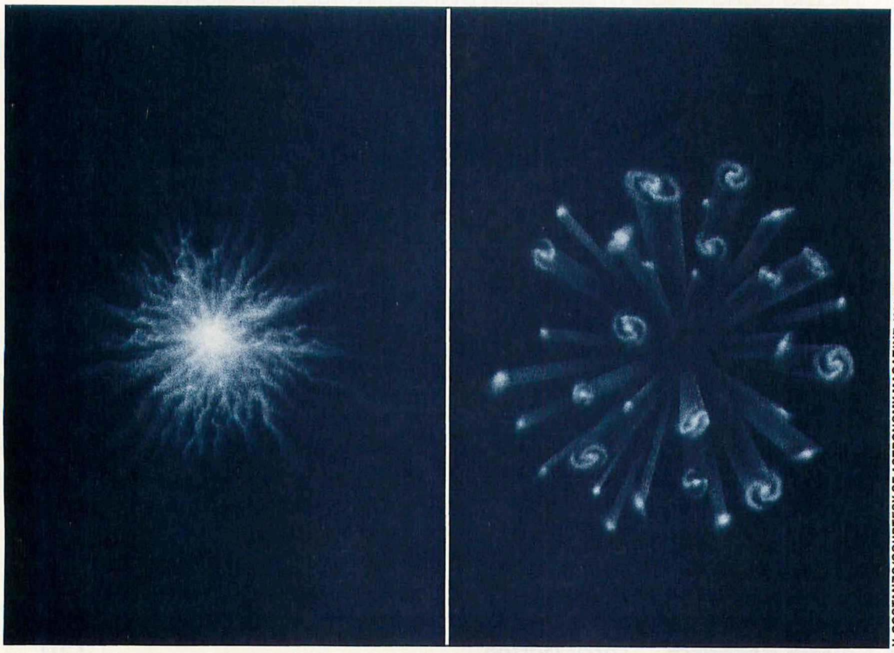
PLASMA COSMOLOGY

Part I. Interpretations of the Visible Universe



V. COSTANZO/COURTESY OF ASTRONOMY MAGAZINE, KALMBACH PUBLISHERS

Although the Big Bang model of the origin of the universe has reigned supreme for the last 20 years, its authority is being challenged by a growing number of observations.

ANTHONY L. PERATT

Cosmology (from the Greek *kosmos*, meaning "the world," and *logos*, meaning "discourse") began when man first asked: What is beyond the horizon and what happened before the earliest event I can remember? Pursued to its extreme, these questions led beyond planet Earth to the celestial surroundings.

As attempts to answer cosmological questions coalesced into systematic worldviews, or cosmologies, encompassing the entire universe, they were inevitably based on fragmented observational evidence, oversimplified assumptions, and incomplete physical theories. Yet, today, it is commonly accepted as a matter of faith that the ultimate cosmological theory will turn out to be simple, just as theories in physics have proven to be simple. For example, the laws of mechanics, electricity and magnetism, and quantum mechanics are all remarkably simple in form. Although we do not have any profound understanding as to why the natural laws have such simple descriptions, the fact of their simplicity is largely responsible for progress in physics, where much has been explained.

Since the universe embodies everything, from the tiny electron to the most distant quasar, there is certainly much to be explained in a given cosmology. Included among the cosmological explanations has been an estimate of the age of the universe. As late as 1948, astronomers estimated the age of the universe to be only about 2 billion years. This brought cosmology into direct conflict with geophysics, since geophysicists had calculated that the Earth was more than 3 billion years old. Today, geophysicists estimate the Earth's age to be 4.7 billion years, and the dominant cosmology, the Big Bang model, calculates the age of the universe to be 20 billion years.

