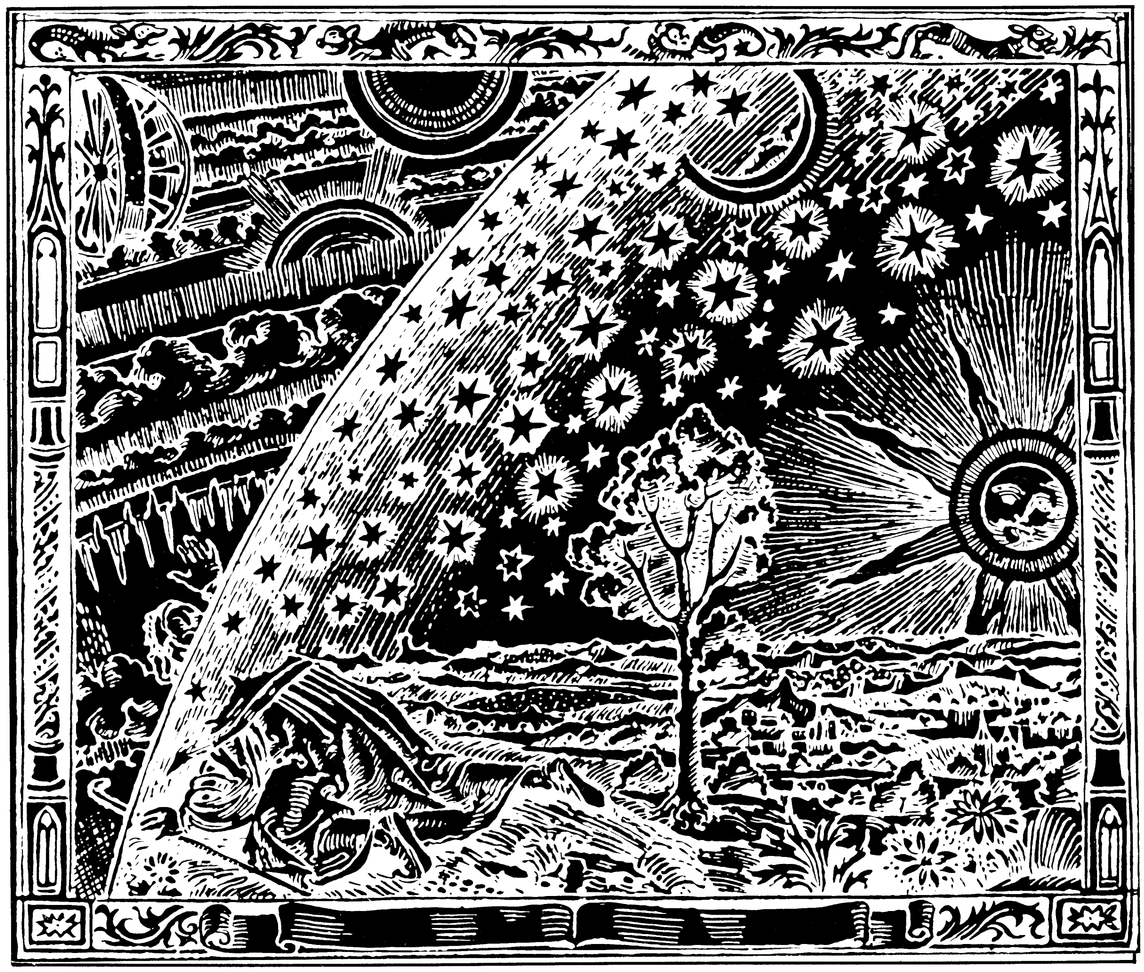

Cosmology Against the Grain

They may or may not be straws in the wind, but a number of alternates are offered to the standard big bang theory

BY DIETRICK E. THOMSEN

The music of the spheres is an ancient metaphor for the motions of celestial bodies, or at least for those near the earth. A sound wave is a cyclic phenomenon, and a musical composition is both balanced among its sounds and tends to return on itself for repeats and *da capo* reprises. The ancients detected cycles and cycles within cycles in the cosmos, and in the contemplation of these matters science, philosophy, religion and astrology influenced one another. The universe stood, endlessly returning upon its cycles, and beneath it the wheel of history turned on and on. As above, so below.

