THE UNIVERSE:
AN EXPANDING CONCEPT

BY DIETRICK E. THOMSEN

Our picture of the cosmos has probably changed more over the last 60 years than over the preceding 60 centuries. In 1922 the universe was small by modern standards, restful and consisting mostly of stars. Among these were some peculiar nebulosities that had been known for centuries. A scientist named Edwin Hubble was studying them.

The concept of a galaxy dawned gradually on the collective mind of astronomy during the 1920s. Hubble had great trouble convincing colleagues of something that 1980s cosmologists take for a starting point: that the universe is articulated into galaxies, and galaxies are the important elements in a cosmological theory. It was even harder to convince people that our own Milky Way was just one of many galaxies.

In 1926 came the beginning of a true revolution. Hubble, Milton Humason and V.M. Slipher reported that the galaxies that they were observing all had redshifts in their light. That could be taken to mean that they are all receding from us. Up to this point astronomers had believed in a static universe — an *a priori* assumption but one that made sense. Nobody knew anything against it. In a static universe observers should see both redshifts and their opposites, blueshifts, in the light of distant galaxies. Some things go away from the observer; some come toward the observer. On the other hand, if everything is going away from the observer, any observer, then the universe has to be expanding.

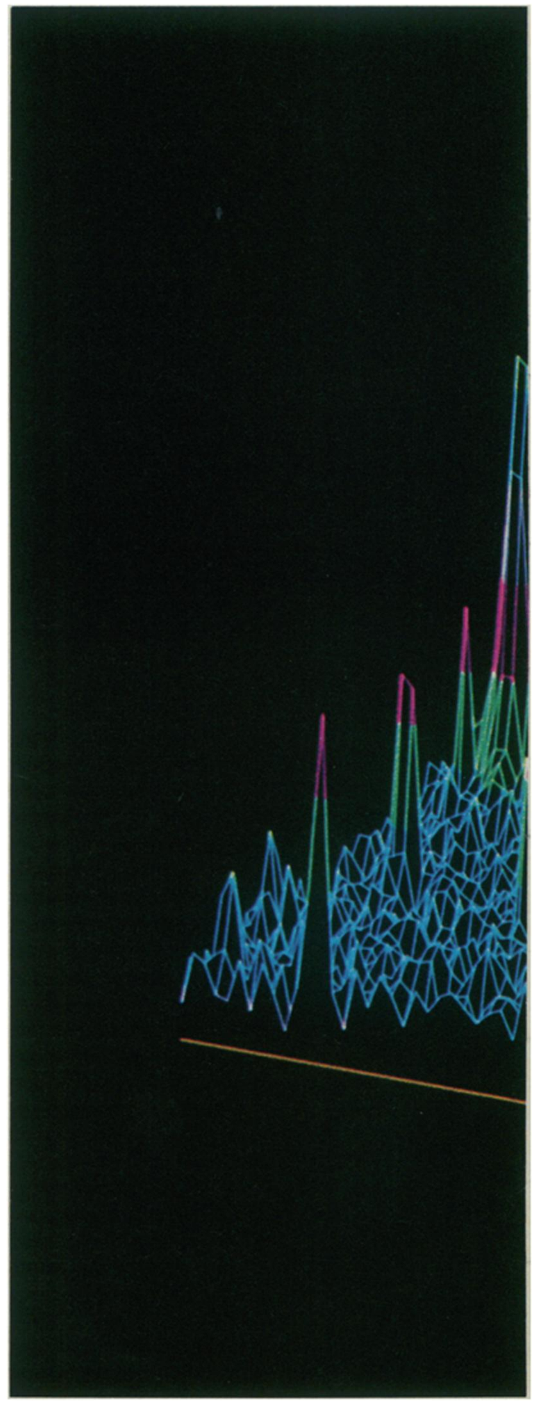
It took a good decade of further observations before the notion of the expanding universe gained general acceptance. Albert Einstein, the most prominent holdout, was finally convinced after a much-publicized pilgrimage to the top of Mt. Wilson.

The model of the "three-decker universe" (hell-earth-heaven) deplored by modern cosmologists and theologians alike, finally died at this point, so it is not surprising that hangovers of that image remain in many people's thinking. Copernicus and Galileo had removed the earth from the center of the universe, but after that the sun could still take its turn to be the center. Even in our own galaxy we can define a center to which we have an orbital relationship and calculate our distance from it. In the Hubblean universe we cannot define a center nor a boundary. We have no way of calculating where we are in absolute terms. We are simply in it, and everything we can see is rushing away from us.

Edwin Hubble posed in 1949 beside a 48-inch telescope.

