PROCEEDINGS OF SCIENCE

Historical Introduction

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50 Years Westerbork Radio Observatory, A Continuing Journey to Discoveries and Innovations
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Chapter 1

Historical introduction

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From the English longbows at the battle of Crécy (1346) to Winston Churchill's world war I mobilized cannon (its true identity hidden behind the pseudonym "[water] tank"), warfare has always pushed technological innovation to new fronts. The second world war (WWII) was no exception. It gave us technology ranging from the dynamo-powered flashlight (a Philips invention) to jet engines, and space-capable rockets (Germany's V2), not to mention (in a completely different realm) the mass production of Penicillin. In fact, it could be argued that WWII inventions marked the inception of the modern technological era[1].

In the field of electronics, the war led to innovations such as radio navigation, aircraft landing systems, and radar. It was these developments which were to have a revolutionary impact on astronomy, initially in Britain, Australia and the United States. But the story begins in the US, with the electronics of the 1920s and '30s.

Figure 1. Karl G. Jansky (c. 1933)

Around 1930, there was increasing interest in the use of radio frequencies for communication. One of the main players, the Bell Telephone Laboratories in New Jersey, asked their research engineer, Karl Jansky (Figure 1), to investigate the interference environment in the "short-wave" band around 20 MHz. (In today's radio astronomy, this would be considered a long wavelength). In particular, Jansky was to look at frequency bands where naturally-occurring radio waves were weak, since this background radiation would be a limiting factor in determining whether faint communication signals could be detected at large distances. Jansky constructed an antenna (Figure 2) suitable for scanning the horizon at about 15 m wavelength. The working of his instrument has been thoroughly described in several publications (Kraus, 1981).

1 see for example on Wikipedia: https://en.wikipedia.org/wiki/Technology_during_World_War_II

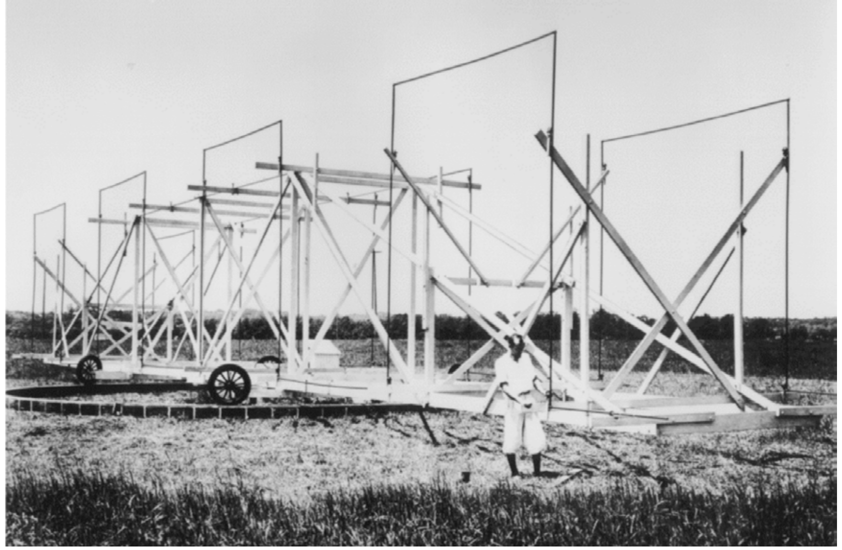


Figure 2. Jansky antenna (c. 1930)

Jansky was both a good radio engineer, and a careful scientist. He detected "static" from local and distant thunder storms, as expected. He also found atmospherics from unknown sources, including one type which was always present, and followed a consistent daily pattern. It eventually became clear that the diurnal cycle adhered to timing, not of 24^h duration, but lasting 23^h56^m: The temporal pattern was sidereal, not solar. The most intense radio static came from the direction of the stellar constellation Sagittarius, which was interesting as it is the location of the center of the Milky Way. The nature of the radiation – the process by which it was produced – was a complete mystery. The Galaxy we see consists of stars and glowing gas clouds. Could the radio waves also have their origin in stars? Since the sun is a star, one might expect a radio signal to reach us from the sun, but in fact, none of the antenna records showed a hint of solar radio emission.

