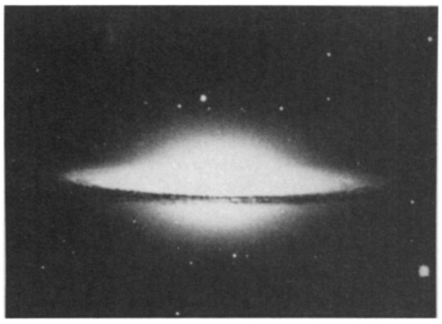
AN OPEN OR SHUT CASE



Cosmology's most durable controversy concerns the shape of the universe

BY DIETRICK E. THOMSEN

The attempt to determine the shape of our universe from within is one of science's most difficult undertakings. It puts us in the position of the flatlanders of the famous novel. Their efforts to understand their two-dimensional world from within have provided great amusement to many three-dimensional science fiction fans who could see at a glance what it took the flatlanders laborious efforts to establish.

Similarly, a being who disposed of five or more dimensions could tell us at a glance the answer to our most basic question about the shape of our cosmos: Is it open or closed? Returning to the flatland analogy, a closed two-dimensional universe could be shaped like the surface of a sphere, an open one could be represented by a saddle, the edges of which can be extended to infinity without closing back on themselves. If we let our flatlander travel in these worlds, he will note an important distinction: In the closed world he can get only a finite distance from his starting point before he starts to return to it. (Magellan could get only so far from Lisbon; after that he was returning to Lisbon.) In the open world, the flatlander can travel infinitely without returning to his start.

The flatlander's travels are important to us because we are, in a sense, flatlanders traveling in one of our dimensions, the one we call timelike. Our universe is expanding as time goes on, and the cosmological question is whether this expansion will reach an utmost extent and then possibly collapse back toward its starting point like the flatlander's journey on the sphere or whether the expansion will continue forever like the flatlander's journey on the saddle.

Cosmologists have no general agreement on an answer. No consensus has appeared in the past, and none was evident at the most recent meeting on the subject, the "neighborhood meeting" sponsored by the Smithsonian Astrophysical Observatory in Cambridge, Mass. The data involved are so difficult to obtain and tricky to interpret that two people can take the same raw information and wind up arguing on opposite sides of the question.

The tests that can be made are both global (involving measurements over as much of the universe as we can see) and local (deducible from conditions in our immediate neighborhood, say, the local cluster of galaxies). James E. Gunn, of the California Institute of Technology, who reviewed them, is pessimistic about the global ones and cautious about the local ones.

All the tests Gunn deals with are dynamic ones that attempt to derive some value for either of the two relevant quantities, the deceleration parameter and the density of the universe. Given the expanding universe, all its parts were endowed by the original big bang with a certain velocity. But all those parts are subject to gravity, and, as long as gravity is the only force acting (suggestions that there may be others are still considered somewhat beyond the pale), the mutual attraction of the parts will gradually slow the expansion. The operative question is whether the deceleration rate is enough to stop the expansion in a finite time and possibly reverse it (closed universe) or not (open universe). If the deceleration parameter, designated by the symbol q_0 is less than one-half, the universe is open; if q_0 is more than one-half, the universe is closed.

The strength of the mutual attraction depends on the density of the matter in the universe, so another handle to the question is to try to determine the density and see if it is more than the density needed for closure. This factor is usually expressed as a ratio of actual density to the critical density and designated by the Greek letter omega (Ω). If omega is less than one, the universe is open; if omega is more than one, the universe is closed. Omega and q_0 are related by the simple equation, $\Omega = 2q_0$.

The traditional way, "how cosmology used to be done," Gunn says, is to look at things very far away. That "may or may not be the best way." The idea is that looking at things very far away is equivalent to looking far in the past, and if the observer can see a difference between how things were moving then and how they do now, he can maybe say something about openess or closure.

The procedure is to set up a Hubble diagram, which compares the redshifts of galaxies with the light flux received from them at earth. The formula that relates the flux at earth to their intrinsic luminosity contains the deceleration parameter.

