GROTE REBER, FOUNDER OF RADIO ASTRONOMY

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ABSTRACT

The author gives an informal account of Grote Reber's life and work.

Grote Reber first became known to me through his Wheaton neighbour, E.H. "Bill" Conklin. Bill was a radio amateur, W9FM, so was Grote, W9GFZ, and so was I, W8JK.

By day, Bill worked for an investment firm in Chicago. By night and while on the commuter train, Bill was an editor of *Radio*, an amateur magazine published in California. In 1937 I published several articles in *Radio* on a new type of antenna, now known as the W8JK beam, which caused a sensation in amateur radio circles. Bill, as editor, and I, as author, became well acquainted and he kept me informed about Grote's activities. For example, according to Bill, Grote came to his house one Saturday and asked if Bill could come over and help him. When Bill arrived at Grote's yard he found many piles of neatly stacked wooden timbers, all drilled, painted and numbered alongside some concrete piers. Bill helped Grote place the timbers which Grote bolted together and within a few hours the framework for Grote's big dish went up without a hitch.

This sequence typifies Grote. Everything he does is planned with meticulous care. He designs and builds most or all of his apparatus himself. But he doesn't stop there. He goes on and makes his own observations, plots and interprets his data and relates his results to theory. In a word, Grote Reber conducts all aspects of his research himself; he is a one-man self-supported scientific laboratory, a veritable one-man Bell Labs. For the most part Grote has not been dependent on any institution, foundation or school. And, as Grote puts it, "There have been no self-appointed pontiffs looking over my shoulder giving bad advice".

From his amateur station W9GFZ, Grote had communicated with amateurs in more than 60 countries on all continents and he looked for more distant conquests. Grote had read Karl Jansky's articles in the "Proceedings of the Institute of Radio Engineers" about radio waves from our Galaxy. Clearly, new equipment especially designed to measure these celestial radio waves was needed. After much consideration and analysis he decided to construct as large a dish as mechanically and economically practical. It was 32 feet in diameter with a 20-foot focal length.

At that time, the most likely explanation of celestial radio radiation was that it was of thermal origin which should be stronger at shorter wavelengths. So on this assumption Grote designed and built his first cosmic static receiver to operate at 9 cm, the shortest wavelength it was possible to use at that time. To build this receiver was a feat of electronic engineering requiring much experimental work and development. But by the spring of 1938, Grote's entire system, antenna, receiver and indicator, was in working order and he began systematic observations of the sky but detected nothing. At 9 cm, thermal radiation should be 26,000 times stronger than at Jansky's wavelength of 14.6 m and Grote Reber's equipment should have easily observed it. From this negative result Reber suspected that the radiation from our Galaxy is not thermal but may become stronger at *longer* wavelengths and, accordingly, he decided to try a wavelength of 33 cm. It was not merely a matter of retuning the 9 cm receiver. An almost entirely new receiver had to be designed and built. This Grote had working by the autumn of 1938 but again results were negative.

So once again he set about constructing a receiver for the still longer wavelength of 1.9 m. At this wavelength, he found that the ignition systems of passing automobiles produced a severe interfering static or popping noise but late at night this subsided and by April 1939 Grote obtained strong indications of cosmic static from the centre of the Milky Way! Pointing his antenna further north he found that the cosmic static became weaker confirming Jansky's findings in a general way.

All this took place while Grote worked by day designing receivers at a nearby radio factory (Stewart Warner, in Chicago). After supper he slept until midnight. Then, until he left for work the next morning, he sat in his basement beside his receiver and recorded the output-meter readings at one minute intervals. On weekends he had the opportunity to record data at other times but during the day the automobile ignition noise prevented him from making good observations. During the summer of 1939 Grote pointed his antenna at many other celestial objects but found nothing besides the Milky Way radiation.

Encouraged by his detection of galactic radiation, Grote Reber next made improvements in his receiver and also purchased an automatic recorder giving a pen trace on a moving paper chart. No longer would he have to sit up all night recording data. With these changes he then embarked on the first survey of the radio sky.

Then, for a while Grote left Wheaton to do research on the protection of ships at the Naval Ordnance Laboratory in Washington, D.C. I was also working at the laboratory on the degaussing of ships and it was here that I first met Grote. We stayed at the same rooming house where he told me about his equipment and observations of the Milky Way with a contagious enthusiasm. Grote instilled a desire on my part to build a radio telescope but my opportunity to do it did not come until 10 years later at the Ohio State University.

During 1940, while we were working together in Washington, we had several discussions about his dish and its possibilities. At centimetre waves it would have a lot of gain and could be pointed at the moon for several minutes during each lunar transit. Radar was still a few years in the future. However, pulse technique had been available since 1926 when Breit and Tuve first directly measured the height of the ionosphere. Accordingly, if centimetre-wave technology could be developed adequately, it seemed as if radio echoes could be obtained from the moon. We discussed this at some length. While such tests were never made, the idea anticipated Jack DeWitt's successful experiments by six years.

