of the basic plan (1968–70) is much greater. Columbia, Maryland, and Reston, Virginia, already provide a bank of experience in the early phases of planned community development, but they are just beginning to face the growth pains Tapiola has endured. What is the role of public policy in dealing with conflicting pressures within a new town for expansion versus "zero" growth? What problems arise when a "completed" new town matures?

Where the author draws conclusions or offers judgments, the lack of sufficient analysis may fault them. For example, she acclaims the quality of French agriculture but does not evaluate its efficiency. Because France's agricultural system is one of the least efficient in Europe, Common Market resource planners now must analyze the trade-offs between French quality and efficiency; but Strong's judgment appears to be one-sided.

One speculates on the reasons for these deficiencies. In part they may arise from the original criteria for selecting countries to study—"variety, novelty, and achievement." The most important one, perhaps, is missing—*relevance*. The book lacks specific relevance to the U.S. scene. The reader is forced to draw it out for himself by asking "So what?" at the end of each chapter, hoping the linkages will occur to him. Another reason may be the lack of focus in the author's concept of "environmental planning." It seems to touch on planning for natural resources, housing, land use, transportation, and social services, but the reader is not given a systematic framework to interrelate these.

The book will probably be widely used as a basic text and a handy reference, and perhaps it will even influence those in today's classrooms who will formulate urban policy 20 years hence. But for today's policy makers and analysts grappling with problems of national urban growth, welfare, housing, and transportation, it is of marginal value. This is unfortunate, because many key policy makers are desperately searching for sound analysis and advice that can be of use now. If planners like Strong, with their knowledge of both old problems and new ideas, do not provide such specific guidance and analytic support, an unusual opportunity to exert a significant beneficial effect will be lost.

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The Universe: Some Facts to Go On

Physical Cosmology. P. J. E. PEEBLES. Princeton University Press, Princeton, N.J., 1971. xvi, 282 pp., illus. Paper, $9. Princeton Series in Physics.

Modern Cosmology. D. W. SCIAMA. Cambridge University Press, New York, 1971. viii, 212 pp., illus. $8.95.

Although great scientists from Newton to Einstein have dabbled in cosmology, it has until recently had a bad name among physicists. The observations were too sparse, the ratio of speculation to fact too great, for cosmology to be called a hard science. These two books try to convince us that a corner has been turned. Recent observational discoveries have yielded solid cosmological information, strongly constraining models.

This change of outlook is largely the result of radio astronomy. When men like Ryle emerged from radar laboratories after the war, they were looking for new fields to conquer. Turning their antennas toward the sky, they found radio waves from the sun, and soon thereafter they found them coming from distant astronomical objects. The second most powerful radio source after the sun proved to be not a nearby star or planet but a galaxy one-fourth as distant as the most distant galaxy observed optically up to that time. Following up Reber's prewar discovery of radio waves from the Milky Way, radio astronomers found a variety of sources both within and beyond the galaxy, all apparently radiating by the same mechanism—synchrotron radiation by relativistic electrons. Overnight, the new capability to observe relativistic particles at vast distances enlarged and challenged the old astronomy, which was based upon thermal radiation from stars and nebulae. The relativistic particles are accelerated in sources which comprise a world unknown to classical astronomers—a world of relativistic explosions, of radio galaxies and quasars, of pulsars and neutron stars.

Hubble's confirmation of Slipher's discovery of the red shifts of galaxies, and his own discovery in 1929 that red shifts are proportional to distance, had earlier shown that we live in a dynamic universe, for which the relativistic gravitational theory of Einstein yields a number of models. But prewar progress on the structure of the cosmos was stymied by the faintness of distant optical galaxies. It proved impossible for equipment then available to push out beyond a red shift $z = \Delta\lambda/\lambda$ (which for small z equals v/c) greater than 20 percent. As v is expected to approach c at the limits of the observable universe according to the relativistic models of Friedmann, such red shifts yield too small a sample of the universe to give us a handle on the global properties of the cosmos.