Cosmological Controversy

Through much of the twentieth century, two cosmologies—the Steady State model and the Big Bang model—vied for general acceptance. The Steady State cosmology was renowned for the brilliance, if sometimes arrogance, of its advocates. According to the Steady State model, the universe is invariant in time. The appeal of this model derived, in part, from the *perfect cosmological principle,* which stated that the universe should present a similar aspect when viewed from any point in space and time. The Big Bang model can be traced back to the 1920s, when the Russian mathematician Alexander Friedman (1888–1925) invented cosmological models having an explosive beginning. The Friedman model was adopted by the Belgian mathematician, physicist, and cleric Abbé Georges Lemaître (1894–1966) whose desire was to invent a cosmology *(l'Atome primitif)* in which he could reconcile science with Saint Thomas Aquinas' theological dictum of creation [see "Hannes Alfvén Versus the Big Bang," May 1988, p. 196]. According to Lemaître's theory, the universe began at some precise moment in time in an immense explosion: the Big Bang, a term derisively coined by the British astronomer and Steady State advocate Fred Hoyle. Hoyle's name for cosmological models having an explosive beginning gained wide acceptance, overshadowing the alternate term *Ylem* promoted by explosive origin advocate George Gamow (1904–1968), an expatriate Russian physicist, science popularizer, and former student of Friedman.

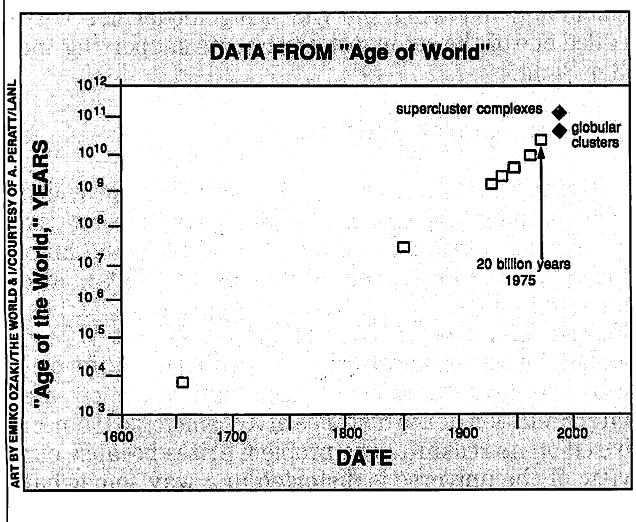
The bitter scientific battles and debates between Hoyle and Gamow are now legendary, and like other disciplines in science, the consequences are all too real. Where resources are limited, the dominant theory will have an advantage in procuring research funding for advancing its ideas and, ultimately, in placing its progeny in influential and flourishing positions.

In the past 20 years, the Big Bang model has reigned supreme. [See "Frontiers in Cosmology," Part I, September 1988, p. 196; Part II, October 1988, p. 178.] Now its authority is being challenged by an increasingly large number of observations.

"Proofs" of the Big Bang Model

Early claims of the Big Bang model were that it could explain the redshifts of the galaxies, as well as the origin of *all* the elements in the universe. In this theory, the recessional velocity of galaxies* as determined based on the redshift† was simply reversed and extrapolated backward in time until a state was

Opposite: An artist's conception of the explosive origin of the universe as proposed by the Big Bang model. This common-sense image, reminiscent of an A-bomb explosion, with galaxies spreading out from a single center, was promoted by early advocates of the Big Bang theory. Attempts to visually represent the Big Bang continue to be modified, as theorists try to explain the existence of galaxies.
Below: The "age of the world" has frequently been estimated during the past three centuries. As late as 1658, the Archbishop J. Ussher asserted that the "creation" took place on Sunday, October 23, 4004 B.C. By 1975, the age of the universe was estimated at 20 billion years. However, age estimates based on the Big Bang model may soon need to be increased because of recent observations of globular clusters of stars and supercluster complexes of galaxies.