Grote worked in a group headed by Joseph Keithley. One day Joe said to me that Grote was the most ingenious and productive person in his group and that he wished he had more like him. I said, "I would expect that. Grote, you know, has done some remarkable pioneering observations of cosmic static." "Cosmic static?" Joe replied, "what's that?" I explained, but in a wartime setting, noise from our Galaxy seemed unimportant compared to urgent matters on planet earth. After the war Joe Keithley started an instrument company in Cleveland specializing in instruments for measuring very small currents and voltages. It has not become as famous or as big as Hewlett-Packard, but his company is well known and highly respected.

Once every week or two some of the laboratory people went bowling. I don't recall if Grote went with us but I should mention that the best bowler in the group was John Bardeen, who subsequently received not one but two Nobel prizes, one for his invention of the transistor and the other for his definitive theory of superconductivity.

When Grote's work at the laboratory ended he returned to his old job in Illinois but I stayed on at the lab. Back in Wheaton, Grote undertook a more complete survey of the sky. This was in 1943. He also detected very strong radio waves from the sun. Although European radars had detected solar emission at about this time, the fact was not announced until after the war.

From his survey, Grote produced the first maps of the radio sky. They showed clearly the concentration of radiation along the plane of the Milky Way. The strongest radiation came from the centre of our Galaxy, in Sagittarius, with other less strong maxima or hot spots in Cygnus and Cassiopeia a precursor observation to the later discovery of the strong discrete sources there.

Although Jansky's merry-go-round antenna was physically larger than Reber's, the Wheaton antenna operated at a much shorter wavelength giving Reber better resolution. Thus, the beam width of Jansky's antenna was about 30° whereas Reber's was about 12°. Later when Reber went successfully to a wavelength of 62 cm, he sharpened his beam to about 4°.

Grote Reber published his results in the *Proceedings of the Institute of Radio Engineers* and in other scientific journals. His first *Proceedings* paper on "Cosmic

Static" was submitted September 1939 and appeared in the February 1940 issue. Grote also submitted a "Cosmic Static" paper to the *Astrophysical Journal* and in my book *Radio Astronomy* I tell a story about it. It was the first time an article reporting cosmic radio observations had been submitted to an astronomical journal and most persons were either skeptical or puzzled about the results. The *Astrophysical Journal* was, and is, a refereed journal, that is, manuscripts submitted to it are sent to anonymous experts for their appraisal. Accordingly, Dr. Otto Struve, the journal editor, sent Reber's manuscript to a number of referees. Astronomer referees returned the manuscript with the comment that they didn't understand the radio terminology. Radio-engineer referees returned the manuscript with the comment that they didn't grasp the astronomical implications. So Struve found no reviewer willing to defend the paper or recommend its publication. In desperation, he wrote to the Institute of Radio Engineers to find out what they knew about this man Reber. As Struve related, the Institute reply was short and to the point, stating that Reber was a member of the Institute in good standing and that he paid his dues regularly!

Struve was in a quandary. He had ample grounds for rejecting Reber's contribution but reasoning that a good article rejected would be a greater evil than a poor one accepted, he approved Reber's article for publication and it appeared in June 1940.

World War II was then in progress and Holland had fallen under Nazi occupation. But eventually a copy of the *Astrophysical Journal* with Reber's article reached the observatory at Leiden. In reading the article, Jan Oort, observatory director, was quick to perceive that the cosmic radiation Reber and Jansky had reported must be a continuum extending over a broad spectrum. Further, he reflected that if some monochromatic line radiation existed, significant advances could result. He referred the matter to Hendrik van de Hulst, a young astronomer at Leiden, who considered various mechanisms for producing line radiation. In a 1944 colloquium at Leiden, van de Hulst reported that the 21-cm ground-state transition of neutral hydrogen in interstellar space was a possible source but the low probability of the transition and lack of knowledge of the hydrogen density in space made it uncertain whether the line could be detected. However, seven years later Harold Ewen and Edward Purcell at Harvard University detected the line and soon others did also. Observations of the 21-cm hydrogen line have been of immense value and constitute one of the most important phases of radio astronomy. In retrospect Reber's paper, which might not have been published at all, turned out to be one of the classics and an important catalyst in the birth of monochromatic radio astronomy.

The *Astrophysical Journal* tale illustrates a basic problem of doing research that bridges disciplines. Most astronomers were either skeptical of Reber's results or they were uninterested. Some stated that although Reber's measurements might be

valid he should leave any theoretical interpretation to "real" astronomers. And, on the other hand, most engineers took little or no note of Reber's work. Reber was in between two groups speaking different languages.

Reber fills an important niche in the history of science.

