

# AMERICAN SCIENTIST

PUBLISHED IN THE INTEREST OF SCIENTIFIC RESEARCH  
AT TWENTIETH AND NORTHAMPTON STREETS, EASTON, PENNSYLVANIA

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VOLUME 45

JANUARY 1957

NUMBER 1

SPECIAL COMMEMORATIVE ISSUE

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THE AMERICAN SCIENTIST is published five times a year (January, March, June, September, December) by the Society of the Sigma Xi at the Mack Printing Co., 20th and Northampton Sts., Easton, Pa.

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The AMERICAN SCIENTIST is entered as second-class matter at the Easton, Pa., post office, under the Act of August 24, 1912. Additional entry at the New Haven, Conn., post office, December 9, 1943.

EDITORIAL CORRESPONDENCE and publications for review should be addressed to P. O. Box 703, Princeton, N. J. The submission of manuscripts is welcomed but no responsibility for safe keeping or return can be assumed.

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Annual Subscription, \$2.00

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The Director of the Physics Division of the Oak Ridge National Laboratory and the genial author of "Geneva Dairy, August, 1955" in the October 1955 issue of the *American Scientist* accepts the invitation of the Editors to review, for the 70th Anniversary issue, the present ideas concerning the fundamental particles of physics.

JOSEPH R. ROYCE, *Psychology in Mid-Twentieth Century*

A young psychologist takes a broad look at the present and future of his area of study. Professor Royce has been primarily working on animal behavior. He has carried out research for the government ranging from submariner aptitude tests to flight experiences. He is Associate Professor of Psychology at the University of Redlands, California.

W. J. CUNNINGHAM, *Automation*J. S. WEINER, *Physical Anthropology . . . An Appraisal*

The Reader in Physical Anthropology at Oxford and author of *The Piltdown Forgery* consented, during a visit to the International Congress on Anthropology at Philadelphia in September last, to provide the readers of the *American Scientist* with an appraisal of the science of anthropology at the mid-century mark.

G. EVELYN HUTCHINSON, *Marginalia*

After an absence of two years from the pages of the *American Scientist*, Professor Hutchinson of Yale University accepted the request of the Editors to contribute once more, for the Special Anniversary Issue, one of his charming essays on the state of science, on this occasion some thoughts on the problem of evolution.

HUGH TAYLOR AND GUEST REVIEWERS, *The Scientists' Bookshelf*

## BOOKSHELF: RECEIVED FOR REVIEW

- Glass* by G. O. JONES; 119 pages; \$2.00; London: Methuen & Co. Ltd., New York: John Wiley & Sons, 1956.
- Man and the Waters of the Upper Ohio Basin* (a symposium); 100 pages; Pymatuning Laboratory of Field Biology. Special Publication No. 1, 1956.
- Mars, the New Frontier: Lowell's Hypothesis* by WELLS ALAN WEBB; 141 pages; Fearon Publishers, 1956.
- The Hardiness of Plants* (Vol. VI of *Agronomy*) by J. LEVITT; 278 pages; \$7.00; Academic Press, 1956.
- Physics and Chemistry of the Earth, Vol. 1*, edited by L. H. AHRENS, KALERVO RANKAMA, and S. H. RUNCORN; 317 pages; \$8.00; McGraw-Hill Book Co., 1956.
- Landmarks in the History of Hygiene* by HENRY E. SIGERIST; 78 pages; \$3.00; Oxford University Press, 1956.
- Insects and Spiders: A Book of Keys with Biological Notes* by C. P. FRIEDLANDER and D. A. PRIEST; 124 pages; \$2.75; Philosophical Library, 1956.
- Ceramics for the Archaeologist* by ANNA O. SHEPARD; 414 pages; Carnegie Institution of Washington, 1956.
- The Psychology of Occupations* by ANNE ROE; 340 pages; \$6.75; John Wiley & Sons 1956.
- A Follow-Up Study of War Neuroses* by NORMAN Q. BRILL and GILBERT W. BEEBE; 393 pages; Veterans Administration Medical Monograph, 1955.
- Musical Acoustics* (4th edition) by CHARLES A. CULVER; 305 pages; \$6.00; McGraw-Hill Book Co., 1956.
- The Concept of Entropy in Communication, Living Organisms and Thermodynamics* by Y. S. TOULOUKIAN; 66 pages; \$1.00; Bulletin No. 130, Engineering Experiment Station, Purdue University, 1956.
- California and the Southwest*, edited by CLIFFORD M. ZIERER; 376 pages; \$11.25; John Wiley & Sons, 1956.
- Elementary Crystallography* by M. J. BUERGER; 528 pages; \$8.75; John Wiley & Sons, 1956.
- Experimental Physical Chemistry* (5th edition) by F. DANIELS, J. H. MATHEWS, J. W. WILLIAMS, P. BENDER, and R. A. ALBERTY; 482 pages; \$6.50; McGraw-Hill Book Co., 1956.