There things stood until the radio astronomers discovered quasars (QSO's) and their red shifts were determined optically. The largest quasar red shift discovered to date is 2.88 ($v = 0.87c$), and the end is not in sight. The extremely large red shifts of quasars stimulated the hope that they could be used as probes in choosing the correct model of the universe. They are so distant that radiation left them when the expanding universe was much younger and smaller. One should therefore be able to sample conditions at early times, and hence nail down the dynamics. Alas, this hope has been dashed by the fact that quasars have a huge range of luminosities, so that it is not yet possible to obtain an independent determination of their distance from their apparent brightness, as required in order to plot the expansion curve of the universe.

Again the radio astronomers came to the rescue, this time by finding the cosmic microwave background radiation. Discovered by chance in 1965 by Penzias and Wilson, this diffuse background has a spectrum at short radio wavelengths like that of a perfect thermal emitter at 2.7°K and is isotropic about the earth within 0.1 percent. It turned out that this effect had been predicted much earlier by Gamow on the basis of the radiation emitted by the primeval fireball in a hot big-bang universe. (Gamow's collaborators Alpher and Herman predicted $T \sim 5$°K in 1948.) This discovery more than any other has stimulated interest in cosmology in recent years. If our interpretation is correct, the cosmic blackbody radiation was last absorbed and reemitted by matter at a red shift $z = 1000$, where $v/c =$ unity to six significant figures. According to Friedmann relativistic models, this matter is the surface of a giant fireball, which emerged from an infinitely dense state at a definite time in the past. Can it be that Friedmann was correct in placing the origin of the cosmic expansion in a singular state at $t = 0$? Can it be that everything that has happened subsequently, from the nucleosynthesis of helium at $t \sim 100$ sec, to the decoupling of matter and radiation at $t \sim 10^5$ years, to the formation of galaxies at $t = 10^8$ years, is a predictable consequence of the relativistic expansion of a constantly curved space-time which obeys Einstein's equations? In short, do we live in a big-bang universe?

It is questions like these which the two books under review are all about. Twenty or thirty years ago, the standard works on cosmology, those of Tolman, Eddington, McVittie, and others, had very few facts to go on. There were Olber's paradox, the Hubble relation, the counts of galaxies (which indicated uniformity on the larger scale), and the various astronomical time scales with which to compare the cosmic expansion time scale; these data comprised the observational basis for cosmology.

Now the theorist must account for a precise Hubble relation extended to $z = 0.46$, for the existence of quasars of very large red shift, for the microwave background radiation, for a diffuse and probably cosmological flux of x-rays, and for nucleosynthesis in the big bang itself and in exploding stars. He must account for the explosions which power the quasars and for the ubiquity of relativistic particles in the universe. Observational material of this sort, much of it derived from radio astronomy and other extensions into new regions of the spectrum not hitherto observable (including x-rays, gamma rays, and infrared), has made cosmology a much more empirical subject. Not a hard science yet, perhaps, but definitely struggling to become one.

Peebles's *Physical Cosmology*, based on notes for a graduate course he has given at Princeton, is a distinctive and very useful way of approaching the field. Peebles has always been a proponent of the big bang, and he is skillful in explaining it in a novel way. The classical texts start with relativity, derive the line element for homogeneous spaces, and elucidate models based on solutions to Einstein's equations for this line element. Peebles doesn't get to this kind of discussion until two-thirds of the way through the book, and even then spends little time on it. He spends much more time meticulously discussing the observational data, giving detailed references, and laying the empirical foundation for the subject. Particularly useful is a complete study of the mass density of the universe, including data on galaxies and intergalactic matter. Here, as throughout the book, Peebles exhibits a refreshing candor about the uncertainties of his subject:

> Apart from the stability problem [of clusters of galaxies] the main task clearly is to devise tests that might reveal each form of matter that contributes an interesting fraction of the total, so that we may in time arrive at a picture of the contents of the universe. It would be naive to suppose that the mean mass density of the universe may be estimated from the one component we can study in some detail, the galaxies, even if we could make sense of these objects, but on the other hand, it would be equally unreasonable to conclude that we cannot hope to determine the density. . . . We are still engaged in the simple task of accumulating the elementary observational picture of what the universe is like [p. 116].

