central although now forgotten place in American culture. As Segal points out, they inherited a variety of traditions. Behind them lay the grandiose and sometimes cranky utopias of Fourier, Owen, and Saint-Simon. And growing up at the heart of industrial capitalism were the explosive political utopias of Marxian revolution. In America, however, which lacked the catastrophic visions of Europe or its rigidities of class and custom, utopians from Edward Bellamy to Harold Loeb could imagine a more perfect future in terms of reorganization, not revolution. Thus they shared a perspective with other reformers who advocated scientific management, city, regional, and national planning, and the use of expertise to solve large social problems. Like the Progressive reformers and like liberals in the 1930's, they believed that bureaucracy and not politics provided the best framework for ending social strife and poverty.

Where the technological utopians departed from the common reform agenda, however, was in the comprehensiveness of their vision and in their extreme faith in the capacity of technology and administration to achieve the good society. In short, they were utopians whose dreams of the future edged off into fantasy but whose writings nonetheless remained firmly grounded in the real world.

Segal obviously admires this group, although he is wary of some of their assumptions: for example, their exaltation of the work ethic and inattention to leisure and play. He recognizes that their social criticism is modest and that many of their predictions have been fulfilled in a technological sense without changing society for the better. On the whole, he concludes, their value lies in their sense of the tension between the real and the possible and in their belief in using the benefits of technology to transform human existence in a thoughtful and comprehensive fashion. With extensive notes and bibliography this work provides an important source for the thought of a fascinating group of practical utopians.

There is a passage that Segal quotes that also suggests a different perspective on this group. King Gillette, the eccentric inventor of the safety razor and a leading utopian writer, remarked of education that children should learn "the miracle of scientific production; the fairy tale of flour; the romance of rubber; the wonder of wood and silk." This endowing of material objects and technology with human, historical, or cultural altributes represents the oxymoron of technocratic thought. This same paradoxical

"Man Corporate," from K. C. Gillette's utopian treatise *World Corporation* (Boston, 1910). "He absorbs, enfolds, encompasses, and makes the world his own. He will do more; he will penetrate the confines of space, and make it deliver up its secrets and power, for Mind, the Child of the great Oversoul of Creation, is Infinite and Eternal." [Reproduced in *Technological Utopianism in American Culture*]

quality is reflected in the tendency of these writers to depopulate their utopias, to withdraw the variety and clamor of human life from the future in favor of smoothly running machines. It is as if technology replaces people. Such a tendency is most apparent in the writings of Edward Bellamy, the most famous of the technological utopians. The society that Bellamy wants to flee teems with variety, social classes, races—people. But his utopia is an enclosed Victorian family circle. Society outside it is described in abstract categories. In abolishing the problems of disorder, Bellamy thus abolishes the disorderly.

Why is this peculiar attitude toward people such a strong strain in technological utopianism? One explanation lies in the social developments of the years from 1880 to 1933. This period of progress and turmoil that created vast technological progress also brought the formation of the industrial working class, the influx of new immigrants and religions, the first flow of black Americans from South to North, the rebellion of women, violence, unions, strikes, and disorder. The technological utopias solve these problems by abolishing the people who personify them. A peculiar sort of abstractness thus lies at the heart of the dreams of a new order. And it is the ultimate failing of these utopians not to have preserved the builders and the victims of the new technological world and not to have granted them citizenship in their imaginary societies.