Figure 3. Grote Reber (c. 1960)

Having completed his investigation of radio static, Bell Laboratories assigned Jansky to other research, and the detection of extraterrestrial radio emission was not followed up. Although there were several proposals to continue studies of radio emission from space, none of them received funding. At the height of the great depression, this may not have been too surprising. The field was open to anyone with time, a large space (Jansky's antenna spanned some 30 m), an interest in radio equipment and a bit of money. In Wheaton, Illinois, there was such a person: Grote Reber (Figure 3). He had the discipline of an engineer, and the curiosity of a scientist. The backyard of his mother's house (also his residence) was just large enough for his project: The construction of a 9 m parabolic reflector and its supporting struts. He had studied radio engineering and electronics, and was a keen "ham" (radio amateur: call-sign – W9GFZ). In his spare time, Reber constructed a steel reflector which could be steered in elevation. It was a meridian-transit radio telescope (Figure 4).

Figure 4. Reber 9-m antenna in Wheaton, Illinois (c. 1938)

With his instrument (and after overcoming initial difficulties), Reber was eventually able to confirm the existence of Jansky's radio emission from the Milky Way, and began making the first maps of the radio sky at declinations >-45°. His first astronomical publication on radio emission appeared in June of 1940. Reber continued his measurements throughout the war. With the 1940 publication, the story takes an unexpected twist.

Figure 5. Jan Oort (c. 1935)

Prof. Jan Oort (Figure 5) of Leiden University Observatory was keenly interested in understanding our Galaxy, having studied it for nearly 20 years. From the motions of stars near the sun, Oort had shown how the kinematics could be unraveled. What one really needed, however, was information on the motion of stars near the galactic center, but obtaining this seemed all but impossible. Research in the 1930s had shown that the disk of the Milky Way is filled with dust particles which obscure its more distant reaches, and in particular mask the vital center, around which everything spins. Seeing through this dusty fog seemed impossible. An important clue to overcoming the obstacle was contained, surprisingly, in Reber's article, but it would only reach Oort by a circuitous path.

In May 1940, the Netherlands was invaded by Germany, and a number of American publishers, with postal delivery in Europe uncertain, suspended the dispatch of their periodicals. By the autumn, Oort expressed his concern about the

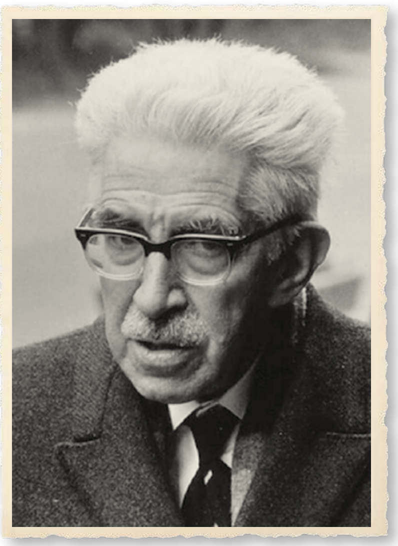
delayed deliveries to his former colleague Bart Bok (then working in America), who looked into the matter. An agreement was reached which would ensure that scientific publications (like important astronomical journals) would reach the major European institutions despite the war. By December, the June issue with Reber's article had reached Oort. There are several facts which indicate that the information about radio emission from the Galaxy had an immediate impact. Oort sent the article to H. Rinia (Figure 6), a senior Philips engineer who had done some consulting work for Leiden Observatory. In his reaction, Rinia notes that the radio waves will penetrate atmospheric clouds as well, making observations of galaxies at radio wavelengths possible, even from the cloudy Dutch environment.

