than we know it to be if the bubbles had really begun as early as the Compton era.

If the seed explosion occurs in a more recent epoch, when cooling is much less efficient, one would have to start out with a whole first-generation galaxy, which is estimated to spew out a total energy of about 10^{61} ergs in a relatively short time, as abundant supernova activity binds a small fraction of the galaxy's original inventory of hydrogen and helium into heavier elements. In that case, one gets only a few generations of detonations, and a bubble diameter of at most 5 Mpc. Furthermore, the bubble diameter increases only as the *fifth* root of the energy output. Therefore, unless one can come up with a lot more energy in the explosive seed, it is difficult to generate holes that will by now have grown larger than 5 Mpc.

The theory in this original form was primarily concerned with the formation of galaxies on the expanding shock waves; it was not thought of as a theory of large-scale cosmic structure. But two years ago Bertchinger and Ostriker discovered[5] a general expanding solution of the theory that would propagate in a self-similar manner, eventually cramming the cosmos full of bubbles. The same solution was discovered independently by theoretical groups at Caltech and Hokkaido. With this general solution, one need no longer invoke explosive seeds. Bubble propagation could be initiated simply by sufficiently large negative density fluctuations. But for the moment, Ostriker told us, it's still difficult to explain why the bubbles observed in the new redshift surveys are so very large. He and his colleagues are currently investigating whether the merging of bubbles in this theory would yield bubble diameters much larger than 5 Mpc in the present epoch.

Silk thinks that asking a single mechanism to explain both galaxy formation and the creation of large-scale structure is asking too much. This, he suspects, is the essential difficulty with the theories of Zel'dovich and Ostriker. Silk is pursuing a different course—as yet without a definitive result. He prefers a scenario in which the galaxies are made first, followed by a different, later mechanism that generates the 50-Mpc structure now being revealed to us by the redshift surveys. "None of the theories put forward thus far explains everything," Silk contends.

To help the theorists along, Ostriker suggests, the observers will have to look for fainter galaxies, to see just how empty the voids really are. Radio and optical-absorption searches will be needed to study gases in the voids. Furthermore, if we are indeed sitting on the edge of an expanding bubble, the Hubble constant as determined from the redshifts of our neighbors is larger than the true, universal Hubble constant by 20 or 30%. One can investigate this by using "standard candles"—galaxies of known intrinsic brightness—to make distance determinations independent of redshifts.

—Bertram Schwarzschild

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PBFA-II is on the air at Sandia National Lab

The second-generation light-ion-beam fusion accelerator at Sandia, PBFA-II, was successfully fired for the first time in December. This $48 million machine is ultimately meant to deliver megajoules of pulsed energy—ten-nanosecond beam pulses of 20–30-MeV ions of lithium or other light species—to a D–T fusion pellet. The goal is to compress the pellet to a thousand times normal density, approaching the conditions for thermonuclear ignition.

Pellet experiments are still years off. Last month the 36 Marx generators, the sophisticated capacitor banks that initiate the accelerating voltage pulse, successfully delivered their full 13-MJ capacity with a time spread of only 27 nanosec. Further downstream, the highly innovative plasma opening switch has begun functioning. □