The mathematical theory of space and time to go with this discovery was developing during the same years. Einstein had published his theory of general relativity in 1917. To make the cosmological solutions to his equations come out static — for him there was no other kind of universe at the time — Einstein had added in a so-called cosmological constant, a factor that did not represent anything in the physics. Others were less concerned to preserve stasis. By 1924 G.A. Friedmann had shown that Einstein's original equations, without the troublesome added constant, yield two cosmologically acceptable nonstatic solutions, provided space really can be curved. According to the oft-told tale, Friedmann published his work first in his hometown newspaper, the Kazan Messenger. This may not have been eccentricity so much as a reflection of the disorder of intellectual life during the years of Lenin's rule in Russia.

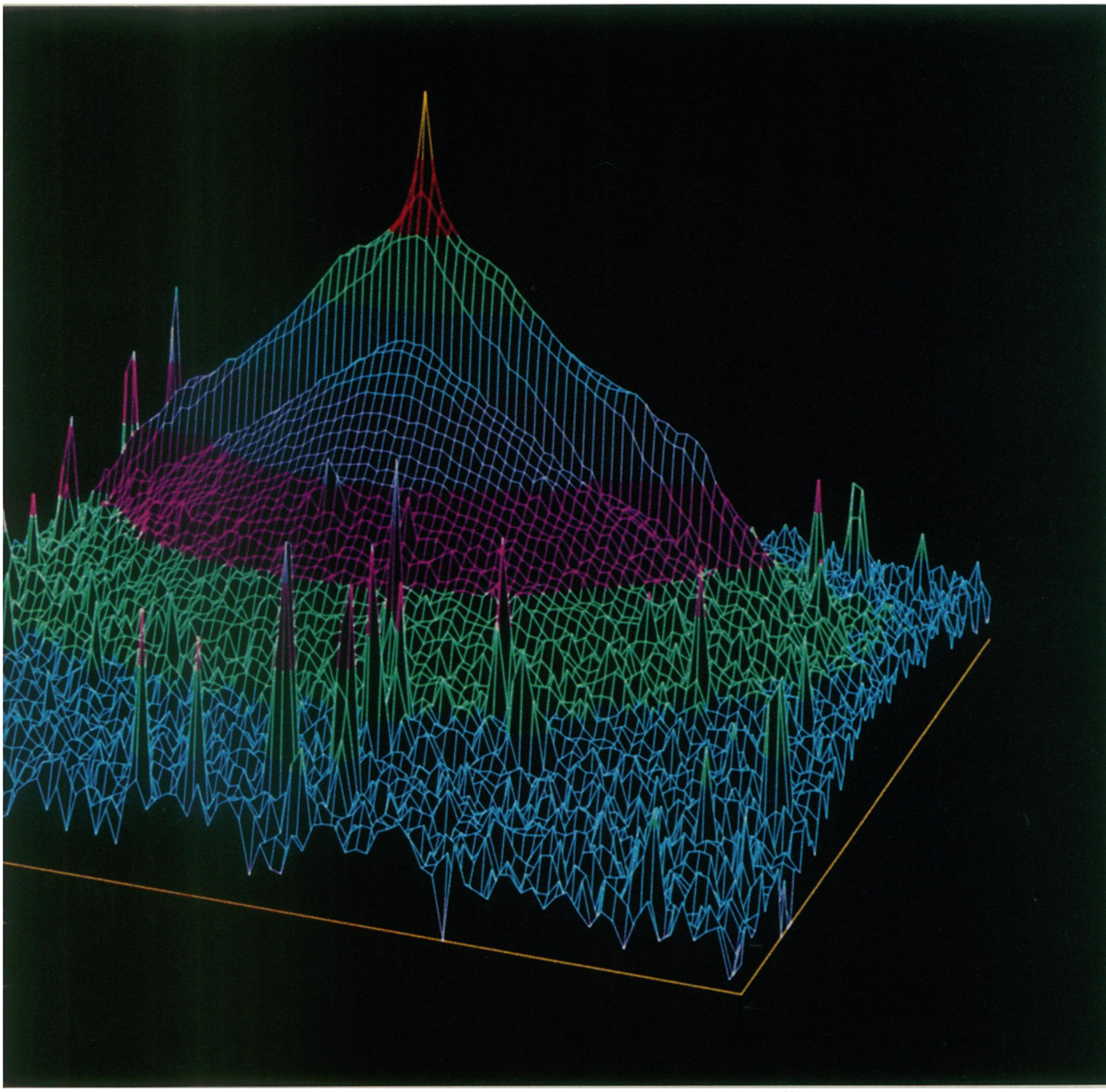
Einstein himself later dropped both the cosmological constant and the static universe. By 1931 he and Willem de Sitter had found the third nonstatic solution of the general relativitistic equations, which calls for a flat-space universe. At about the same time Georges Lemaitre came forth with models of an expanding universe, in which everything starts from a compact primal state, the so-called cosmic egg. Lemaitre is almost always cited by his title, *abbé,* as though cosmologists were extremely proud to have had a priest in their craft. Lemaitre later became a bishop,



which may go to show that in some churches, at least, espousal of the most advanced cosmology is no bar to promotion.

