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HIGHLIGHTING THE HISTORY OF JAPANESE RADIO ASTRONOMY. 2: KOICHI SHIMODA AND THE 1948 SOLAR ECLIPSE

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Abstract: Just two years after Dicke carried out the first radio observations of a solar eclipse, a young Japanese physics graduate, Koichi Shimoda, attempted to observe 3,000 MHz emission during the 9 May 1948 partial solar eclipse. In so doing he unwittingly became the 'founding father' of Japanese radio astronomy. In this paper as our mark of respect for him, we list Shimoda as the lead author of the paper so that his observations can finally be placed on record for the international radio astronomical community.

Keywords: Japan, radio astronomy, solar eclipses, Koichi Shimoda.

1 INTRODUCTION

The early history of Japanese radio astronomy has recently been reviewed by Ishiguro and Orchiston (2013) and Ishiguro et al. (2012), updating the account provided by Tanaka (1984). In the above-mentioned papers Ishiguro and Orchiston and their collaborators mention in passing Koichi Shimoda's pioneering observations of a solar eclipse in 1948. This was the first radio astronomical experiment conducted in Japan, and as such Shimoda must be recognised as the 'founding father' of Japanese radio astronomy. In this short paper we provide details of Shimoda's instrumentation and observations, and place his pioneering experiment in an international context.[1] Japanese locations mentioned in the text are shown in Figure 1.

Figure 1: Japanese localities mentioned in the text. Key: 1 = Hiraiso, 2 = University of Tokyo, 3 = Tokyo Astronomical Observatory (Mitaka), 4 = Toyokawa Observatory, 5 = Nagoya University; and 6 = Osaka City University.

2 SOLAR ECLIPSES AND EARLY RADIO ASTRONOMY

In the years immediately following WWII the angular resolution of radio telescopes was poor, and observations of total and partial solar eclipses offered a particularly elegant way of pinning down the positions of the localised radio-emitting regions. The logic behind this was that as the Moon's limb moved across the Sun's disk during the eclipse and successively occulted and then unmasked different radio-emitting regions there would be associated dips and rises in the chart record. Ideally, more than one observing site was desirable as any dip in the chart record obtained at a single site would only indicate that the emitting region was located *somewhere* along the arc subtended by the lunar limb *at that particular moment*. However, if there were several widely-spaced observing site the intersections of the different limb profiles allowed the positions of the radio-emitting regions to be identified with considerable accuracy (e.g. see Christiansen et al., 1949a).

In addition, radio astronomers could use observations of solar eclipses to determine the distribution of radio brightness across the disk of the Sun, and the shape of the corona at radio wavelengths (see Castelli and Aarons, 1995).

The American scientists, Robert H. Dicke (1916–1997) and E. Robert Beringer (1917–

2000) and Britain's Kenneth F. Sander were the first to use this technique in radio astronomy when they carried out observations of a partial solar eclipse on 9 July 1945 (see Dicke and Beringer, 1946; Sander, 1947).

3 KOICHI SHIMODA AND THE SOLAR ECLIPSE OF 1948

Early in the northern spring of 1948 Koichi Shimoda (b. 1920; see Figure 2) had just begun working at the Institute of Science and Technology on the Komaba Campus of the University of Tokyo. The Institute had been founded the year before to replace the Aeronautical Research Institute, and upon searching through the 'scraps' left over from this earlier institute Shimoda discovered a parabolic reflector:

> The surface of the reflector was made of copper plates mounted on a hardwood frame. The shape of the paraboloid was precise to within a few millimetres with a focal length of about 73 cm.
>
> I was much delighted with this reflector, because it had the quality comparable to, orbetter than the best radar antenna for 10 cm waves. Moreover, the size of 2 m in diameter and 35 cm in depth was just [what] I wanted. (Shimoda, 1982: 32).

From his childhood Shimoda had an interest in astronomy and liked to visit the Tokyo Astronomical Observatory (TAO). As a high school student he had observed a solar eclipse with a small telescope, so when he read in a newspaper about a partial solar eclipse on 9 May 1948 that would be visible from Japan he also decided to observe it—but this time at radio wavelengths.