This procedure works best if galaxies all have the same intrinsic luminosity. The fact is that they don't. Furthermore, galaxies are extended objects. Brightness varies across a galaxy's image, and the observer must be sure that his telescope aperture is adjusted to compare them.

The observer can take the brightest galaxy in each cluster, or whole clusters, and hope that these will have the same intrinsic luminosity; but then evolutionary problems intervene.

Galaxies evolve as units. Big galaxies tend to eat their satellite galaxies, and this changes their brightness as it goes on. Furthermore, stars evolve and change their brightness. As we look farther and farther away we look farther back in time to a period when perhaps the stars in the galaxies we see were all very young and therefore differently luminous from those in older galaxies.

All these pitfalls lead Gunn to propose using local tests to get at the density ratio, omega. Using the local cluster or supercluster of galaxies obviates some of the evolutionary problems because they are nearly contemporary. If one can establish a relationship between a galaxy's luminosity and its mass, one can get some idea of the mass in the local volume, assuming a reasonable estimate of unseen matter from the dynamics of the galaxies, and thereby arrive at an estimate of the density ratio, omega.

Depending on the exact local test chosen, the figures vary from a low of 0.05 to a high from which a value of one cannot be excluded, but Gunn tends to favor a figure of about 0.1, which would argue for an open universe.

P.J.E. Peebles of Princeton University uses clusters of galaxies and their dynamics in a cosmological test. This deals with distribution of galaxy clusters, especially those in the catalogue drawn up by George Abell. Peebles studies the mean densities of the Abell clusters, their distribution in space, the velocities of the galaxies and correlation functions he sets up to test the probability of a given number of galaxies being in a given piece of space. From this he can argue to the density ratio, and although different assumptions give different values, the one he comes down to is 0.7, rather close to a closed universe. This was received with consternation in some quarters.

Instead of the dynamics of galaxies, a cosmologist can choose to try to get the cosmic density ratio from the abundances of certain elements. These attempts were reviewed by Gary Steigman of Yale Uni-

(Continued on page 15)

. . . Universe

versity.

Given that the universe started with a big bang, that event should have synthesized a certain amount of the lighter elements, especially deuterium. Some of that has gotten processed by nucleosynthesis in stars and possibly elsewhere; some remains. If one knows the present amount and the history, one can get a handle on the density then and the density now, since the rate of nucleosynthesis depends on the density. One can make the argument for deuterium or for lithium, as Steigman did to admiring remarks from some in the audience, and one can even use the formation of heavier elements such as metals to help the argument.

The problem is the need to make assumptions about things that happened. Depending on how the assumptions differ, one could get either a closed or open universe.

One thing it would be nice to know is the abundance of deuterium in the far reaches of the universe. The figures now generally used are those for the solar system, especially the earth's oceans and atmosphere, and cosmologists piously hope they are representative of the universe as a whole. Jay M. Pasachoff of Williams College reported that interstellar deuterium had been recently discovered by radio astronomical means. The figures on abundance are preliminary but seem to fit an open universe. He and his group have obtained time on the radio telescope at Parkes, Australia, to continue the observations.

The near future will see the establishment of new and better observing facilities including the Very Large Array radio telescope, the Multimirror Telescope and the X-ray astronomy satellite HEAO-B. Their possible effect was reviewed by Herbert Gursky of the Smithsonian Astrophysical Observatory and several others.

The VLA may help improve some of the local measurements, but is not likely to have any "terribly direct relation to cosmology," says Gursky. The Multimirror telescope being installed on Mt. Hopkins in Arizona is the pioneer of a cheap way to make big optical telescopes. It and possible imitators could be very important in providing the large amounts of time to observe extremely distant galaxies and record their spectra, which are crucial to the global tests. The effect of HEAO-B is unpredictable. Right now in X-ray astronomy, observers see about all the sorts of things in our galaxy that astrophysicists might expect to give off X-rays, but they do not see much in the way of extragalactic sources. HEAO-B will see such things, and "some really new stuff may come in," Gursky says.

Nevertheless, as George B. Field of the Smithsonian Astrophysical Observatory, who convened the meeting, remarked, "the question is unlikely to be settled for a while yet." □