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An Anniversary in Astronomy

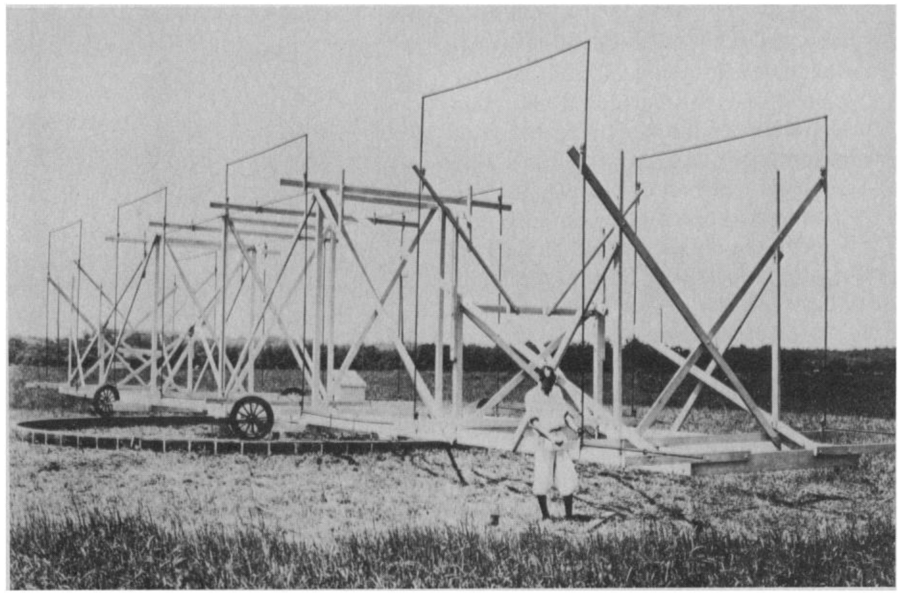
The Early Years of Radio Astronomy. Reflections Fifty Years after Jansky's Discovery. W. T. SULLIVAN III, Ed. Cambridge University Press, New York, 1984. x, 421 pp., illus. \$39.50. From three conferences, San Francisco, Calif., Jan. 1980; Washington, D.C., Aug. 1981; and Patras, Greece, Aug. 1982.

Serendipitous Discoveries in Radio Astronomy. K. KELLERMAN and B. SHEETS, Eds. National Radio Astronomy Observatory, Green Bank, W.Va., 1984. viii, 321 pp., illus. Paper, \$7. From NRAO Workshop no. 7, Green Bank, May 1983.

In 1933, Karl Guthe Jansky presented and published his seminal work on extraterrestrial radio waves, or "star noise" as he was wont to say. These two volumes honor, in different formats, the golden anniversary of the discovery that founded the field of radio astronomy and that we now know presaged a vast expansion in our ken of the external universe.

But the beginnings were not auspicious. In writing to his father after presenting his paper at a scientific meeting in Washington, D.C., Jansky refers to "an almost defunct organization . . . attended by a mere handful of old college professors and a few Bureau of Standards engineers." He complained that his supervisor at the Bell Telephone Laboratories insisted on a cautious title for his main publication, "Electrical disturbances apparently of extraterrestrial origin," although Jansky felt certain his work demonstrated the galactic origin. He received brief notoriety on the basis of several popular and news accounts of his work, including a front-page headline in the *New York Times* of 5 May 1933, which read, "New Radio Waves Traced to the Center of the Milky Way." Nevertheless, Jansky did only a modest amount of follow-up work on this subject, for a complex set of reasons about which there is still some controversy, and with the exception of a few isolated but notable efforts (for example, those of G. Reber, the consummate radio amateur, and of J. Greenstein on the theoretical side), neither the astronomical community nor other scientists or radio engineers made a concerted effort to explore this new field until the end of World War II.

Jansky never received any major recognition for his fundamental discovery up to the time of his death, by stroke, in 1950 at age 44, but since 1973 he has been honored by the official unit of electromagnetic flux density, the jansky, being 10^{-26} watts per square meter per hertz. By quaint custom, the scientific giants included in this definition regain capital status for their names in the abbreviated form, but without the period, so 1 Jy = 10^{-26} W m^{-2} Hz^{-1}.



Karl Jansky and his rotating antenna, nicknamed the merry-go-round. [Bell Labs photo]

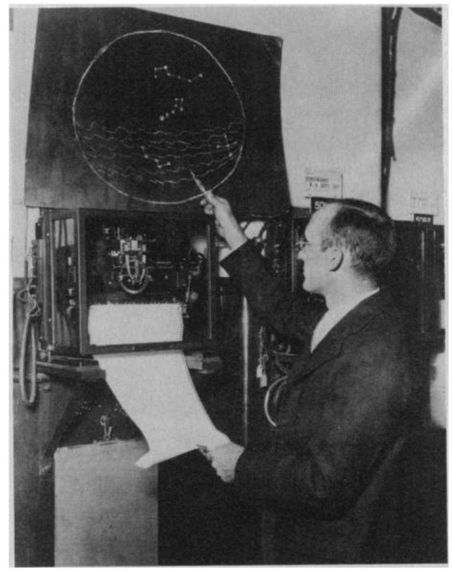
In *The Early Years* Sullivan presents accounts by 21 authors of the development of radio astronomy, including the earliest observations of Jansky (summarized by Sullivan) and Reber but then concentrating on the postwar period when the major radio astronomy groups were formed and then prospered in an era of dynamic, almost frenzied, development. Most of the accounts deal only with the years up to about 1960, when the field might be said to have become "big science."