It was a long-running symphony, and it was hardly disturbed when Copernicus removed the earth from the center. Indeed, centuries later, after Einstein had completely altered the meaning of space and time, he nevertheless strove mightily to preserve the static picture of the universe by inserting a term, the cosmological constant, into his equations, that was designed to counteract the collapse of the universe that it seemed would otherwise occur according to his equations. The cosmological constant offended Einstein's sense of mathematical esthetics, and it was not readily explicable in terms of physical effects, but so unwilling was Einstein to hear of a universe that was not the same yesterday, today and tomorrow unto ages of ages, that he mangled his own equations.

In a few years he was told about it. Edwin Hubble's observations of distant galaxies showed that they all had redshifts in their light. Interpreting the redshifts conventionally as Doppler shifts, meant that all the galaxies were receding from us. So the universe was expanding; there was no other explanation under the Doppler shift assumption.

Einstein could and did throw away the cosmological constant. Solutions for his equations that apply to an expanding universe don't need it. Never mind what caused the expansion; it's there. It took 20 years and many developments in nuclear physics to produce the big bang theory published by Ralph Alpher, Hans Bethe and George Gamow, which attributed the expansion to a giant primordial explosion. Seventeen years after that, in 1965, came the discovery of the cosmic three-degree background radiation. The theory had predicted such a relic of the explosion.

Coincidence of prediction and observation made the big bang seem the most plausible of cosmological theories. From plausible it became predominant and then virtually an orthodoxy, so much of an orthodoxy that recently the "Nova" television series could devote a program on cosmology almost entirely to it. But now its decade of total dominance may be starting to close. Suddenly it seems new cosmological theories and new twists on old ones are coming up all over the place. All the ideas that the big bang seemed to have put to rest are back.

One could say that it is hundred flowers time in cosmology. Many of the pre-Hubblean ideas are back. The static universe seems to be growing in popularity; it is a feature of several new formulations. On the other hand, lest schools of thought stop contending, there is now a serious proposal for an expanding universe that is accelerating. (The standard expanding universe is believed to be *decelerating*, because the gravitational attraction of the galaxies for each other should pull them back together.) An accelerating universe requires resurrecting the cosmological constant as something, physical nature unspecified, to cause the acceleration. To go to yet another extreme corner, there are those who would reverse Hubble's verdict entirely by reinterpreting the redshifts so as to do away with the expansion. And last, but hardly least for a conceptual shocker, there is even one cosmologist who wants to go back to the rather pre-Copernican notion that we are in the center of it all.

Of course some of these ideas have been with us for a long time. Cosmologists who were unhappy with the expanding universe and its big bang theory because it does not answer important questions in philosophy and theoretical physics were never silent, but they tended to be rather lonely and gave the appearance of arguing against or around the evidence. Now the evidence has changed a little (see accompanying article p. 141). The Hubblean — big bang view of a smooth isotropic universe without privileged points or privileged frames of reference seems a good deal less evident than it used to.

Putting us back in the center

Yet so strong is the reflex feeling against privileged locations in space and time — not only is the traditional Hubblean evidence against them, but Einsteinian relativity works much better without them — that when G. F. R. Ellis of the University of Cape Town proposed such a thing in a recent essay in GENERAL RELATIVITY AND GRAVITATION (Vol. 9, p. 87), another prominent cosmologist, P. C. W. Davies of Kings College, London, called it "Cosmic Heresy?" in a review in the June 1 NATURE.

Davies wonders (facetiously?) whether Ellis might be threatened with burning at the stake: "He goes the whole way and abandons the entire conceptual and philosophical foundation of modern cosmology." After that sweeping remark, it is perhaps not unfair to say that Ellis turns traditional cosmology inside out or, rather, back upon itself. He proposes a universe organized around two centers, or rather a center and an anticenter — in Davies's words "a higher dimensional version of the antipodes"; cosmology stood on its head.

Ellis describes his model as a static, spherically symmetric universe. The two centers come about because of the way he reinterprets Hubble's redshifts. Ever since Einstein propounded general relativity there has been an alternate to the Doppler shift as an explanation for redshifts — gravity. The existence of a gravitational redshift is predicted by the theory of gravity contained in Einstein's general relativity and so was available at the time of Hubble's discovery, but it has always been rejected because of the asymmetry of the redshift.