During the latter part of WWII Shimoda had worked on the development of microwave radar, and by the cessation of hostilities he was thinking about the ways in which radar could be applied to scientific research. Through various conversations with Professor Hatanaka at the TAO he was aware of Jansky's and Reber's research in the exciting new field of radio astronomy, and then he read Dicke and Beringer's 1946 paper about their observation of the 9 July 1945 partial solar eclipse using a small parabolic antenna and a 24,000 MHz receiver.[2] Shimoda noted that they successfully recorded a considerable decrease in the signal strength in the course of the eclipse (see Figure 3), and he decided to observe the 1948 eclipse, but at 3,000 MHz, where he felt there was more chance of detecting limb-brightening. This was his principal motivation for conducting the 1948 eclipse observations.

With just one month in which to assemble the necessary equipment Shimoda hurried to construct a radio telescope. He began by installing a microwave feed at the focus of the dish, and

Figure 2: Koichi Shimoda as a 26-yr old in 1947, one year before he observed the solar eclipse.

connected this to an ex-WWII Japanese "… 3-GHz radar receiver using a magnetron local oscillator [which] was modified into a rudimentary Dicke-type radiometer." (Shimoda, 1982: 32). In order to complete this simple heterodyne receiver he had to develop a crystal mixer, and the components of this are shown in Figure 4.[3] The signal would be displayed on an oscilloscope. Shimoda then fabricated a simple yet effective mounting to support the antenna.

The path of totality of the eclipse passed over coastal China, the Korean Peninsula, the Sea of Japan and between the northern Japanese island of Hokkaido and neighbouring Sakhalin Island, so from Tokyo it would only be visible as a partial eclipse. There, the eclipse would commence at 10h 05m 51.4s local time, reach a maximum at 11h 33m 46.5s, when 77.3% of the solar disk would be covered, and end at 13h 05m 43.3s. Shimoda's simple radiometer had a half-power beamwidth of about 3° (Shimoda, 1982: 35), so it was necessary to move the antenna manually about every 5 minutes in the course of the 3-hour eclipse to make sure the Sun always remained in the beam.

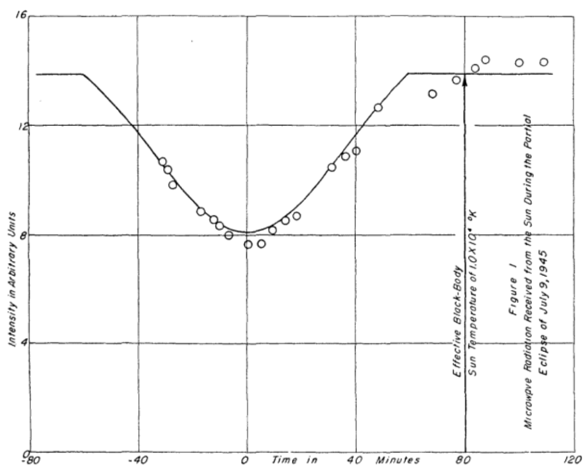

Figure 3: Observations of the 9 July 1945 partial solar eclipse (after Dicke and Beringer, 1946: 376).

Figure 4: Components of the mixer that Shimoda made in 1948 for the 3,000 MHz receiver.

The vital day, 9 May 1948, finally arrived, and Shimoda proceeded to observe the eclipse, recording details of his instrumentation and of the event in a notebook (Figure 5), along with a tracing of the oscilloscope record from the start of the eclipse until just before it ended (he did not have access to a chart recorder). He developed a sawtooth wave generator at ultra low frequency to sweep the oscillator (see Shimoda, 1951). Because he did not make any on-Sun/off-Sun measurements before or after the eclipse Shimoda could not be certain that he actually had detected any solar radio emission.