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# THE BEGINNINGS OF RADIO ASTRONOMY\*

By C. M. JANSKY, JR.

Jansky & Bailey, Inc., Washington, D. C.

**K**ARL Guthe Jansky was born October 22, 1905, in what was then the Territory of Oklahoma. At that time his father was Dean of the College of Engineering at the University of Oklahoma at Norman. He was the third son of Professor Cyril, Methodius Jansky and Nellie Moreau Jansky.

The following facts with respect to his parents are of interest. His father, now eighty-six years of age, was born in Richland County, Wisconsin, the son of Czech immigrants who came to this country on a sailing vessel in the early 1860's. Father Jansky started teaching school at the age of sixteen. He was a teacher throughout his active life, retiring as Professor of Electrical Engineering at the University of Wisconsin. Karl Jansky's mother's maiden name was Nellie Moreau. She was of French and English parentage, her ancestors having come to the United States prior to the Revolutionary War.

Although already a graduate of Valpariso University, about 1902 Father Jansky decided that he should have more education. Therefore, he resigned his position as Superintendent of Public Schools in a small Michigan town and entered the University of Michigan. Here he obtained both graduate and postgraduate degrees in Physics and Electrical Engineering. By this time there were two children in the family—I, the oldest, and a second son.

While at the University of Michigan, Father Jansky worked under and became a great admirer of Dr. Karl Guthe, a German-American physicist and a member of the faculty of the University of Michigan. In 1904 both Dr. Guthe and our father became members of the staff of the United States Bureau of Standards at Washington at the time this institution was founded. In 1905 the family moved from Washington, D.C., to Norman, Oklahoma. When the third son was born shortly after reaching Oklahoma he was named after Dr. Karl Guthe, the scientist and teacher whose guidance had meant so much to his father.

I have gone into some detail with respect to this family history to show that the perseverance with which Karl Guthe Jansky accumulated scientific data, and the objectivity and creative ingenuity he demonstrated in making the fundamental discovery upon which the Science of Radio Astronomy is based, were not accidental. His family life and background contributed much. Even his name, Karl Guthe, preserves that of a great physicist and outstanding teacher.

\* Presented at the Ninety-Fourth Meeting of the American Astronomical Society, The Ohio State University, Columbus, March 23, 1956.

After three years in Oklahoma the family moved to Madison, Wisconsin, where Father Jansky became a member of the faculty of the University of Wisconsin. Here Karl Jansky received his public school and his university education. He received his Bachelor of Science degree in Physics in 1927. He was graduated with honors having been elected to membership in Phi Beta Kappa, Phi Kappa Phi, and Phi Sigma Phi. Nine years later he received the Master's degree in Physics from the same institution.

Karl Jansky was no bookworm. He was an excellent tennis player and an outstanding star on the University of Wisconsin's ice hockey team. I might also mention here that later in life, while with Bell Telephone Laboratories, he became the table tennis champion of Monmouth County, New Jersey.

It is unrealistic and, therefore, unscientific to underestimate the impact of the element of chance on human destiny or as a factor affecting man's acquisition of knowledge concerning the universe in which he lives. This in no way detracts from the credit due those who take the fullest advantage of the opportunity chance affords. When Karl Jansky applied for a position with Bell Telephone Laboratories in 1928 he was at first turned down for physical reasons. It so happened that ten years previously I had been a member of the staff of the Bell System Laboratories and more recently, while a member of the faculty of the University of Minnesota, I had spent summers at the Laboratories. Therefore, by chance, I happened to be in a position to argue with members of the personnel department, with whom I was well acquainted, that Karl Jansky was a good risk. This may have had some small influence in the Laboratories' decision to hire him. Certainly, Bell Telephone Laboratories and the world of science never had reason to regret this decision.