According to Einstein's theory, light climbing away from a massive object will lose energy and have its color shifted toward the red; light falling onto a mass gets blueshifted. In a universe with a homogeneous distribution of galaxies, all standing still, we should see blueshifts as well as redshifts. We do not. The lack of blueshifts would mean that the earth was at the center of a universe with galaxies inhomogeneously distributed. Most cosmologists are unwilling to contemplate an inhomogeneous universe, because statistics overwhelmingly favor a random distribution of everything, that is, homogeneity.

Such a thing is what Ellis proposes. Using the curvable space-time of general relativity, he arranges for the universe to be structured so that the earth is at a center where only redshifts will be seen. Space curves around to the other center. At this location is the singularity, the point where space ends and time stops, the point that big bang cosmologists have equated with the act of creation. In the big bang theory the singularity is primarily a boundary in time, the point of beginning behind which few inquire. (Fred Hoyle did; see SN: 6/14/75, p. 386). In Ellis's theory the singularity is primarily a boundary in space. It is always there, and it serves the function of a cosmic rejuvenator: Old matter from burnt-out galaxies falls into the singularity. Fresh new hydrogen is spewed out by the singularity to start the process of galactic and stellar evolution again. The famous three-degree microwave background comes from hot gas near the singularity.

Thus, in Ellis's universe nearly everything that the big bang theory sees as a once-and-for-all happening is continually present. Processes that the big bang tends to see as linear, such as the history of galaxies, are recurrent and cyclic. This gets around the big philosophical uneasiness with a big bang theory: Where did it come from? Where is it going? And, maybe, why? Ellis's universe isn't coming, and it isn't going, but there's still an important why.

Why should we be in the center, or rather at a center of the universe? Those who answer positively tend to assume that there is an intelligence controlling the universe that overrules mere chance and that favors humanity. (Though nobody seems to spell out why being in the center is a favor.) This inherently religious assumption seems beyond the bounds of science. Yet one need not be all that religious. The belief that we are at the center "is certainly unreasonable," Ellis writes, "if the implication is taken to be that the universe has been centered on our presence; however, there is no need for this implication. Rather one should ask: ... where would one be likely to find life like that we know on earth? The answer must be, where conditions are favorable...near the center *C* where the universe is cool."

Inspired by the big numbers

Why certain things are what they are and not something else equally chancy animates another cosmological school, that which now bears the name of P. A. M. Dirac. Dirac began the formulation of this cosmology about 40 years ago. He let it lie for a long time, possible because conditions in theoretical physics were not opportune for its development. In recent years he has taken it up again (SN: 11/16/74, p. 317). It is a cosmology that is more radical, in the original sense of the word, than many in that it attempts to link together a wide-ranging variety of things in physics, and it is inspiring some theorists to push the connective links even farther than Dirac originally did.

Dirac's cosmological hypothesis has its roots in two strains of thought that have been prominent in the physics of the twentieth century — many physicists would have said prominent will-o'-the-wisps — the large number hypothesis and unified field theory. The large number hypothesis concerns the many constant numbers in physics, such as the universal gravitational constant, the electric charge of an electron, and so on, and so on. These numbers are usually determined empirically; there is nothing in the mathematics that specifies them. In a random universe produced by chance, those constants could have any value. In the universe that is, they have the values they do, and they make physics what it is. A lot of physicists have thought that a comprehensive theory of the science should contain an explanation of them.

Much has been written about how the large number hypothesis does this. Suffice it to say here that equations can be set up that relate the fundamental constants to the age of the universe, provided one allows the universal gravitational constant (which Newton and almost everybody since took to be a constant) to decrease slowly with age. This decreasing gravity is the foundation principle of Dirac's cosmology. V. Canuto of the Institute for Space Studies at the Goddard Space Flight Center in New York stressed its implications in a paper given at the 1975 assembly of the Norwegian Physical Society in Bergen: "The gravitational constant will continue to decrease forever and the physical conditions of the Universe will depart more and more from what they were at the moment when everything started. Dirac's hypothesis clearly contains the most far-reaching and deepest concept of evolution."

It seemed at first that a little too much evolved. Dirac's universe needed to be able to change its standard of length from place to place or time to time. This means that the distance between two bodies as measured in kilometers, say, may change (as the universe ages — this is really the point) although the bodies have not moved. A universe with elastic measuring rods sounds weird, but such an idea had already come up in unified field theory.