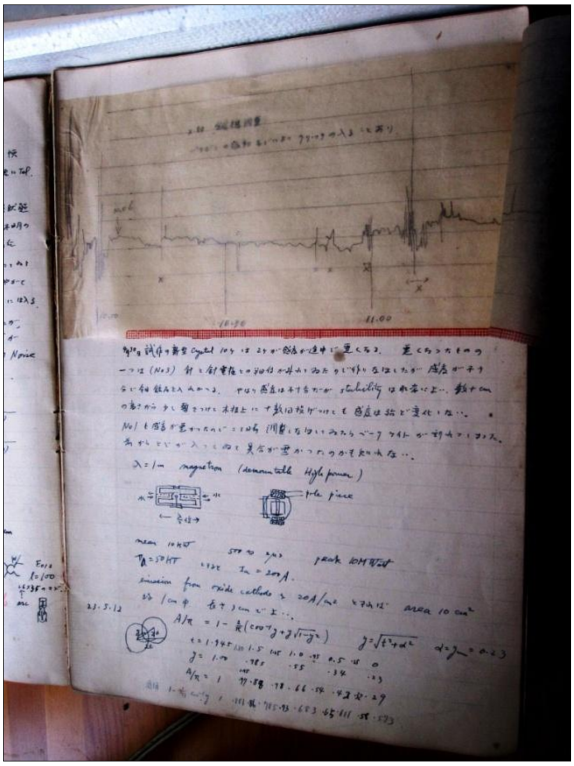

Figure 5: The relevant page of Shimoda's notebook listing details of the radio telescope and the eclipse, plus a tracing of the oscilloscope record.

The oscilloscope display is reproduced here in Figure 6, and it fails to show the anticipated decline in signal strength during the eclipse. As Shimoda (1982: 32-33) was quick to point out:

> Because of the poor sensitivity and stability of the receiver, a decrease in received power can barely be recognized. The background noise and external disturbance prevented me from revealing any fine structures.

Interference recorded at about 1110 and at 1230 local time is very apparent, while the large variations in the signal strength between about 1050 and 1120 make it very difficult to interpret this section of the record.

Fortuitously, this eclipse occurred exactly one year after the previous solar maximum (Aldrich and Hoover, 1954), and at this time the Sun was still very active, with many sunspot groups present (e.g. see Whitney, 1949). Indeed, the sunspot numbers recorded for the months of April, May and June 1948 (187.6, 170.6 and 170.6, respectively), far exceeded those listed for any other month of 1948 (Aldrich and Hoover, 1954: 166). Normally, when sunspots are abundant there is a greatly-increased likelihood that solar bursts will occur in the course of an eclipse (Hey, 1955), but fortunately these are rare at frequencies as high as 3,000 MHz, where Shimoda's radio telescope was operating. So if his equipment had been sensitive enough, then Shimoda should have been able to detect minor variations in the signal strength when major sunspot groups were masked and unmasked by the Moon's disk in the course of the eclipse.

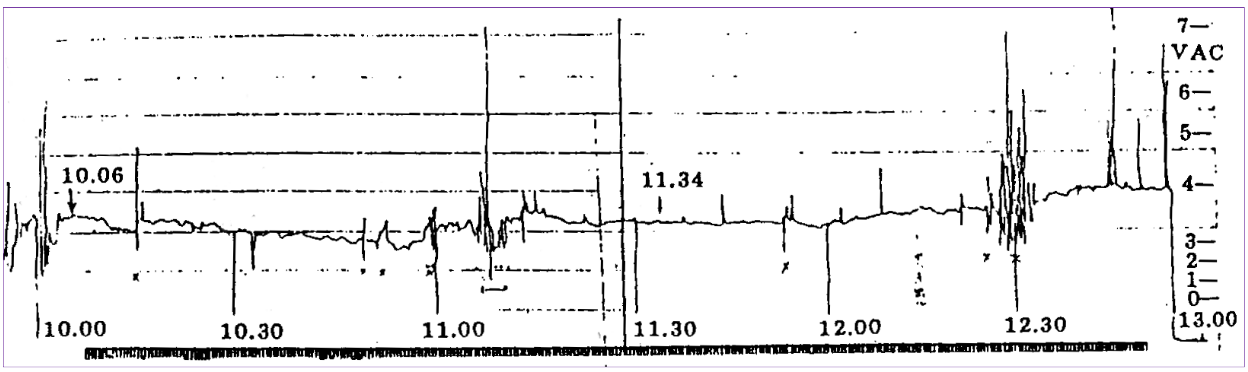

Figure 6: A copy of the oscilloscope display during the attempted observation of the 9 May 1948 partial solar eclipse at 3000 MHz (after Shimoda, 1982: 33).