Again the element of chance enters into the picture. This was the assignment of Karl Jansky to the Bell Laboratories' field station at Cliffwood, New Jersey, and the decision of his supervisors to assign to him a project involving studies of certain radio propagation phenomena.

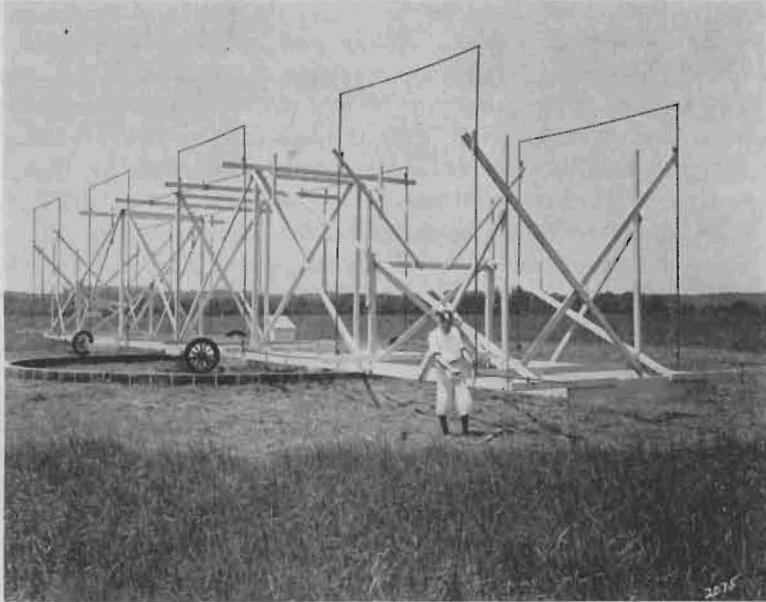
All of these factors, namely—basic elements of character, inherent abilities, family environment, scholastic environment, etc., together with the decisions of people—the choice of a course of study in college, the choice of a life work, the choice of an employer, the decision to employ, the assignment to a laboratory branch and to a specific project, had a vital influence upon what followed. The stage must be set before the play can begin.

The steps in Karl Jansky's work from 1928 to 1932 which led to the discovery which furnished the foundation for the Science of Radio Astronomy are fully described by Dr. George C. Southworth in his article, "The Early History of Radio Astronomy," in the *Scientific Monthly* for February, 1956. I will review these briefly because I believe

this history contains many lessons for those of us whose life work is in the field of either pure or applied science, and particularly for students and young people who hope to become scientists.

Karl Jansky was given the task of studying certain factors affecting the operation of Bell System transoceanic radiotelephone circuits. It is important to note that this was an applied scientific project with a very practical objective, namely, improvement in transoceanic radiotelephone service.

I used to tell my students in radio engineering at the University of Minnesota that a radio circuit consists of three parts—(1) a radio transmission installation, (2) a radio receiving installation, and (3) a trans-



Karl Guthe Jansky and his 14.6 meter rotatable directional antenna

mission medium which carries signals from the transmitter to the receiver. Man can and has throughout the years made remarkable progress in the development and improvement of radio transmitters and receivers and radio transmitting and receiving antenna systems. However, he can do nothing to modify the characteristics of the transmission medium. He must use this medium as nature gives it to him. Nevertheless, he can by field study and scientific analysis of the results obtain valuable information on what the transmission medium does to his radio signal and the types of static, noise, etc., affecting his use of it.

In 1928 Karl Jansky began his studies of the radio transmission medium and specifically of static and interference noises. While some

of his work was done on long wavelengths of the order of 4000 meters, of particular concern to radio astronomy are his studies on 14.6 meters (20.53 megacycles). These required instrumentation and it is important to note that in the late 1920's and early 1930's adequate instrumentation for his project, and particularly for wavelengths as short as 14.6 meters, involved many new and unsolved problems.

Every scientific worker makes use of the results obtained by others who have gone before and of advice and help from co-workers. Karl Jansky had much help from the results, of past research work and from other engineers in Bell Telephone Laboratories. This in no way detracts from the credit due him for his scientific discovery. Rather, it extends credit to those who by advice and counsel contributed to the final result.