Today's cosmologists argue whether the actual universe follows a Friedmannian (curved-space) or Einstein-de Sitter (flat-space) model. Lemaitre's basic idea is very widely regarded nowadays; it forms the kernel of the big-bang theory. The modern big-bang theory developed during

"Ah, but a man's reach should exceed his grasp, or what's a heaven for? Thus Robert Browning contemplating Andrea del Sarto. As we contemplate cosmology, too, the heavens recede farther and farther from our grasp, and the reach of our minds is enormously extended.



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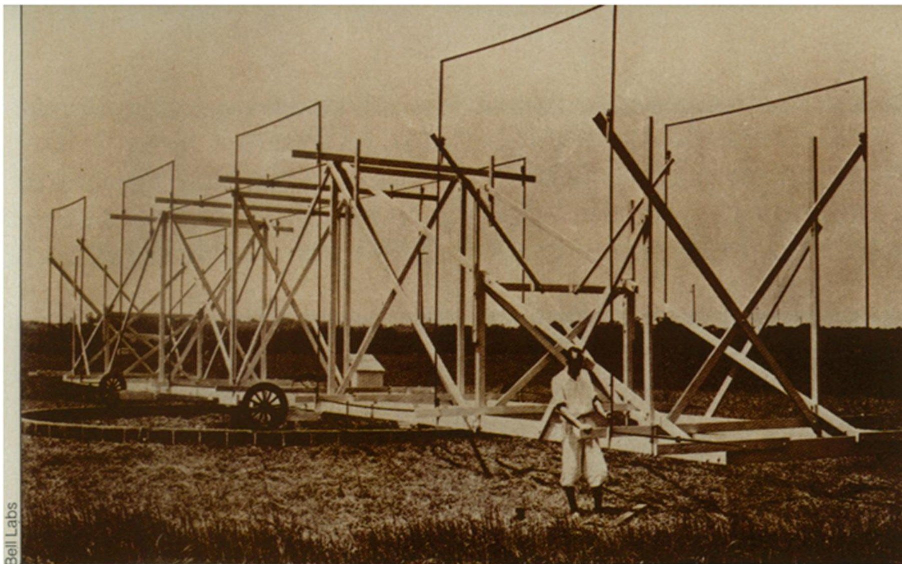
the 1930s and 1940s out of the interest in the abundances of chemical elements and their origins and evolution. It put a physico-chemical content in the models of the astronomers and the mathematical physicists.

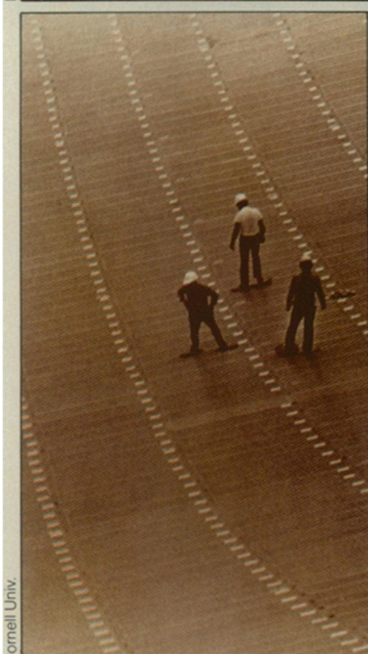
For Hubble the universe had been a cozy place even after it stopped being such a restful one. Hubble's observations of the redshifts of distant galaxies are readily translated into relative velocities between them and our galaxy. In the relation that Hubble found, relative velocity is proportional to distance, but the constant of proportionality cannot be readily measured. Hubble had more or less to guess, and he supposed that it might be 500 or 600 kilometers per second per megaparsec.

Modern astronomers make it 50, or 75 or 100. The proportionality is inverse, so this makes the visible part of the universe 10

What we now know as the Sombrero galaxy was number 104 in Antoine Messier's list of "nebulae." The very idea of a galaxy developed out of the study of objects in his catalogue. This is a false color intensity diagram of the Sombrero. Each column represents a small element of the galaxy's surface (one pixel). Both the colors and the heights of the columns represent the relative brightness of that pixel. Bright stars show as sharp spikes.