Because of this rather unsatisfactory outcome, Shimoda chose not to publish his observations. Instead, "The observed result was only orally reported at a meeting and has not been published anywhere." (Shimoda, 1982: 33), and it was only much later, when he realised that this was the first radio astronomical experiment carried out in Japan, that he chose to rectify this by summarising his project during an 'After Dinner Talk' that he presented at the 13th Okazaki Conference in 1982. His account subsequently was published in the record of that meeting (Shimoda, 1982), thus belatedly entering the public domain for the first time

The present paper, for its part, is the first detailed account of Shimoda's experiment, and it is particularly fitting that it is the first of the published case studies in the IAU Early Japanese Radio Astronomy Project, and that as our mark of respect for him, Shimoda can be listed as the lead author of the paper and finally place his observations on record for the international radio astronomical community.

Long after the 1948 eclipse, and only after conducting extensive historical investigations, Shimoda (1982) discovered that his antenna originally was one of two that were manufactured for the Aeronautical Research Institute in 1930 (see Figure 7) and used for experiments in acoustics.

As it turned out, in 1948 Shimoda's little radiometer was merely beginning its 'career' in radio astronomy, even though Shimoda decided to move on to other research projects and had no further use for it. Kenji Akabane from the TAO had a brother who also was a Professor at the University of Tokyo and through him met Shimoda and learnt about the 1948 experiment. By this time TAO had begun regular solar monitoring at low frequencies and Akabane was keen to start observations at much higher frequencies. Shimoda's antenna would be ideal for this, so in 1951 Akabane arranged for it to be transferred to Mitaka. Once there it was remounted (see Figure 8), and for many years was used very effectively by the TAO radio astronomers (as will be detailed by Nakajima et al. in the next paper in this series).

4 DISCUSSION

4.1 Shimoda's Observations in an International Context

Shimoda's interest in solar eclipses during the late 1940s was part of a world-wide trend as radio astronomers from Australia, Canada, England, France, Russia and the USA all sought to use these celestial events to further our understanding of the Sun and its radio emission (see Table 1).[4]

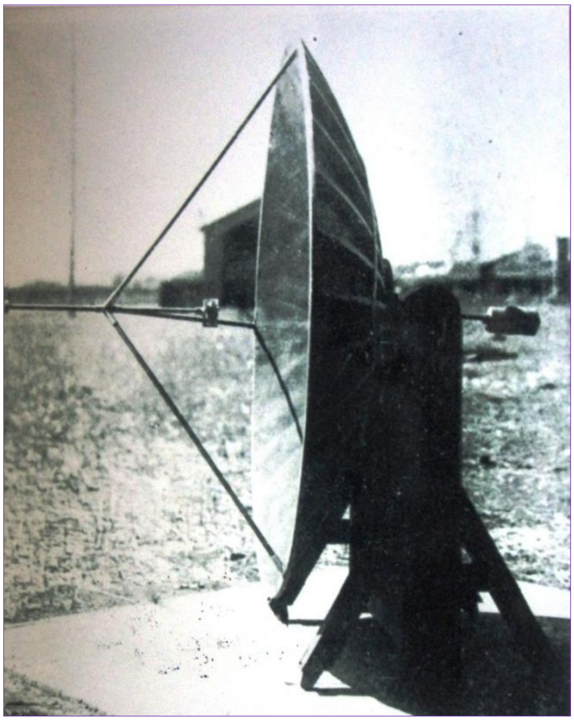

Figure 7: A view of the 2-m parabola at the Aeronautical Research Institute in the 1930s.

By the time Shimoda observed the 1948 eclipse, three earlier solar eclipses had been observed at radio frequencies (see Table 1, and Hey, 1955 and Sullivan, 2009: 290-292 for details), but the breakthrough in the use of solar

Figure 8: The radio telescope at Mitaka, completed by Kenji Akabane, which used Shimoda's original parabolic reflector.