About March 1929, Karl Jansky began the design of a 14.6 meter rotatable, directional antenna system and the development of the associated receiving apparatus. Construction of the antenna was started in August 1929. At the same time he was still working on the study of static on long wavelengths. In 1930, the Laboratories' field station with which he was connected was moved from Cliffwood to Holmdel, New Jersey. Therefore, it was not until the fall of 1930 that the 14.6 meter rotatable antenna and its associated receiving and recording equipment were in good working order. Next came the long period of time devoted to the unimpressive, prosaic, and laborious taking of data, that is, data on the characteristics and intensity of static received on 14.6 meters as a function of two variables—(a) time, and (b) direction.

I wish to dwell for a moment on the subject of data taking. It is one thing to sit at a desk and on the basis of information and data gathered by others hypothesize with respect to the laws of nature. It is another to design, develop, and build apparatus and equipment and then to embark upon a long, tedious program of taking accurate, dependable data on what actually takes place. There are some who look upon data taking as beneath the dignity of true scientists preferring to leave this detail work to assistants. I do not wish to disparage the value of theory and speculation as necessary elements in any scientific study but rather to emphasize that Karl Jansky's work demonstrates how essential is the accumulation of adequate, accurate data. This is as true with respect to studies of radio propagation phenomena as it is in astronomy.

A fair share of my life as a radio engineer has been devoted to the field study of the radio propagation medium. I subscribe to a philosophy of approach with respect to work in this field of science. If an objective scientist takes sufficient data and then without the prejudice of preconceived theories or hypotheses analyzes the results, somehow nature's laws will become almost self-evident. The scientist's problem is to recognize basic facts even though they are obscured by a wealth of ex-

traneous material, and then to apply creative imagination in their interpretation. This Karl Jansky did.

In a paper titled, "Directional Studies of Atmospheric at High Frequencies," presented at Washington, D.C., in April 1932 before the International Scientific Radio Union, Karl Jansky described his equipment and classified the types of static he was receiving on 14.6 meters into three distinct groups. The first group he described as static from local thunderstorms, and the second as static from thunderstorms some distance away. Then he stated, "The third group is composed of a very steady hiss static the origin of which is not yet known." While he speculated on the possible source of this new type of static, it is important to note his comment that "the data as yet only cover observations taken over a few months and more observations are necessary before any hard and fast deductions can be drawn."

I am not concerned here with specific dates. They are all a matter of record. What is important is the long period of time devoted to the accumulation of data on static as received on 14.6 meters as a function of time and direction and the creative interpretation of this factual evidence. Dr. J. H. Dellinger, a prominent authority on radio propagation, at one time stated in effect that no one is interested merely in data but in what the data show. Before the Washington meeting of the International Scientific Radio Union held in April 1933, Karl Jansky presented his paper in which he stated his conclusion as to what the data showed. The title of this paper is, "Electrical Disturbances Apparently of Extraterrestrial Origin." Note the use of the word "apparently." This illustrates a modesty which I am sure astronomers, physicists and all true scientists both understand and appreciate.

In his paper Karl Jansky set forth with reasonable accuracy, considering the limitations of his antenna, the point of origin of the extraterrestrial hiss static he was receiving. I will quote from the paper:

"In conclusion, data have been presented which show the existence of electromagnetic waves in the earth's atmosphere which apparently come from a direction that is fixed in space. The data obtained give for the coordinates of this direction a right ascension of 18 hours and a declination of  $-10$  degrees.

"The experiments which are the subject of this paper were performed at Holmdel, N.J. (Latitude  $40^{\circ} 22' N$  and Longitude  $74^{\circ} 10' W$ ) during the year 1932."

Now, I am an electronic engineer and not an astronomer. My comments must be taken with this limitation in mind. I look upon Karl Jansky's paper, "Electrical Disturbances Apparently of Extraterrestrial Origin," as a classic. It is in effect a wedding ceremony. It weds the science of astronomy and the science of radio and electronic engineering. It ties these sciences together by inseparable bonds.

My collegiate studies were in a field of pure science, namely, physics. Then I became a teacher of an applied science, namely, radio and elec-

trical engineering. In my teaching days when I was perhaps more willing to generalize than now, I used to define a pure scientist as one who if he saw a practical application of what he was doing somehow felt contaminated by commercialism and an applied scientist as one who if he could not see a practical application of his work would lose interest.