In the major sections covering the early years of radio astronomy in Australia and England, nine of the key participants present their recollections and interpretations of the origins and developments at the Division of Radio Physics of the Australian Council for Scientific and Industrial Research, at the Jodrell Bank Observatory of the University of Manchester, and at the Cavendish Laboratory of Cambridge University. In each case, a leader and mentor or senior adviser, plus a small group of colleagues, emerged from the crucible of the war years determined and able to put their wartime experience in electronics, radio, and radar to use in peacetime scientific endeavors. The leader-adviser combinations of J. L. Pawsey and E. G. Bowen in Australia, A. C. B. Lovell and P. M. S. Blackett at Manchester, and M. Ryle and J. A. Ratcliffe at Cambridge set different styles for their organizations. However, the groups wrestled in common, sometimes cooperatively and sometimes competitively, with major problems associated with instrumentation (for example, large dishes *vs.* giant antenna arrays and interferometers), analysis (Fourier techniques and early computer developments), interpretation (for example, in distinguishing radio "stars" and extended sources as well as their galactic or extragalactic distances and in obtaining reliable statistics on the number of sources as a function of their flux densities), and research funding (where the senior advisers played key roles).

In the fourth section of Sullivan's book, A. E. Salomonovich and V. L. Ginzburg cover the early years of radio astronomy in Russia and J. F. Denisse, A. E. Covington, and H. Tanaka do the same for France, Canada, and Japan, respectively. (Accounts of the corresponding postwar developments in the Netherlands and the United States are notable by their absence, as the editor acknowledges.) In a final section, four authors present their broader reflections on research styles and on radio astronomical developments and their importance. For example, W. H. McCrea outlines the direct influence of radio astronomy on cosmology. As regards scientific fallout in other fields, R. N. Bracewell in an earlier section discusses how the development of imaging theory in radio astronomy may have influenced major new departures in medical imaging.

Though not complete as history, the Sullivan book is a rich treasure of recollections and analyses of past events by many of those who were personally responsible for the explosive growth of this new science. A delay of many more years would have made this feature impossible. Photographs of antennas, equipment, and people provide an intimate look into how it all came about. I am particularly struck by the similarities in the developments in diverse countries. There is a common thread involving wartime experience in radar, the availability of equipment from the war (captured German steerable radar antennas were used in the early days in a number of countries), a talented group of radio physicists ready and eager to apply their capabilities to radio astronomy, initial radar studies and radio observations of the quiet and disturbed sun as precursors to a broader range of observations, development of equipment with better and better sensitivity and angular and frequency resolution, individual resourcefulness in attempting to understand surprising observations, individual and institutional perseverance despite the slowness of the astronomical community to understand or appreciate the potential of radio astronomy (when the Australian Commonwealth Astronomer was asked in the early postwar years where he thought radio astronomy would be in ten years, he replied, "It will be forgotten"), and the mix of unselfish corroboration and bitter competition in what must be considered to be, in the final analysis, complementary factors in the development of this field.

One of several high points in *Serendipitous Discoveries* is the wealth of information about Karl Jansky as an individual. Two of the short papers are by his son and daughter, who also supplied 63 pictures for the book from their collection. (The workshop reported in this book was attended by 27 members of the Jansky family.) Other selections by A. C. Beck, J. D. Kraus, Reber, and Greenstein recount personal recollections of



Karl Jansky pointing to the position on a chart of the sky where radio noises from space were first detected. [Bell Labs photo]

Jansky and the influence of his work during the earliest days of radio astronomy, and Sullivan provides a short historical study of the beginnings of radio astronomy.