The foregoing passage might tend to suggest that Peebles avoids detailed application of physics to the problems encountered in cosmology. On the contrary, there is a detailed discussion, with much of the necessary mathematics, of physical processes in the big-bang fireball, including nucleosynthesis, coupling of matter and radiation, the damping of turbulence, and the initial growth of perturbations slated to become galaxies. In fact, it is one of the best treatments of such topics available in book form. One could only wish that Peebles had included more on the theoretical problem of galaxy formation, one of his own research specialties. He promises another monograph on that subject in the future, however.

One can't help wondering whether Sciama doesn't mean Big-Bang Cosmology by his title. Much of his previous work, at Cambridge University, had been concentrated on the implications of the steady-state model, first proposed by his colleagues Bondi, Gold, and Hoyle. Yet in this book he has essentially discounted the steady-state model. We find him saying,

> The steady-state model is attractive in many ways, although the physical origin of the tension [meaning the negative pressure which occurs formally in the steady-state equations] has never been satisfactorily explained. However, the recent evidence from the radio source counts (Chapter 6), the red shifts of the QSO's (Chapter 7), and the cosmic microwave radiation (Chapter 14) all tell heavily against it, and we shall consider it no further [p. 117].

So much for the model over which Sciama had lovingly labored. As does Peebles, Sciama has a refreshing ability to face facts.

Sciama's book is much less technical than Peebles's; I found it eminently readable at one sitting. Those who enjoyed Sciama's previous books, particularly *The Unity of the Universe* (1959), will not be disappointed with this one either, for Sciama shares with many of his British contemporaries an ability to write about science in a lively and interesting way.

Sciama assumes a less sophisticated audience than does Peebles, and therefore gives more background in the first few chapters. If anything, he stays even closer to contemporary observations, relating historical incidents and frequently illustrating his points with graphs and pictures of all kinds of phenomena. Like Peebles, he emphasizes discussion of intergalactic matter and the cosmic background radiation. Although there are many references to persons, particularly in the later chapters where recent work is under discussion, there are regrettably few detailed references to the literature.

Neither of these books is a formal comprehensive treatise on cosmology aspiring, let us say, to the role of Tolman's or McVittie's. Nor would it be helpful to write such a work at this time: The whole field is changing so rapidly under the impact of fresh observations that the book would be out of date before the ink was dry. Sciama's book reminds one of the book *Cosmology* by Herman Bondi (Cambridge University Press, 1960), which many of us have used as a basic introduction to the field. Like it, it seems to be suitable as a text in an undergraduate course on cosmology for physical scientists. I for one immediately adopted it for such a course I am teaching this spring. It is really thoroughly delightful reading and will be also enjoyed with great profit by any scientist wishing to catch up in this field.

Peebles's book is definitely more of a monograph, with considerable detail on the specialized topics into which he chooses to go. Although it is not a comprehensive treatise, it is very suitable as one of the main references for a graduate course on cosmology. Indeed, the publisher suggests that it can be used "as a guide to current points of debate in a rapidly changing field." I agree with that.

We are fortunate that two active cosmologists of the stature of Peebles and Sciama have put their thoughts down at this time. The books they have created are, each in its own way, very useful. Fortunately for everyone concerned, they complement each other nicely.

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Experiments Touching on Relativity

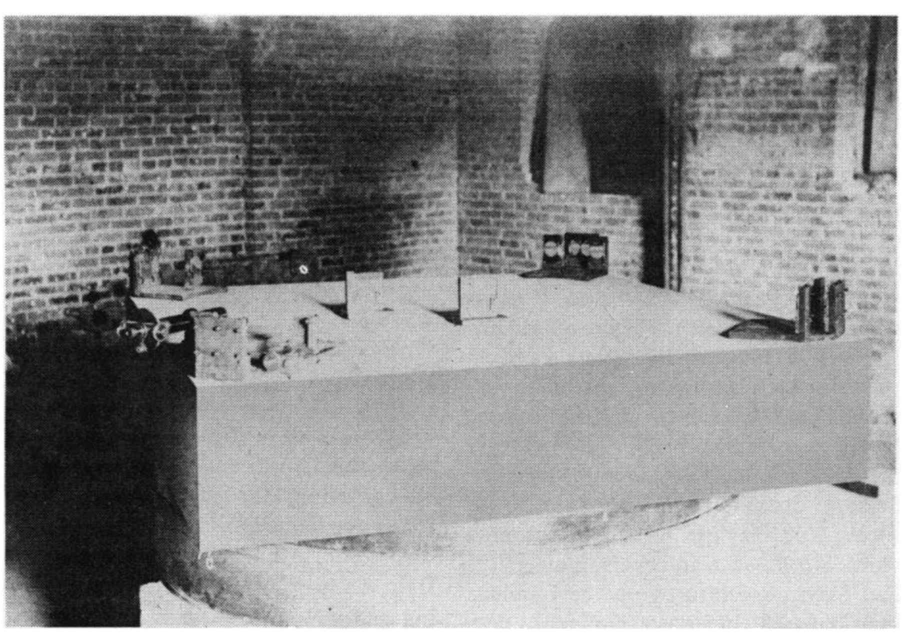
The Ethereal Aether. A History of the Michelson-Morley-Miller Aether-Drift Experiments, 1880–1930. LOYD S. SWENSON, JR. University of Texas Press, Austin, 1972. xxii, 362 pp. + plates. $10.