1 He was the first to follow up in a significant way on Jansky's discovery.
2 He laid the foundation of the new science of radio astronomy. Whereas, Jansky expressed results in volts per metre, Reber related his results to the cosmos in terms of flux density (watts per square metre per hertz) and brightness (watts per square metre per hertz per steradian or equivalent).
3 He recognized the significance of a radio telescope as a radiometer in which the radiation resistance of the telescope antenna measures the equivalent temperature of distant regions of space lying within the antenna response pattern.
4 His measurements suggested that the galactic radiation is non-thermal.
5 He produced the first maps of the radio sky. According to George Southworth, famous for his waveguide research at the Bell Telephone Laboratory, it was not until after Grote Reber literally drew them a picture of the radio sky that astronomers began to take notice.
6 For a decade Grote Reber alone nurtured and developed the new science of radio astronomy, doing it in his free time at home while working during the day designing receivers at a radio factory.
7 His backyard dish was the largest of its kind in the world and is the prototype of the modern radio telescope. It is fortunate that in 1937 Wheaton had no ordinance against backyard dishes. Grote Reber was the right man, doing the right thing in the right place at the right time.
8 And while most radio astronomers have moved to shorter wavelengths, Grote Reber has pioneered in long-wave radio astronomy first in his work atop Mt. Haleakala on the island of Maui, Hawaii, at 3 to 15 m wavelengths and later at 144 m in Tasmania and now at the same wavelength in Ottawa. Whereas birds migrate between hemispheres with the sun, Grote migrates opposite to the sun. In his observations at 144 m through occasional holes in the ionosphere, he has found a reversal in the appearance of the radio sky with the galactic poles being bright and the centre of the galaxy dim. To accomplish this work, Grote had to do extensive research on the earth's ionosphere and when and where he could find holes to observe in the cosmos at long wavelengths.

Grote's 144-m wavelength antenna which he designed and built in Tasmania covers an area of over 1 square kilometre and is physically one of the world's largest radio telescopes. In 1985 the shuttle *Challenger*'s crew fired maneuvering engines while passing over Grote's telescope opening the ionospheric hole so that longer wavelengths could come through. And, while in Tasmania, Grote has also built a north-facing solar house.

For northern-hemisphere long-wavelength observations, Grote is now operating a counterpart of his Tasmanian array here at Ottawa, converting an abandoned ionosphere-scatter antenna array previously used to investigate potential military communications applications into a radio astronomical telescope – a swords into celestial ploughshares project.

Did you know that there is a Reber-Hubble connection? As I relate in my book *Big Ear*, around 1900 the Hubble family lived in Wheaton, Illinois. As his 7th and 8th grade teacher young Edwin Hubble had a Miss Harriet Grote who later married Schuyler Reber and bore Grote Reber as her first son. She often commented to Grote that young Edwin Hubble stood out from the other students in his class and that she felt he would go far. In later years, when Hubble's fame was spreading, she took special pride in his accomplishments and that she had been one of his teachers.

In addition to radio astronomy, Grote Reber has many other interests. For some years, especially while a guest radio astronomer at Ohio State in the early 1970's, he did cosmic ray research. While atop Haleakala he observed atmospheric pressure variations, publishing the results in a meteorological magazine. Grote is a keen observer of nature and has made observations on a number of plants finding that if you unwind a twining bean plant and wind it back in a reverse sense the ratio of bean to shuck weight is increased. Although many textbooks state that a plant which winds as a right handed helix in the northern hemisphere winds as a left handed helix in the southern hemisphere, Grote found that his plants wound the same way in both hemispheres.

Grote has published a series of articles on his botanical work and while in Australia visited prominent botanists to discuss his findings. While he was there, the new radio observatory at Parkes held a dedication ceremony which Grote attended. Many Australian dignitaries and scientists from many disciplines were invited. One of these was a famous botanist Grote had visited previously who came over to Grote and remarked "We botanists really don't belong here do we?"

A compilation of Grote's diverse publications is given in the bibliography.

Grote is a botanist, an engineer, an astronomer, a meteorologist, an archaeologist and an explorer of the cosmos in its broadest sense. Grote is a renaissance man, a modern-day Michelangelo.

In 1962 Grote delivered the Russell Lecture to the American Astronomical Society and he also received the Bruce Medal of the Astronomical Society of the Pacific. The following year he received the Elliot Cresson Medal from the Franklin Institute.

A young student once asked Grote's advice about what to do to discover something really new. Grote replied: "Pick a field about which very little is known and specialize in it. But don't accept all current theories as absolute fact. If everyone else is looking down, look up or in a different direction. You may be surprised at what you will find".

Put another way, Grote was saying don't go with the buffalo herd. But I might add, if you do find something watch out because the herd may turn and trample you.

I have known Grote now for almost a half-century. I was his sponsor for an honorary doctor's degree he received from the Ohio State University in 1962. His citation reads, in part:

> Grote Reber is America's pioneer radio astronomer who turned to the heavens and opened an unseen universe to the exploration of man. Today, Grote Reber is acclaimed by the radio and astronomical scientific communities as the foremost pioneer in this new field and as a productive research scholar whose leadership continues. This university, one of the first in the United States to undertake work in radio astronomy, honors the founder of this science and becomes the first university to recognize formally Grote Reber's brilliant contributions to knowledge.

These statements are even truer today than they were 25 years ago in 1962.

Grote Reber is a living legend. He is my friend and fellow explorer of the cosmos and it is my privilege to participate today in his 76th birthday celebration in Ottawa. Congratulations and many happy returns!

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