* According to the standard Big Bang theory, it is the expansion of space separating the galaxies that causes redshifts.
† The shift of spectral lines toward longer wavelengths.

reached in which all the observable galaxies were crushed together in an infinitely dense singularity representing the beginning of the Big Bang. According to Gamow, "The elements were produced in less time than it takes to cook a dish of duck and roast potatoes." However, contrary to the presentation by many Big Bang advocates today, many scientists of the 1930s, including the redshift discoverers Milton Humason (1891–1972) and Edwin Hubble (1889–1953), were loath to interpret the redshifts as being due to a recession of the galaxies. (Interested readers are referred to Hubble's own writings in *The Observational Approach to Cosmology)* Also, the synthesis of all elements in a single creation event seemed overambitious. Thus, an impasse developed between the Steady State and the Big Bang that persisted through the 1950s and early 1960s. In 1950 Austrian physicist Wolfgang Pauli (1900–58) voiced the sentiments of the time with the statement: "If matter could be created it would be very good, but you must tell me exactly how it happened."

This impasse came to an abrupt and dramatic end in 1965 when two radio engineers at Bell Laboratories—Arno Penzias and Robert Wilson—using a converted transcontinental telephone system microwave *horn* antenna, reported the discovery of a background of microwave radiation having an apparent temperature of about 3.5 degrees Kelvin. This discovery was immediately interpreted as a cosmological relic of the birth of the universe in a primordial fireball. The importance of the measurement was acknowledged in the awarding of the 1978 Nobel Prize in physics to Penzias and Wilson. As recounted by R.D. Davies, president of the Royal Astronomical Society, during his bicentennial address to the society: "The new areas of study opened up by the discovery of the cosmic microwave background include . . . the ultimate proof of the Big Bang or evolutionary cosmology, as a direct consequence of the precise blackbody spectrum of the radiation."* Davies concluded, "The verification of its blackbody spectrum provided the death blow to the standard Steady State theory."

By the end of the 1960s, the Big Bang had become nearly universally accepted and today has penetrated the popular consciousness as a truism of science, influencing contemporary philosophy and religion. For example, when the president of the United States called upon the Congress to support a multibillion-dollar superconducting supercollider, one of the announced goals was "to recreate the first moments of the Big Bang" in the production of high-energy particles. The phenomenal success of the Big Bang is based on three observations: the redshift of galaxies, the cosmic microwave background, and the abundance of light elements.

The redshift data from galaxies strongly indicate that the galaxies appear to be receding with velocities proportional to their distance from Earth. This supports the Big Bang's view that the universe is expanding.

Numerous measurements of the cosmic microwave background have been made since the discovery by Penzias and Wilson. These measurements have shown excellent agreement with a thermal fireball history of the universe. Some balloon-borne radiometer measurements taken in the late 1970s did indicate a possible deviation from the type of blackbody spectrum predicted by the Big Bang. However, in 1986, researchers, again using balloons, reported "a spectrum of the cosmic microwave background that matches the expected Big Bang 20 billion years ago, 2.78±0.11 degrees Kelvin." The conclusion drawn was that "the Big Bang is alive and well."

While cosmologists no longer claim that all elements were created in the Big Bang, modern-day Big Bang calculations regarding the relative abundances of helium-4, deuterium, and lithium-7 are impressive. The close agreement between observed abundances of these light elements and their abundances as calculated following the Big Bang model has been called one of the strongest arguments supporting the Big Bang.

Problems and their Solutions

Redshifts—Although redshift data have provided considerable support for the Big Bang theory, the compilation of such data, first for galaxies and later for quasars (discovered in the early 1960s), also mounted one of the earliest substantial challenges. Halton Arp, a noted observer at the Mount Wilson and Palomar Observatories in southern California, was the first to raise a discordant voice on the interpretation of the distance of a cosmological object based on its redshift. The problem arises because our view of the universe is distorted in a way somewhat

* Blackbody radiation is radiation with the same energy density in each wavelength range as the radiation emitted from a totally absorbing heated body. The radiation in any state of thermal equilibrium is blackbody radiation.

