was the most distant object known, but if it was the second strongest radio source, what could the fainter ones be? Lovell's approach to this problem was to lead by continuous steps to the very-long-baseline interferometry which is continuing to yield rich results at the forefront of extragalactic radio astronomy and will in time have nonastronomical applications. The intervening stages were as follows. Hoyle calculated that, in an Einstein–de Sitter universe, a source having the absolute dimensions of the Cygnus source would, if it receded indefinitely, pass through a minimum apparent angular diameter of 15 seconds of arc. Henry Palmer's group therefore performed a sequence of observations, using the big dish as one element of a long-baseline interferometer, that not only promptly pushed angular resolution to 3 seconds of arc but revealed the existence of number of sources having diameters less than this. These were to come to be known as quasars. Astonishingly, when one of these sources was photographed at Palomar by Allan Sandage it not only looked like a star but varied in light output over the course of a year so that interpretation as a large, distant galaxy seemed impossible. The introduction of the method of lunar occultation on the 250-foot telescope by Cyril Hazard then took the angular resolution down to hundredths of a second of arc and helped quasar research out of this impasse by showing distinctly nonstarlike structure; meanwhile, interferometer baselines became intercontinental, involving many nations.

Pulsars became a big activity at Jodrell Bank immediately the remarkable news of their discovery was announced from Cambridge, U.K., and three chapters are devoted to them. Jodrell became very good at discovering new pulsars and at the end of 1972 was coming up fast behind Sydney University, the two observatories together accounting for three-quarters of the 84 then known. When the announcement of pulsars appeared in *Nature* in February 1968, radio astronomers were astounded, and not least by the fact that the first records had evidently been taken many months previously and kept under a dark cloak of secrecy, which, as Lovell says, was almost as much of an accomplishment as the discovery itself. Lovell defends this withholding of data up to the point where the existence and astronomical nature of the unprecedented signals were established, on the grounds that "a scientific discovery of enormous fundamental importance would have been submerged in a torrent of science fictional nonsense."

Other topics dealt with include flare stars, the radar detection of Venus, and the Mark IA radio telescope. A marvelous anecdotal chapter deals with plans for the United States to exchange greetings with the Soviet Union via the Echo balloon. Because a single hop was not feasible, NASA proposed to include Jodrell Bank in the circuit. Wonderful three-nation confusion reigned for more than three years, but the transmissions were successfully established, including facsimile transmission (see illustration). However, Lovell doubts that the Echo experiments had any useful scientific or technical consequences. He says, "Their major value was the maintenance of contact in the space field between the U.S.A. and U.S.S.R. at a most difficult period of their relations."

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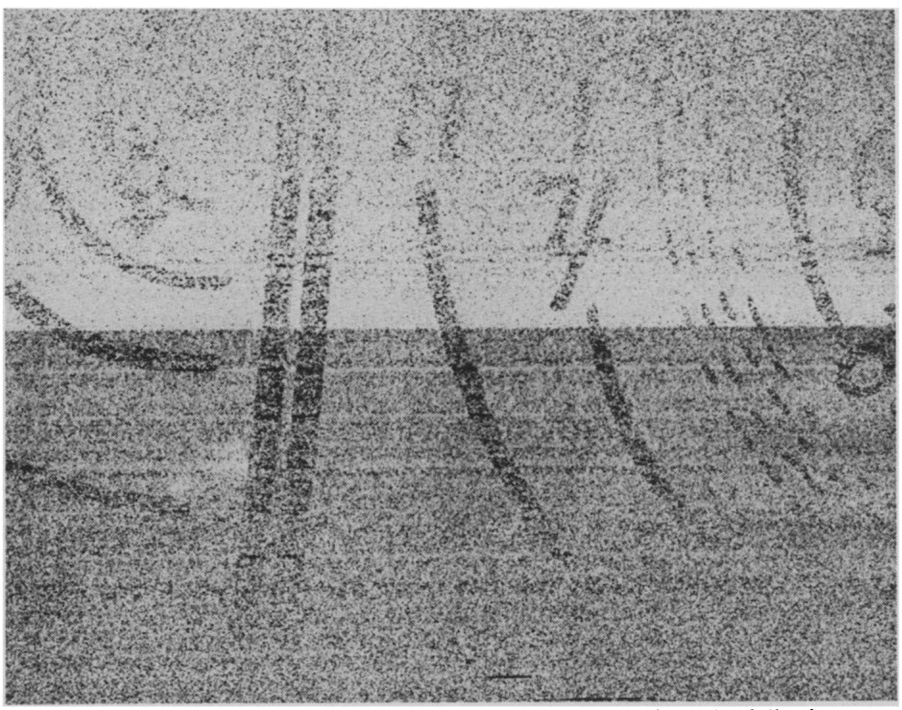

had no idea what we were transmitting. Over the telex we received the following message: '. . . We have received the following picture: Some pieces of continuous geocentric circles between them there are four dotted circles. It seems to us that we have seen on these circles the planets signs of the solar system.' " [From *Out of the Zenith*]

Michelson

The Master of Light. A Biography of Albert A. Michelson. DOROTHY MICHELSON LIVINGSTON. Scribner, New York, 1973. xii, 376 pp., illus. + plates. $12.50.