Einstein's general relativity depicts the force of gravity as an effect of the curvature of space. This geometrization of physics has a strong appeal to the minds of physicists and it comes down through the decades with especial force to modern theorists of particle physics. At the time, it provoked efforts to do for the other kind of force then known to physicists, electromagnetism, what had been done for gravity.

Hermann Weyl suggested the idea of changeable measuring rods. The appearance of electromagnetic effects would be a result of the changes in measuring standards as gravitational effects resulted from changes in space curvature. The idea fell through as studies of atomic physics showed that there are in fact immutable standards of length in nature: Atoms in a given energy state emit light of particular wavelengths. The wavelength for a given state is the same everywhere and at all times. This makes a convenient standard of length — it is now the international standard in fact — and once a single immutable standard exists to appeal to, the idea of mutable standards seems doomed, and so the idea was dropped.

A few years ago Dirac picked it up again with a significant modification: The fixed standard of length characterized by the light emission of atoms applies to units and processes proper to the atomic level of physics. On the macroscopic level other things can happen. Dirac proposes two standards of measurement: atomic units with a fixed standard length and what he calls "Einsteinian" units, which are mutable. How you see something depends on the units you use. If you measure galactic redshifts with the atomic units appropriate to emission and absorption of light, you see the effect that Hubble postulated. The galaxies are getting a larger number of fixed-size units away. In Einsteinian units, however, which are appropriate to a theory of gravity, let us say, there is no change in the number of units and therefore no expansion. The universe is thus formally static since there is no expansion in the number of Einsteinian units in its radius.

If that sounds surreal, it is just a matter of degree. All cosmology is surreal; some cosmologies are more surreal than others. The modern Dirac cosmology adds yet another mind exploder. The disjunction between the two kinds of measuring standards means that mass is not a constant quantity, and the universe needs to have new matter continually added. Continuous creation shocks a lot of scientists. Creation that took place once and for all long ago is hard enough to handle. This is matter popping up anywhere at any time. An atom may appear suddenly in the middle of a rock and dislocate the structure of a crystal. Such things are in fact being looked for as tests of the theory.

In spite of its difficulties the Dirac cosmology has an appeal based on its scope and the large number of things it tries to explain all at once. It has the potential of becoming a general theory of just about everything. In Dirac's hands it was not specifically a unified field theory, but Canuto and his colleagues P. J. Adams, S.-H. Hsieh and E. Tsiang seem to be moving it that way. They are working on a theory of gravitation compatible with the geometric assumptions of Dirac cosmology and with the geometrical qualities of the modern theories of particle physics. These theories also link physical phenomena to the geometric qualities of space, and they descend from Weyl's work by a slightly different geneology. They are strongly cosmological themselves, and ultimately a linkage will have to be made, though not necessarily with Dirac's cosmology.


Hale Observatories

Can you argue with a telescope? Edwin Hubble's discoveries put a lot of ancient cosmological ideas to rest. Or did they?

Things seem to going faster and faster

Static universes and expanding universes (and collapsing universes) are not the only kinds there are. There can also be accelerating ones. Nowadays everything seems to be coming apart much faster than it used to. Why not the universe too? The current evidence—the redshifts again — seems to be convincing a few cosmologists that we do indeed live in a universe in which the expansion is accelerating.

The usual expanding universe picture of recent years (whether specifically the big bang theory or not) has the expansion gradually slowing down. We are all aware of the force of gravity. It should act as a brake on the motion of the galaxies. Eventually the expansion may come to a stop and gravity may start to pull things back together, or the brake may not be strong enough to do that. Investigating this question led James E. Gunn of the Hale Observatories and Beatrice Tinsley of Yale University to the conclusion that the universe is in fact accelerating. They first proposed this a couple of years ago, and now Tinsley comes back to it in the May 18 NATURE, citing new evidence on the structure of distant radio sources.

Einstein's equations are so protean that they also allow the derivations of solutions for accelerating universes. A group of them was studied in the 1920s by the Belgian priest-physicist Charles Lemaitre. Lemaitre's models were ignored for decades because there was no evidence for them, but Gunn and Tinsley resurrected them and Tinsley again refers us to them. These models require breathing new life into Einstein's cosmological constant, and that causes the same problem it always did.

In an accelerating universe the cosmological constant represents the cause of the acceleration. In physics an acceleration means a force. But the only known force that acts between galaxies, gravity, is always attractive and therefore represents a deceleration of the expansion. Acceleration requires a repulsive force between galaxies.