Bell Labs



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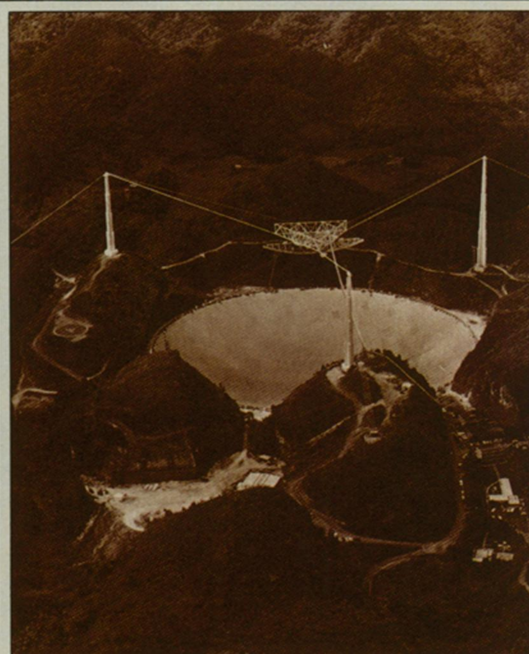

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Karl Jansky at the world's first radio telescope (above). Near Arecibo, P.R., is the world's largest single radio telescope (below). Maintenance men use "snowshoes" to walk on its wire mesh surface.

times as far across and 1,000 times as voluminous as Hubble's figure does. It also makes the universe older—something between 10 and 20 billion years old. Hubble's figure would make the universe about 2 billion years old. Part of the change was forced over the years by better statistics on more and more distant redshifts obtained with better telescopes. Some of it was forced by geologists who found rocks older than 2 billion years. And some of it came from theoretical astronomers calculating the life histories of stars, who found that stars had to be older than that.

The knowledge of the physics of atomic nuclei that was gained during the 1930s contributed greatly to the development of theories of stellar formation and evolution and vice versa. As the cycles and processes for the production of various chemical elements in the stars were worked out, it became clear that for the lightest elements something before the formation of the first stars would be necessary, something perhaps in Lemaitre's cosmic egg. These considerations led to the big-bang theory published by Ralph Alpher, Hans Bethe and George Gamow in 1948.

This alpha, beta, gamma of cosmology does not reach to omega, but it does present a beginning of the universe in which primordial radiation engenders neutrons and protons, which then fuse into the lightest elements (deuterium and helium mostly, but extending to lithium). After this the stars take over. What makes possible this sequence of development is adiabatic cooling as the universe expands. As space expands, the available matter is spread thinner, and so the universe cools.

This idea was attacked in a rival theory, the so-called steady-state cosmology. This proposed that expansion does not make the universe thinner. Creation of new matter out of nothing keeps the density the same; hence the theory's other name, continuous creation. The steady-state theory became a serious rival to the big-bang. Aside from possible mystic appeals, it recommended itself to many people because it managed not to predict something the big-bang did predict and which was a long time being found, the microwave background radiation at a temperature of three degrees above absolute zero.

The big-bang theory predicts that some of the primordial radiation will survive down the ages. As the universe expands, this leftover cools. At the present stage its temperature should be a few kelvins. This means its wavelength has shifted from very high energy gamma rays to something in the microwave radio range. Since the whole universe is a self-contained blackbody, this radiation should have a blackbody spectrum and should pervade all space.

In Hubble's day, radio astronomy didn't exist. Radio, Marconi's wireless, was mainly a medium for communicating with ships at sea. Commercial entertainment broadcasts had barely begun. However, the first radio receivers had already discovered that there are natural sources of radio waves. In 1932 Karl Jansky, a communications engineer working at Bell Labs in Holmdel, N.J., was able to show that some of this natural radio was from extraterrestrial sources. He did it by noting that the signal peaked every day when the constellation Sagittarius (the center of our galaxy) was overhead.

Radio astronomy developed very slowly at first. The other pioneer of the 1930s, Grote Reber, erected an antenna in his backyard and did what amounted to spare-time observations. It was not until after World War II, when equipment developed for radar and military communications became available to civilian research, that radio astronomy really took off. There is no space here to detail the entire new dimension it added to astronomy, but one of the things it did for cosmology was to find the microwave background radiation. This was first measured in 1965 by Arno Penzias and Robert Wilson working also in Holmdel.

In the two decades since, the spectrum of the blackbody has been filled in more and more, and the big-bang has gained more and more adherents. It is certainly now the majority view. The steady-state theory still has friends, however. Some of them continue to attack the validity of the evidence for the blackbody radiation; others try to revise the steady-state theory to fit it in. Discussing these matters at a recent seminar, Alpher remarked that in 1952, Pope Pius XII had made a speech endorsing the evolutionary theory of cosmology (that is, essentially, the big-bang). The British Astronomer Royal at the time, Harold Spencer Jones, responded to Pope Pius with a statement in favor of the steady-state theory. Having the pope on your side is no small bit of influence, but most astronomers would probably sooner have the astronomer royal. Provided he was right. □