The Big Bang has influenced contemporary perspectives—for example, in popular comic strips.

similar to the way distortions are introduced by projecting three-dimensionally distributed objects onto the surface of a sphere. This factor compounds the difficulties of differentiating distances of objects at cosmological distances. Only in the solar system do we know distances precisely. The distances of the closest stars can already have an uncertainty amounting to nearly 50 percent, and the uncertainty is compounded for farther objects. Since redshift is astronomers' only "yardstick" in deep space, they are understandably loath to abandon it.

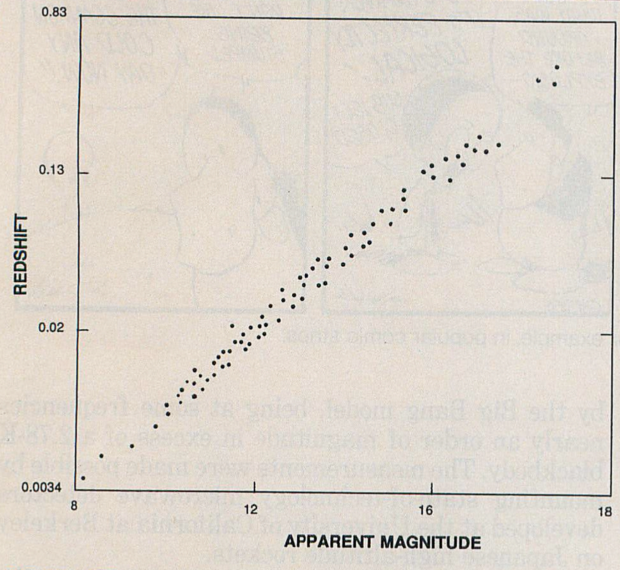
Arp found many groups of apparently interrelated galaxies that had discordant redshifts. This finding, if proven, would be a direct challenge to the Hubble expansion, since a Big Bang requires galaxies to recede. (However, a receding universe does not need to have started with a Big Bang; i.e., a singular point of origin in time and space.) Compelling evidence accumulated over the past two decades indicates that quasars' enormous redshifts do not arise from the expansion of the universe, but are rather intrinsic properties of the quasars themselves. This is possible because redshifts can be caused not only by receding objects (Doppler effect), but also by contraction of an object (pinch effect) and by wave-mixing phenomena. Still, most cosmologists do not find discordant redshifts a convincing enough reason to abandon the Big Bang hypothesis.

The Cosmic Microwave Background—Just over two years ago, Japanese and American scientists made an astounding discovery in the submillimeter spectrum of the cosmic microwave background. They recorded a microwave radiation spectrum that clearly falls outside the blackbody distribution predicted by the Big Bang model, being at some frequencies nearly an order of magnitude in excess of a 2.78-K blackbody. The measurements were made possible by mounting state-of-technology microwave detectors developed at the University of California at Berkeley on Japanese high-altitude rockets.

The most plausible way that the blackbody prediction of the Big Bang can be reconciled with this observation is to assume that at a time up to about one billion years after the Big Bang, an early generation of massive stars heated dust in the universe. This dust could then have produced the large amount of excess radiation in the observed spectrum. However, for these stars to produce so much excess energy by heating dust they would also have to produce nearly as much helium-4 as is currently observed. This raises the problem that if the amount of helium produced by these massive stars is added to the amount of helium predicted to have been produced by the Big Bang, the total helium would be nearly twice the amount actually observed. Thus, the Berkeley-Japanese collaboration has produced cosmic microwave background data implying that at least one prediction of the Big Bang is wrong—either the blackbody spectrum, or the light-element abundances.

Some Big Bang theorists believe that the new measurements are wrong, perhaps contaminated by the exhaust from the rocket. Of course it may be possible to modify the initial moments of the Big Bang in some way other than the production of massive stars. The news of the cosmic excess started a flurry among theoreticians who soon proposed numerous, although less likely, alternative explanations.