It is said that scientists do not in general make good subjects for biographies, as their results are obtained methodically and logically and with little drama. They are remembered by other scientists for their works rather than for their personalities. Few of them ever challenge the establishment and even fewer of them get rich, so what benefit is there in studying their lives? This observation does not apply to Michelson (1852–1931), who from improbable beginnings rose to become in 1907 the first American to win a Nobel Prize in science, and who helped move America onto the world scene in physics.

Albert Michelson was three when his family emigrated from Poland to America, settling in Murphys, California, where his father ran an emporium for miners' supplies. His early schooling was rugged and rudimentary, but after high school he managed to obtain an appointment to the Naval Academy. After four years of training, he joined the fledgling physics department there as an instructor, and one of his first assignments was a demonstration experiment repeating Foucault's rotating-mirror measurement of the speed of light. In studying this experiment he

Albert A. Michelson as a cadet midshipman, class of 1873, at the U.S. Naval Academy, sketching himself with the aid of a mirror. [Reproduced in *The Master of Light*. Photograph from the Michelson Museum, China Lake, California, courtesy Philip L. Alger]

made some rearrangement of the optics that much improved the accuracy of the method, and in 1878 he published the first of his many papers on improved determinations of the velocity of light. The Navy then sent him for two years to study with Helmholtz in Berlin, where he attempted to measure ether drift (and invented the Michelson interferometer). In 1882 he joined the newly formed Case School of Applied Science, where he remained for seven years. The 1887 Michelson-Morley experiment is the best-known result of that period. In 1889 he joined Clark University, just founded to become, it was hoped, a school for advanced studies. The stellar interferometer and interferometric measurement of the meter date from this period. And in 1894 he was lured away to found the physics department of the new University of Chicago, where he remained until retirement in 1929. He died in Pasadena in 1931, still working at 79 on a velocity-of-light experiment.

Dorothy Michelson Livingston (b. 1905), Michelson's youngest daughter, was not trained in science, but about ten years ago began a "quest for her father." She obtained copies of his correspondence and scientific notebooks; she interviewed relatives and scientific contemporaries; she haunted the Center for History of Physics at the Amercan Institute of Physics. She even took a course in history of science. She knew that her father had had an earlier marriage, and that there had been three other children; but that was a taboo subject in the family and it was not until 1966 that she located her half sister Elsa, then 85, and discovered that her two half brothers were long dead.

From personal recollection, from much reading, and from interviews, Mrs. Livingston has written a well-organized scientific biography of her father that is in the same general style as Silvanus Thompson's life of Lord Kelvin or the fourth Rayleigh's biography of his father.

The scientific material in this book is largely narrative, rather at the level of Michelson's own two books of popular lectures on optics. This should prove no hurdle to an interested lay reader. Some writers assert that the negative result of Michelson's 1887 ether-drift experiment led Einstein to postulate relativity; others say Einstein simply reasoned from first principles. Be that as it may, Michelson's experiment shook most physicists of his day.

In this book the author has attempted not only to discuss his scientific achievements, but also to portray Michelson the man—his personality and character, strengths and foibles. He was dedicated but demanding and could be arrogant, strict, and severe. An interesting part of the book is the portrayal of physics in the United States, as it grew from a handful of individuals working alone in 1880 to the well-developed science scene of 1930. Michelson was involved in the founding of three universities and in the founding of the American Physical Society, the *Astrophysical Journal*, and the National Research Council. The author has assembled a wealth of anecdotes of Michelson interacting with his colleagues and friends.

Michelson disliked administration and left this largerly to such associates as Samuel Stratton, George Hale, and Robert Millikan, all worthy disciples. He once (after he was already famous) threatened to withdraw his application for a grant because he had been asked to fill out a standard form. (They funded him anyway; that was a different world.) He preferred his work to vacations (he did not know how to loaf), but he was also a talented artist and violinist and enjoyed tennis and billiards. Everything he did he did with enthusiasm. This book portrays Michelson not as a legend, but as a real, believable person.

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Roots of Modern Analysis

Functional Analysis in Historical Perspective. A. F. MONNA. Halsted (Wiley), New York, 1973. viii, 168 pp. $16.50.

Some half dozen years ago Michael Bernkopf published in *Archive for History of Exact Sciences* two substantial papers tracing the rise of the concept of function spaces to specific aspects in the earlier history of mathematics. The first paper (vol. 3, No. 1 [1966]) emphasized the role of integral equation theory; the second (vol. 4, No. 4 [1968]) traced the first steps back to the study of infinite linear systems. The present little volume by Monna similar-