There was another indication that the research on radio emission from the Milky Way had significant impact in the Netherlands. At the time, there was a popular Dutch astronomy magazine called *Hemel en Dampkring* (Sky and Atmosphere), rather similar to America's *Sky and Telescope*. Within a couple of months, a summary of the Reber article was published by D. Koelbloed (an Amsterdam astronomer, who never did any research in the radio field). Oort had close contacts with *Hemel en Dampkring* 's editor, the astronomer J.J. Raimond. It seems fairly likely that Oort had something to do with the appearance of an article on the topic of radio astronomy.

Figure 6. Herre Rinia

After this flurry of activity and interest in the possibilities offered by radio research of galaxies, several years of relative silence follow. While the trigger had been Reber's 1940 article, it is unclear to what extent Dutch astronomers might have been aware of Jansky's work, most of which had been published in engineering journals. There are hints in a 1977 interview that Oort might have heard of it before 1940. He spent most of 1939 visiting astronomers in the U.S., and Jansky's discovery might well have come up in discussions. There is, however, no hard evidence that Oort was aware of it, and it seems that if he was, it had not made much of an impression on him.

Figure 7. Marcel Minnaert (1967)



In 1941, not long after Reber's article had caused some commotion amongst Dutch astronomers, Marcel Minnaert (Figure 7), the director of Utrecht Observatory, organized the first national astronomy conference (NAC). There is a remarkable photograph of the participants (Figure 8), noteworthy because it includes many of the people involved in this early interest in radio astronomy (and almost as notable because the original is in color). There is also a program

Figure 8. 1941 NAC participants: Oort (far left), Minnaert (3rd from left), Houtgast (back centre, with beard), Van de Hulst (front centre, in shirt sleeves), Koelbloed (far right)

which lists the talks given during NAC 1941. Not a single one is related to radio emission, but this absence is probably not too surprising. No one present would have had much knowledge of the radio technique, whatever their interest might have been (though Koelbloed might have given a brief summary).

Here the matter rested for most of the war years. Oort did pursue the problem of interstellar dust, its production and destruction. He got Henk van de Hulst (Figure 9), then a student of Minnaert, to participate in this research, and to that end he arranged an extended visit to Leiden in the first quarter of 1944. Minnaert, who was politically left wing, was taken hostage, as were other prominent Dutch citizens, from 1942 to 1944. Oort left Leiden for most of the war years, to avoid a similar fate. From his undercover address he would regularly cycle the 100+ km to Leiden, to keep contact with colleagues and astronomy. He kept busy researching a planned book on the Galaxy, a work which never saw the light of day. One can only imagine that sometime, while thinking of the book, the possible use of radio astronomy in galaxy studies may have occurred to him.

Figure 9. Henk van de Hulst

In the planning for Van de Hulst's 1944 visit, no mention is made of radio. It only comes up after the visit has already begun. In Van de Hulst's own words, "In the spring

Figure 10. 1944 Leiden colloquium: Van de Hulst speaking, Oort far left (from 1957 film)

of 1944 Oort said to me: 'We should have a colloquium on the paper by Reber. Would you like to study it? And, by the way, radio astronomy can really become very important if there were at least one line in the radio spectrum.' " That line was, of course, the 21 cm HI transition, the likely detection of which was predicted by Van de Hulst at the April meeting.

The 1944 colloquium (Figure 10) in Leiden had as its title, *Radiogolven uit het Wereldruim* (Radio waves from space), and Oort had arranged for two speakers to discuss Reber's results. Cornelis Bakker (a physicist with the Philips NatLab., Figure 11) reviewed radio technique. Van de Hulst considered the origin of continuum radio emission, then possible lines: Recombination, and that of neutral hydrogen at 21 cm.

The existence of a hyperfine transition in atomic hydrogen was already known, but its physical properties were rather uncertain. Moreover, the conditions in interstellar space were unclear. The line might appear in absorption or in emission. On top of that, the hydrogen might all be in molecular form (H_2), rendering it undetectable by radio. In view of all these uncertainties, Van de Hulst was cautious in what he said.