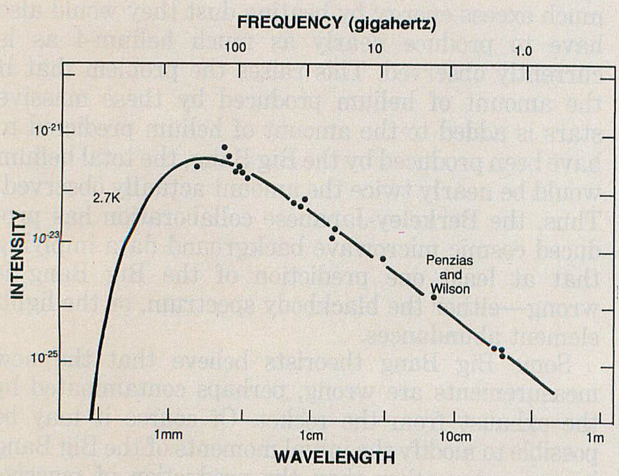
SUPPORTS FOR THE BIG BANG MODEL



REDSHIFT

Galaxies appear to be receding with velocities proportional to their distance from the Earth. Supports the expanding universe.

ADAPTED FROM A GRAPH BY A. SANDAGE

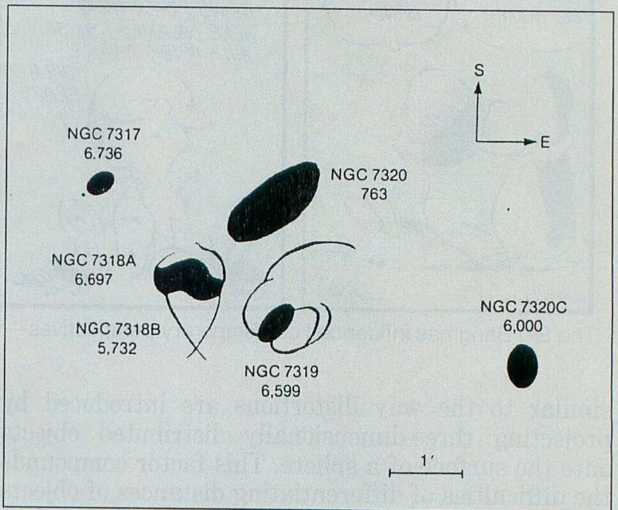


COSMIC MICROWAVE BACKGROUND

Supports the thermal fireball.

ART BY E. OZAKI/THE WORLD & I/COURTESY OF A. PERATT/LANL

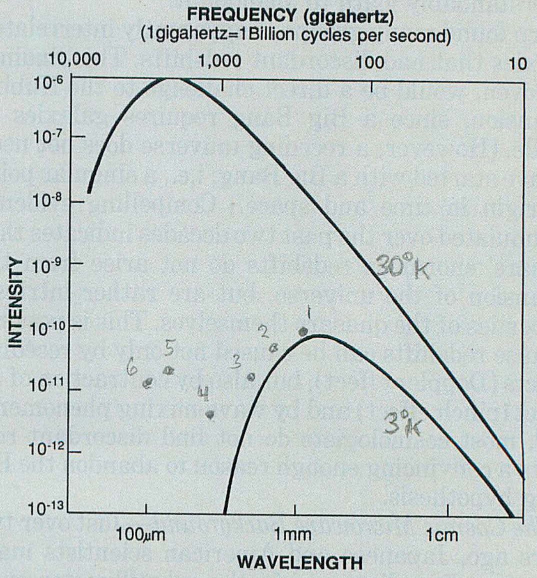
CHALLENGES TO THE BIG BANG MODEL



ANOMOLOUS REDSHIFT DATA

Challenges uniform correlation of redshift with distance. Calls the expanding universe into question.