Is it not true that there exists no definitive boundary between pure and applied science? The discovery of extraterrestrial noise came as a result of a research program originally directed to a very practical end. Today, radio astronomy is making possible the development of radio sextants which will enable the navigators of ships and aircraft to take celestial bearings without regard to visibility conditions. What better illustration is there that a practical scientific study may lead to discoveries in the field of pure science, or that research in pure science may yield highly practical results?

Naturally, I had at least a limited appreciation of what was going on in Karl Jansky's mind in the early 1930's when he was gathering large amounts of data and also trying to figure what the data meant. I remember well when he started the study of the basic principles of astronomy, a field of science in which he had had no previous training. He felt this necessary if he were to interpret the mass of factual information he was collecting. I find his description of astronomical coordinates as lucid as anything on the subject I have read elsewhere. Very probably this is because my training and experience had been in the same field of science as was his, namely, physics and electronic engineering.

I recall among other things that after Karl Jansky concluded that his hiss static came from the center of the Milky Way he went back and tried correlating the data he had taken some time previously. At first it looked as though in some instances no correlation existed. Then suddenly he realized that some of these early data had been recorded using daylight saving time. When he applied the correction, he found these previous data tended still further to support his discovery.

Karl Guthe Jansky died in Red Bank, New Jersey, in February 1950 at the age of forty-four. In the trying period that followed his death I told the members of his family that his contribution to basic science was such that the full value of his discovery would not be recognized for at least half a century. How wrong can a man be! Here just six years later I find myself before a group of astronomers, physicists, and radio engineers far more competent than I, viewing with amazement the progress which has taken place in recent years in a new branch of astronomy based upon a scientific discovery made by a man I am proud to say was my brother.

In the atmosphere of international tension that exists today there are those who view with alarm all scientific effort, whether pure or applied, because they fear that the destructive potentialities of modern imple-

ments of warfare developed by scientists are so great that they may lead to the extermination of civilization. I suggest we should view man's search for scientific knowledge in a different light. The frontiers of radio astronomy are being pushed back by the efforts of workers in many nations—Great Britain, The Netherlands, Australia, the United States, Canada, Russia, France, Japan, Norway, Sweden, etc. As workers in one country develop new instrumentation and acquire new knowledge, that information is conveyed to fellow workers in other countries. Meetings held in one nation are attended by scientists from others. The emphasis is not primarily on competition but upon mutual understanding and cooperative effort directed towards a common objective—the acquisition of more and more knowledge of the universe in which we live.

Have I not described a mode of living and a philosophy of life which must be understood and followed by mankind generally if there is ever to come a day when there will be eternal peace between nations? Therefore, is it not appropriate to say that among the most effective apostles for peace are the scientists who not only by their discoveries make life more worthwhile but who also through their way of life demonstrate how the peoples of different nations should cooperate with one another and live together on this planet, a planet which somehow seems to grow smaller and smaller as our knowledge of the universe is enlarged?

Progress in science is based on fact but scientists are as human as anyone else—lawyers, politicians, or business men. There exists in each of us to a more or less extent, a tendency to be somewhat envious of the superior accomplishments of others. However, there seems to be something which affects the viewpoint of those who have dedicated their lives to the search for scientific knowledge, which more than counteracts this tendency. I do not know just how to explain this except to state that to be effective the search for truth must be objective and if one is objective then one is quick to give credit where credit is due.

In my limited and admittedly superficial study of astronomy and particularly radio astronomy, nothing has moved me more than the readiness with which astronomers and others have not only extended credit to Karl Jansky for his discovery but also have given full credit to other early workers in radio astronomy and to each other. I note that already there is coming into common use a basic unit of power flux density named after Karl Guthe Jansky.

Karl Jansky gave us our first brief look at interstellar space through a new and previously unknown window in the electromagnetic spectrum. We now know that this new window is from 50 to 100 times wider than the optical window previously available. He pulled back the curtain only a very little but it was enough to inspire others to attack the

problems of instrumentation and data gathering so necessary to take advantage of the opportunity now available.

In remembering Karl Jansky, his work and his discovery, we should remember that his philosophy of life was that of a true scientist—perseverence in the accumulation of data, objectivity in analysis, modesty, credit to others for their contributions, and a willingness to leave the ultimate evaluation of one's work to the future.