Oort, never one to let things stagnate, wrote Bakker just four days after the Leiden Colloquium, thanking him for his contribution, but also asking whether Philips could build a receiver for the radio antenna reflector which was already taking shape in his mind. In his reply Bakker said that while there was interest at Philips, little could be done before the end of the war.

Figure 11. Cornelis Bakker (1959)

What was needed to look for the 21 cm HI line? The antenna, which was only the most visible component required (it is pictured in Figure 4), would in Oort's original plan be constructed by the Observatory workshop. He may have reasoned that if Reber could construct a 10 m dish with his own labor and funding, then the Observatory would surely be able to build something larger using its manpower, and public funding. This was rather optimistic, and a year later he was in contact with a civil engineering firm. Oort may not have realized that it would be almost as difficult to acquire a sufficiently low-noise receiver: 21 cm was an extremely short wavelength at the time. Bakker indicated that Philips could build low-noise amplifiers only for wavelengths of 30 cm and longer. Finally, there was the problem of finding an excellent radio engineer, as Reber had strongly advised in correspondence.

Figure 12. A.H. de Voogt (c. 1947)

Despite the challenges, Oort and others began serious efforts to carry out radio astronomical research from the Netherlands. In 1946 or 1947, Ir A. H. de Voogt (Figure 12), head of the Post Office Radio Division, appropriated a number of abandoned German Würzburg radar dishes and set up the country's first radio astronomy observatory near Kootwijk. He, Minnaert and Jaap Houtgast (Figure 13) helped form a workgroup to study the ionosphere and radio emission from the sun. By 1947, Oort was also involved in the discussions.

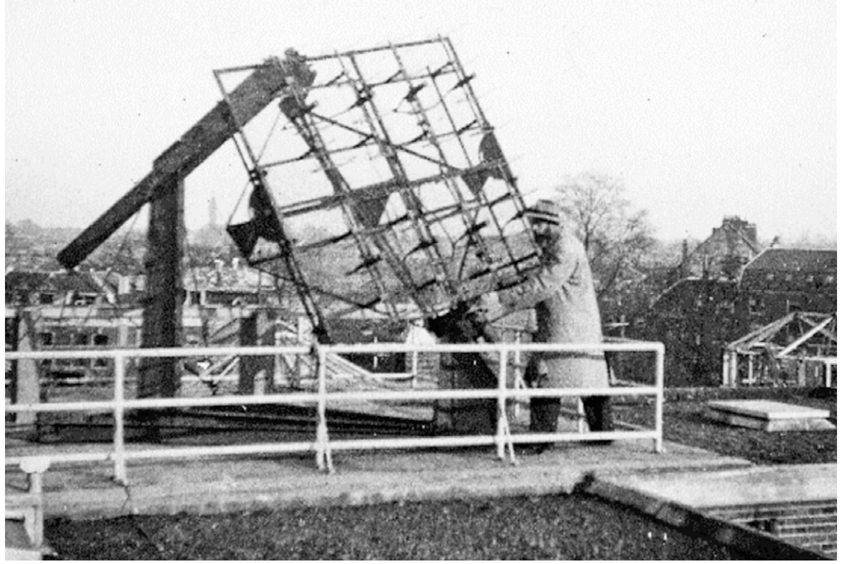


Figure 13. Jaap Houtgast with radar antenna for solar observations (Utrecht, Dec. 1947)

Figure 14. Cornelis Gorter (portrait by Harm Kamerlingh Onnes)