COURTESY OF H. ARP AND SCIENCE AND TELESCOPE MAGAZINE



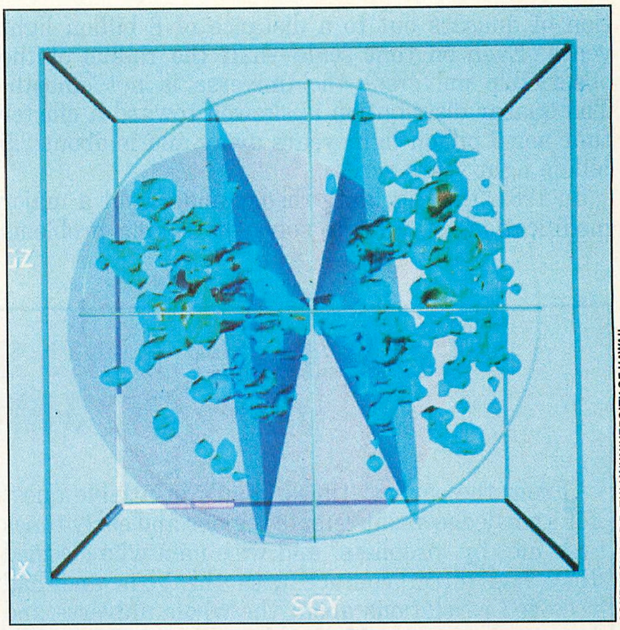
ANOMOLOUS MICROWAVE BACKGROUND

Challenges either abundances of the light elements or the cosmic microwave background calculation.

ART BY E. OZAKI/THE WORLD & I/COURTESY OF A. PERATT/LANL

Opposite top left: This Hubble diagram for clusters of galaxies plots average measured redshift versus apparent magnitude (brightness) as viewed through a telescope. By assuming that the cause of the redshift is recession of the source (Doppler effect) and that the magnitude of each cluster indicates its distance, the Big Bang theory replaces the *redshift* and *magnitude* axes with *recessional velocity* and *distance* axes, respectively. In this way, scientists infer that galaxies are receding away from us in a universe 10–20 billion years old. Only one well-documented example of a non-Doppler redshift is required to invalidate the recessional velocity/distance interpretation of the Big Bang model.
Opposite top right: Stephen's quintet of five galaxies provides one of hundreds of examples of anamolous redshift data. Assumed to be in close proximity based on standard astronomical techniques, the quintet of galaxies contains one, NGC 7320, whose redshift velocity (763 km/sec) is widely disparate from the others, which range from 5,732 km/sec to 6,736 km/sec. The disparity is impossible if the galaxies are as closely connected as they seem, and this fact casts some doubt as to the validity of the Doppler-shifted explanation of the redshift.
Opposite bottom left: The observed cosmic microwave background radiation (dots), fit to a 2.7 K blackbody curve (circa 1986).
Opposite bottom right: The cosmic background radiation measured in February 1987 by a Japanese-American experiment. Data points 1,2, and 3 show an appreciable excess of microwaves beyond the blackbody spectrum predicted by the Big Bang model. The excess in points 4, 5, and 6 is attributed to interstellar dust at a temperature of 20 K.
Above right: Complexes of galaxies populate a sphere two billion light years across in a map made on a supercomputer. The Pisces-Cetus Supercluster Complex is the horizontal structure. Three other supercluster complexes—Aquarius, Hercules-Corona Borealis, and Leo—appear respectively at the upper left, upper right, and lower left. The empty wedges represent regions that have been obscured by dust in the Milky Way.

Large Scale Structure—According to Big Bang theory, the universe must once have been incredibly smooth. Microwave radiation supports that notion: When radio astronomers sweep the sky with radio telescopes in search of microwaves, they find that the intensity of the radiation varies by no more than 0.003 percent no matter what direction the telescope is pointed.* In contrast to the smoothness of the background radiation is the uneven distribution of matter in the universe. Matter is clumped in stars, stars in galaxies, galaxies in clusters, and clusters in superclusters as much as 100 million light years long. Even though such clumps have long been troublesome for the Big Bang theory—it cannot yet fully



COURTESY OF R.B. TULLY/UNIVERSITY OF HAWAII

explain how they formed—they are not a fatal flaw. The theory requires only that the universe be smooth over distances of billions, rather than millions, of light years.