It has been suggested that there is some such force. It would act only over intergalactic distances and not appear at shorter distances, so that we on earth would have no knowledge of it. The idea makes a lot of physicists choke. Yet there is a precedent. There are forces that act only over subatomic distances. Their range is limited, and they simply are not felt over longer distances. Their existence was unknown before the advent of nuclear physics. Physicists did not go into the nucleus of the atom expecting to discover a new force, but they did. □

It is nothing to you, all ye that pass by?

The line at the top of this column is from the prophet Jeremiah. It frequently becomes the title of Good Friday sermons, probably because it finds a place in one of the Holy Week liturgies (Maundy Thursday Tenebrae, if I remember correctly), and people will have it in their minds. In the context Jeremiah is bemoaning the destruction of Jerusalem which he, the old kvetch, attributes largely to the heedlessness of the city's inhabitants. So it's probably a good sermon text.

Jeremiah comes to mind because it is now 50 years since Edwin Hubble told a waiting world that the universe was expanding. It is not merely that Hubble's news could mean that the world will end someday in a frozen desolation that would warm the heart of Jeremiah (imagine Hans Christian Andersen's little match girl expiring in a bank of methane snow), but that the world did not want to acknowledge that a revolution in cosmology would not leave other things alone. The expanding universe got a lot of gee-whiz publicity. Its scientific implications as the overthrow of thousands of years of cosmological assumptions have been spelled out. And then what?

It is maybe just playing intellectual games, but it seems the world has become terribly dynamic lately. The ancient ideal that contemplative stasis is a good thing seems to have gotten lost somewhere. Everybody has always to be going somewhere. If nothing is happening, make it happen. If something doesn't concern you (in Zaire or Vietnam), get into it. Respected people are actually going around saying the president of the United States needs a crisis. The way an infant needs incisors?

While Hubble was using the newest telescopes in the first systematic study of distant galaxies, two other serious alterations in physical thought were working themselves out, quantum mechanics and general relativity. The next person at a cocktail party who tells me that everything is relative to going to get a libation of amaretto and cream. (Actually, since I never drink cocktails, it will more likely be Calistoga water.) Some things are relative, and some things are not, and Einstein didn't say anything was relative in the sense that cocktail party people usually mean.

What Einstein did was to introduce a certain elasticity into our attitudes toward space and time, and one place where that feeling pops up brilliantly and contemporaneously is the movies. It may be that film as medium suggested the twisting, stretching and compressing of space and time that are characteristic cinema techniques, but the temporal parallel to Einstein's life and the beginnings of work in general relativity is suggestive.

Quantum mechanics seems to have influenced quite a number of literati. The problem is that today we read Kafka as a collection of horror stories, not as parables of our lives. Of course the *opus classicum* for the uncertainty principle is *Waiting for Godot.* Beckett may not have set out deliberately (artists seldom act with malice aforethought) to illustrate the notion that under the uncertainty principle an expected event may never happen, but he did a good job. The contemporary Spanish government understood the point so well that it banned the play.

There at last is my point: Physical science has multiple connections to the thinking and artistic creation going on in the world. It does not exist in some watertight compartment of its own. Yet a lot of people tend to act as if it did. When John A. T. Robinson wrote *Honest to God,* he included an attack on what he called the threedecker universe. It had been 300 years since the threedecker universe left cosmology (and 100 since the last actual threedecker sailed), but Bishop Robinson replied to critics that his pastoral experience had taught him that people still thought that way.

So where is that whole class of intellectuals who are supposed to take note of intellectual trends and tell us about them: philosophers, analysts, critics, theologians, people writing Ph.D. dissertations about the costumes in Busby Berkeley musicals? The titles suggest themselves: Einstein's Ideas and the Work of Harold Lloyd, The Expanding Universe and How to Lose Weight Without Really Trying, The Uncertainty Principle and the Theater of the Absurd, The Dada Movement and..., Complementarity and Hypostatic Union. Anent Bishop Robinson's problem, I wish someone would do for Christian dogma and modern physics what Bishop Gore did 60 years ago for Christian dogma and 19th century biology. Instead we are likely to get The Mellow Christian. It'll be a best seller if it has a sexy-enough dust cover. The problem with keeping ideas in watertight compartments is that it's dangerous. The *R. M. S. Titanic* had watertight compartments.

—Dietrick E. Thomsen