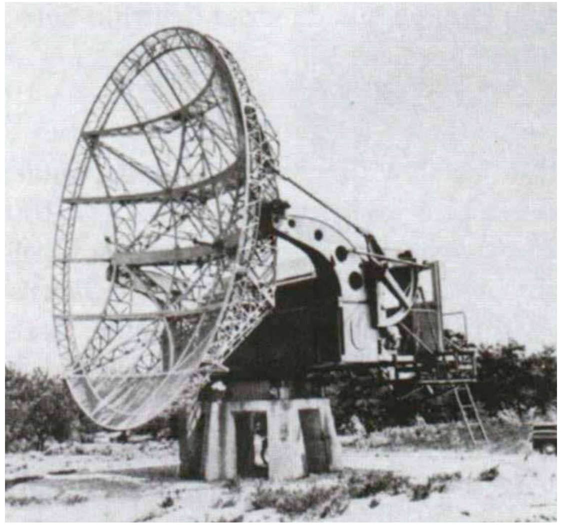


Figure 15. Kootwijk Würzburg 7.5-m radar antenna, observed HI, 1951

The Leiden physicist Cornelis Gorter (Figure 14), who had done laboratory experiments with microwaves, was also interested in detecting the 21 cm line, and apparently began an independent project in 1946. By 1948 he had an engineering student from Delft, H. Hoo, working on the problem. Meanwhile, De Voogt had suggested that Oort might use one of the Würzburg antennas (Figure 15) for the 21 cm line search, and the Gorter and Oort efforts were merged. Oort and Minnaert set up a Foundation for Radio Astronomy (Figure 16), which included representatives from Philips, the Meteorological Institute (KNMI) and the Post Office, and Hoo became its first employee.

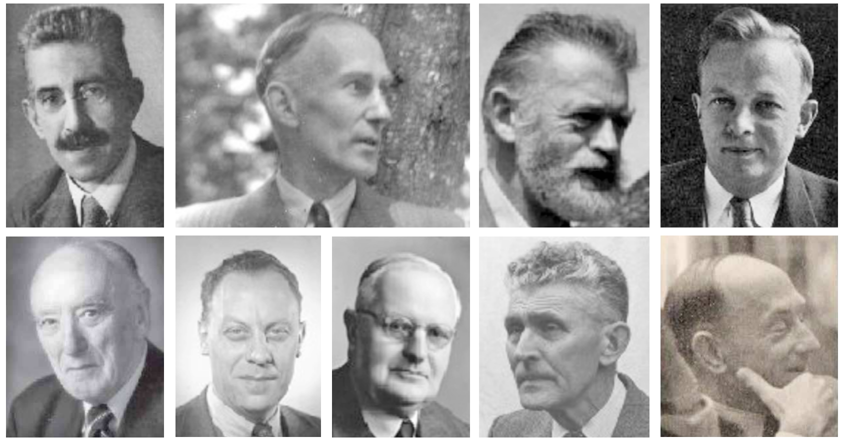


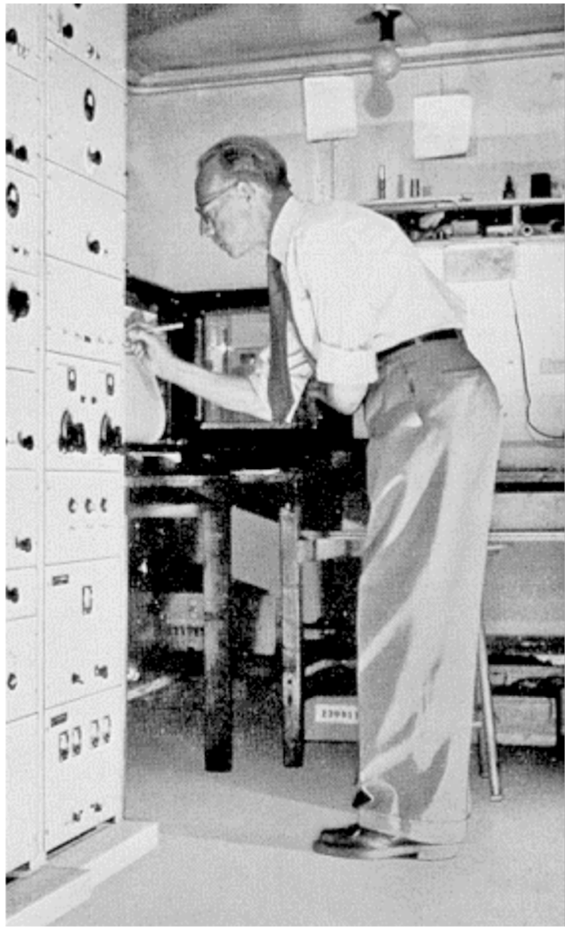
Figure 16. First Board of SRZM (1949).
Top (l. – r.), Minnaert (vice chairman), Oort (chairman), Houtgast (secretary), Van de Hulst.
Bottom (l. – r.), Frans Stumpers and Rinia (both Philips NatLab), Vening Meinesz and Jan Veldkamp (both KNMI), De Voogt (PTT)