Now, however, it appears that even that assumption may be wrong. In the past few years astronomers have discovered "supercluster complexes" of galaxies that span a billion light years or more, stretching across a sizable fraction of the observable universe. A structure a billion light years long conflicts with all current versions of the Big Bang theory. If clumpiness of this extent exists in the universe, Einstein's equations do not support the concept of a Big Bang singularity. Moreover, the length of time for a billion-light-year-long superfilament to form has been estimated to be in excess of 100 billion years, that is, five times the age of the current Big Bang estimate for the age of the universe.

The existence of such structures was disputed by Big Bang theoreticians when first reported. Yet recently, by plotting the locations of nearby galaxy clusters, astronomer Brent Tully of the University of Hawaii has found that they are grouped in a "supercluster complex" about one billion light years long. Similarly, Peter Shaver of the European Southern Observatory in West Germany plotted the distribu-

* Our motion in the Milky Way galaxy can be measured with respect to the cosmic microwave background.

tion of quasars out to a distance of 8 billion light years. Even on that scale—half the radius of the observable universe—the universe is not smooth: The quasar distribution is skewed toward a cluster that lies 5 billion light years away and is about 2.5 billion light years across.

In 1981, the Big Bang theory underwent a major modification. In order to solve the vexing problems associated with its supernatural beginnings, an "inflationary expansion" period was hypothesized. While solving these problems, the new theory introduced many more. The latest calculations based on this model require that as much as 99 percent of the mass in the universe be in the form of "missing" or "dark" matter.

To date we have no idea as to what the "dark

SCIENCE AND SPECULATION IN COSMOLOGY

From the earliest times, man's insatiable quest for knowledge about remote regions and early times was met by "prophets" and wise men who claimed they had direct contact with the gods and had received revelations about the whole universe and how it came to be. Myths about the creation were incorporated as essential parts of religious traditions. Thus, primitive cosmology was developed in all ancient civilizations as part of their religion or folklore, even before there was any astronomy.

Naturally, early cosmological speculations were simple, seeing the cosmos in: the churning of the oceans by Vishnu; the marriage of the heavens to Chaos; the fishing exploits of a sea-god like Tiki; the slaughter by Marduk of Tiamat; the emergence of a Spirit on the face of the waters; or simply the fiat of an almighty God.

Almost by definition a cosmology must be able to explain the celestial surroundings, and with the emergence of astronomy, the explanations became increasingly sophisticated. Nevertheless, cosmology has always had a theological-cum-mythical appeal, since it represents a borderland between science and philosophy and between fact and speculation. Thus, cosmology has much in common with religion, in spite of the fact that cosmologists today like to think that their subject is science. The questions asked of cosmology and the answers derived often tell us more about ourselves and our times than of the universe.

Changes in cosmology occurred over the centuries and were usually accompanied by fierce conflicts between the advocates of opposing views. These changes followed new discoveries or new information, brought about by better instrumentation or observational technique, or the application of newly acquired insights or knowledge, perhaps from a discipline other than astronomy.

Ptolemy's earth-centered or geocentric cosmology (ca. A.D. 140) was a result of an illusion. As the earth rotates on its axis different stars are constantly brought into view while others drift below the horizon. This motion results in the illusion that the sky is doing the moving and the Earth is fixed. The illusion is so convincing that the geocentric cosmology was not seriously challenged until the sixteenth century. The Greek astronomer Aristarchos of Samos (ca. 280 B.C.) had proposed a heliocentric universe 2,000 years before Copernicus (1473–1543), but without a telescope he did not have the observational evidence to prove it.

The "Copernican revolution" was to a large extent due to the introduction of the telescope by Galileo Galelei (1564–1642). This new instrument made it possible to observe, for example, that Jupiter was surrounded by a Copernican system in miniature, but found no trace of the "crystal spheres" of the geocentric system. At the same time, the Danish astronomer Tycho Brahe (1546–1601) made observations of unprecedented accuracy that allowed the German mathematician Johannes Kepler (1571–1630) to discover laws from which led a straight road to the mechanics of Isaac Newton (1643–1727).