Today the long involvement of scientists with the ether problem may seem strange, especially to younger scientists, but Swenson's detailed account of the quest that began with Arago and Fresnel in the early 19th century and only subsided at last when Joos was able to bring to bear on the problem the full technical expertise of the Zeiss Company at Jena is still of considerable interest. Swenson's book is the culmination of ten year's study and research, beginning with his Ph.D. thesis. He has been indefatigable in his search for historical facts and letters and papers, both published and unpublished, bearing on the century-long search for the ether, and he has written with remarkable objectivity. The book deals in greatest detail with the interferometer experiments of Michelson and Morley and Miller, which held the chief interest for both experimental and theoretical developments throughout the greatest part of the period. Other significant experiments by Maxwell and by Lord Rayleigh, the Trouton-Noble experiment suggested by Fitzgerald, Zeeman's work urged by Lorentz, and the results of Ives and Stilwell, of Essen, and of Townes are all discussed, but they are not Swenson's central concern. Neither are the astronomical tests of general relativity of prime interest, although Einstein himself always considered the Michelson-Morley experiment important for his progress from the special theory to the general theory of relativity and gravitation (*1*).

It is scarcely surprising that the many theoretical developments that continued throughout the century (1830–1930) are not treated in this book. It would have been valuable, however, to have some details of this continuous evolution, starting with Fresnel's contributions and continuing with those of Maxwell, Fitzgerald, Lorentz, Poincaré, Larmor, and Einstein, because of the stimulation and constraint which the century-long succession of experiments exerted on advances in theory; certainly for most of these theories the ether-drift experiment had a special significance.

Perhaps the most outstanding aspect of the history of the theories of relativity was the amazing public interest aroused in 1919 when Eddington's solar eclipse expeditions in West Africa and Brazil confirmed the prediction of the deflection of starlight passing the edge of the sun as given by the general theory of relativity. Prior to that time interest in the theories of relativity had been steadily growing among professional physicists and astronomers but the theories were practically unknown to the general public. Coming soon after the end of World War I, Eddington's spectacular achievement had a tremendous impact on both scientists and the public which to this day is a matter of amazement, considering the small connection between the general theory and everyday life. In 1919 this reviewer heard a lecture on relativity in his parents' living room attended by a group of adults who certainly could not have understood the details of the theory yet who, in common with innumerable similar groups throughout the world, were fascinated by the new concepts of space and time that had entered scientific thought. Popular excitement was probably greatest in Germany, where an educated public had for many years been nurtured on the philosophy of Immanuel Kant with its emphasis on absolute space and time, which in fact carried these concepts much further than had ever been the intent of Newton.

One important reaction to this great uproar touched the Michelson-Morley experiment, which had been performed in Cleveland in 1886–1887 and refined and extended there in 1902–1904 by Morley and Miller. By 1919 Morley had retired and Michelson, by then at



The Michelson-Morley interferometer used for ether-drift experiments in 1886–1887. The only known photograph of the apparatus, this picture was discovered in Michelson's laboratory notebook in the archives of the Mount Wilson Observatory by D. T. McAllister, curator of the Michelson Museum, Naval Weapons Center, China Lake, California. [Reproduced in *The Ethereal Aether*, courtesy of the Hale Observatories]