By 1949 test observations were being made on the borrowed Würzburg at Kootwijk using Gorter's amplifier. Progress was steady, but slow. Then, on 10 March 1950, disaster struck. A fire destroyed the receiver hut and all the equipment. Some personal items were also lost. The total loss was estimated at 8000 guilders, about 50% of the annual budget, and nothing was insured. Fortunately, no one was hurt, but Gorter's amplifier and a new Brown recorder worth 3500 guilders had to be written off.

Meanwhile, across the pond... By 1950, another team was also looking for the line. Harold Ewen and Edward Purcell (Figure 17) at Harvard had heard about Van de Hulst's prediction at a conference in 1949. Both had radar experience and came up with a simple solution to the antenna problem: A horn. Their equipment was similar to that of the Dutch, based upon a super heterodyne receiver, with one important innovation. Frequency switching was used to remove amplifier drift. In addition, certain electronic components in Ewen's possession

Figure 17. Harold Ewen and Edward Purcell, 1956

Figure 18. C.A. (Lex) Muller in the Kootwijk Würzburg receiver room (c. 1954)



were probably of higher quality. The line was detected on Easter weekend, 1951. *Finally, Dutch success just weeks later...* With the newly employed engineer Lex Muller (Figure 18), the Dutch team detected the line just 6 weeks after Ewen and Purcell, and both results were published simultaneously. For Ewen it meant the completion of his Ph. D. thesis. He and Purcell did not follow up their detection. For Oort and his team, it was only the beginning of systematic studies, first of the Milky Way, and later of other galaxies.

While the Foundation was occupied with its effort to detect the HI line, planning also continued with the intention to construct a 25 m class radio telescope to investigate the characteristics of atomic hydrogen in the Milky Way. Once the line had been detected, some of the manpower could be switched to the 25 m effort. Observations with the 7.5 m Würzburg at Kootwijk continued, and a survey of the visible sky was made in 1952-1953. The data were reduced and interpreted under Van de Hulst's guidance with the help of several students, and in collaboration with Muller and Oort (1954). By 1951, the 25 m antenna

Figure 19. Queen Juliana and Prof. Oort, opening of Dwingeloo 25-m Telescope, 1956

project was contracted to the civil engineering firm Werkspoor, and at the end of 1953 a site had been chosen near the village of Dwingeloo. Construction began in 1954, and the Dwingeloo Telescope was opened by Her Majesty Queen Juliana in April, 1956 (Figure 19).

Oort once again used a two-track approach by starting the next large telescope project during the latter stages of its predecessor, in this case, the Dwingeloo Telescope. Always aware that angular resolution at radio wavelengths, around 1 arcmin, would usually be inferior to that of optical telescopes, where 1 arcsec was possible, the plan would be to build an array of some 5 km overall size, in collaboration with Belgium and Luxembourg. The array would be in the form of a cross (or T), building on several successful radio telescopes in Australia, Canada and the US. It became the Benelux Cross Antenna Project (BCAP), to be constructed near the Belgian/Dutch border. The details of the project are described by E. Raimond. In the end, Belgium withdrew from the project, and it was modified, to become the WSRT.