—*A.L.P.*

matter" consists of, but to save the Big Bang's estimate of the abundance of light elements, cosmologists assert that dark matter cannot be in the form of ordinary matter such as electrons and neutrons.

To handle the problem of supercluster complexes, some theorists have turned to yet a newer modification of the Big Bang that hypothesizes the existence of "cosmic strings." Cosmic strings, if they exist, have the correct geometry to account for filamental superclusters, although they probably cannot account for the length involved. Cosmic strings are supposed to have "crystallized" space itself into string-like cosmic defects in the early moments of the Big Bang. Particle theorists hypothesize that cosmic strings are extremely thin, 10^{-22} the radius of a hydrogen atom, but weigh 10^{15} tons per centimeter and travel at the speed of light. At present, all admit that this theory is in the working hypothesis stage, and its advocates are the first to admit that the mathematical theory is far from the simple theory sought by cosmologists a generation earlier. To make matters worse, some scientists are now suggesting that the inflationary cosmologies are the epitome of an unverifiable cosmology—they require the Big Bang to be only one expanding bubble in a "steady state" of other bubbles.

At this point it appears that twentieth-century cosmology has come full cycle: Less than a decade after the conceptual birth of inflation, it is again fashionable for astrophysicists to believe that the mass of the universe is really only a tenth of that required in an inflationary scenario. Are there any alternatives left?

An Alternative: The Plasma Universe

When a scientific theory no longer has a predictive capability it is usually abandoned unless its author can "fix" it. If the theory forms the basis for a number of subsequent theories or observations, the vested interest can be quite considerable and "fixes" must be attempted by many in the field. However, the credibility of a theory suffers as the number of ad hoc assumptions or "fixes" required increases.

Like most scientists, cosmologists are loath to abandon a successful theory, even a flawed one, when there is no plausible alternative. In fact, there is an alternative cosmological theory, one whose foundings even predate the Friedman Big Bang model by about two decades. That alternative is the Plasma Universe. The Plasma Universe is an entirely different view of the nature and evolution of the universe.

Until 1900, all cosmologies shared a common legacy; they were based on sightings in the visible region of the electromagnetic spectrum. As man's celestial observation capabilities improved over the centuries, ever more of the heavens had become known. This included (in Pythagorean order) the Sun, Moon, Venus, Mercury, Mars, Saturn, Jupiter, the stars, meteorites, and occasional comets; and later the discovery of the remaining outer planets; their satellites; and eventually star clusters, nebula, and galaxies. All this could be seen using the naked eye or a variety of ever more sophisticated optical telescopes.

In contrast, the Plasma Universe model is a cosmology based on data carried by the entire electromagnetic spectrum. The model's roots are found in the pioneering work of Kristian Birkeland (1867–1917), a Norwegian physicist and mathematician who based his theory on laboratory experiments and a worldwide network of magnetometers to measure deviations in the Earth's magnetic field during auroras. From his measurements Birkeland imagined that interstellar and intergalactic space was filled with matter in its fourth state, which he called "corpuscular matter" and we today call plasma. Birkeland hypothesized that immense electrical currents flowed through the corpuscular matter along magnetic lines of force.

Starting from the observed fact that the universe, stars and all, is 99.999 percent plasma [see "Space Plasmas," March 1988, p. 166], the Plasma Universe is sculpted much more by electrical currents and electromagnetic forces than by gravitation. General relativity with its gravitational linkages is important in the Plasma Universe, but only in the mature stars and galaxies, not in a moment of "birth" as in the Big Bang.

In part 2 we examine the predictions of a Plasma Universe and the recent observational evidence in support of it, derived from measurements across the full electromagnetic spectrum rather than from the narrow visual octave or from a decade of radio frequencies.■

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