However, the rest of the 39 selections by 37 authors (seven of whom also contributed to the Sullivan book) pick up the story after World War II, with particular emphasis on the major discoveries of radio astronomy. These include quasars, pulsars, active galaxies, giant molecular clouds, and the cosmic background (or "big-bang") radiation, which together have constituted a revolution in our knowledge of the universe. The contributors wrestle with whether the discoverers (many of whom are also contributors) had a "gift for finding valuable things not sought for," whether such serendipity can be augmented by design, and whether there is a set of recognizable circumstances common to different discoveries. Most of the papers were transcribed from recordings of oral presentations given at the workshop, and comments and questions from the floor are included. Also included are the figures and pictures used by the speakers to illustrate their papers. Thus, though some polish may be lost, the reader gains from the flavor of interaction and immediacy captured in the final product.

As might be expected, the question about the nature and role of serendipity in important discoveries is not settled. One is tempted to say that the simpler word "luck" may also be part of the story. But let me add that luck in this sense does not accrue to the unprepared. In the first decades of radio astronomy, the discipline was strongly technique-oriented, and new equipment that pushed the frontiers of sensitivity, spectral and angular resolution, and wavelength coverage was fundamental to discovery. What seems to have been required in addition is the "right person, in the right place, doing the right thing, at the right time." Getting all those "rights" aligned is where a certain measure of luck appears to have been involved.

Examples abound of how discovery might have been made by a different person if a minor change of circumstances had occurred and how a small change might have prevented the actual discovery. These samples date back to Jansky, who might not have been able to make much sense out of his measurements if the experiment had been conducted during a time of sunspot maximum (when interfering signals would have been prevalent) instead of minimum. In a different example, several experimenters reported residual background sky noise before 1965 when A. A. Penzias and R. W. Wilson, with key help from the theoretical predictions of R. H. Dicke, homed in on the source of their measured noise as the remnants of the primeval fireball. The earlier reports included a published value of 0 to 5 degrees Kelvin given by workers in Japan in 1951 and a residual average value of 3.3 degrees found by E. Ohm using the same antenna as was employed in the discovery. No mention is made of any prior observation of pulsars, but J. Bell Burnell, in her account of her work with A. Hewish in this discovery, makes clear that with the right antenna and recorder time constant pulsars could hardly be ignored indefinitely as ignition or other artifactual noise. In retrospect, it seems amazing indeed that these space beacons remained undetected for so long, for they continually flashed their signals to earth at essentially every carrier frequency of the electromagnetic spectrum. From the additional examples of hits and near misses given in the Kellermann and Sheets book, it occurs to me that, though major recognition of radio astronomers by Nobel prizes (to Penzias and Wilson, Hewish, and Ryle) and British knighthoods (to Lovell and Ryle) was appropriate, there were quite a few additional giants in the fray. Perhaps these two books can provide a bit of a tune for these unsung heroes.

Though discovery strikes only the prepared, several contributors to the workshop conclude that sometimes it helps not to know too much. In a related vein, informative anecdotes are presented about how a little more knowledge might have affected adversely the development of several major observatories. The earliest justification for building the 250-foot Jodrell Bank telescope was based on the mistaken idea that radar echoes could be obtained from atmospheric ionization produced by cosmic ray showers, providing a new way of studying them. And the dimension of 1000 feet for the Arecibo Observatory antenna was thought to be needed to obtain detectable echoes scattered incoherently from ionospheric electrons, but the computed bandwidth of such echoes was incorrect by a factor equal to the square root of the ratio of the mass of ionospheric ions to that of the electrons. Thus a dish only about 65 feet in diameter would have been called for by a corresponding correct computation. At about the time this error was recognized, support for continuation of the big antenna came from a further mistaken idea that the earth-orbiting satellites of other nations could be tracked by radar reflections from disturbed trails of ionization in their wake. Think of the loss to radio astronomy if the Jodrell Bank and Arecibo antennas had never been built owing to earlier recognition of these flawed justifications, at a time when the most important "justifications" could not have been anticipated.

Both books create an air of nostalgia about the early times when a few dedicated individuals, working with their own hands on radio receivers and antennas, could create and use their instruments and could make and decipher fundamental observations through new windows on the universe. We have surely lost at least part of the excitement and satisfaction of those days in the current era of institutionalized science, very expensive and complex instruments at national laboratories, and increasing division of effort into hardware, software, and theoretical specialties. Have we in this way made serendipitous discovery less likely? In the past, experimenters had intimate knowledge of all aspects of their equipment, observations, analyses, and interpretations, and their success sometimes depended in unanticipated ways on this breadth of understanding. We cannot go back, but we can study the past for enlightenment about the present. I recommend these books for this purpose.

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