Table 1: Solar eclipses observed at radio frequencies between 1945 and 1952.

1945
• In England, observations of the 9 July partial eclipse at 9,428 MHz using a small parabola (Sander, 1947).[5]
• In the USA, observations of the 9 July partial eclipse at 24,000 MHz using a small parabola (Dicke and Beringer, 1946).

1946
• In Canada, observations of the 23 November partial eclipse at 2,800 MHz using a small parabola (Covington, 1947).
• In the USA, observations of the 23 November partial eclipse at 480 MHz using a small parabola (Reber, 1946).

1947
• Off the coast of Brazil, Russian radio astronomers observed the 20 May total solar eclipse at 200 MHz using a broadside array (Khaykin and Tchikhatchev, 1947).
• At sea in the Atlantic Ocean, an American radio astronomer observed the 20 May total solar eclipse at 9,428 MHz using a small parabola (Hagen, 1949).

1948
• In Japan, observations of the 9 May partial eclipse at 3,000 MHz using a small parabola (Shimoda, 1982; Shimoda et al., this paper).
• In Australia, observations of the 1 November 1948 partial eclipse at 600, 3,000 and 9,428 MHz using an ex-WWII radar antenna and small parabolic antennas (Christiansen et al., 1949a; 1949b; Minnett and Labrum, 1950; Piddington and Hindman (1949).

1949
• In France, observations of the 28 April partial eclipse at 158, 555, and 1,200 MHz using a small parabola and two 7.5m Würzburg antennas (Laffineur et al., 1949; 1950; Steinberg, 1953; cf. Orchiston and Steinberg, 2007).
• In Australia, observations of the 22 October partial eclipse at 60, 100, 200, 600, 1,200 3,000 and 9,400 MHz using Yagi antennas, an ex-WWII radar antenna and small parabolic antennas (Wendt, et al., 2008).

1950
• At the remote site of Attu Island in Alaska, American radio astronomers observed the 12 September total solar eclipse at 470, 3,000 and 10,000 MHz using three small parabolas (Haddock et al., 1951; Hagen, 1951; Reber and Beck, 1951).

1951
• At the remote site of Markala in French Sudan, Africa, French radio astronomers observed the 1 September annular eclipse at 169 and 9,350 MHz using a small parabola and an ex-US radar antenna (Arsac et al., 1953; Blum et al., 1952a; 1952b; Bosson et al., 1951; Denisse, et al., 1952; cf. Orchiston and Steinberg, 2007).

1952[6]
• At the remote site of Khartoum in the Sudan, Africa, French radio astronomers observed the 25 February total solar eclipse at 225 and 555 MHz using a small parabola. French radio astronomers based in Dakar (French West Africa), Bizerte (Liberia), Paris and Onsala (Sweden) also observed this event as a partial solar eclipse at 169 and 255 MHz using three ex-US radar antennas and two 7.5m Würzburg antennas (Arsac et al., 1953; Blum et al., 1952b; Denisse, et al., 1952; Laffineur et al., 1952; 1954; cf. Orchiston and Steinberg, 2007).
• At the remote sites of Lwiro-Bukavu and Ngili-Leopoldville in what then was the Belgian Congo, Africa, Belgian radio astronomers observed the 25 February partial eclipse at 169 MHz using two ex-US radar antennas (Coutrez et al., 1953).

eclipses to investigate the locations of radio-emitting regions only came later in 1948 with the advent of the 1 November partial solar eclipse. This event was observed by five different teams of Australian radio astronomers from three quite separate geographically-spaced sites, and at three different frequencies (see Orchiston, 2004; Orchiston et al., 2006; Wendt et al., 2008; Wendt et al, 2011). Meanwhile, French radio astronomers were the first to derive the form and areal extent of the radio corona, when they analysed 169 MHz observations of the 1951 and 1952 solar eclipses listed below (for details see Orchiston and Steinberg, 2007).

4.2 Shimoda's Career and Subsequent Research Fields

Despite unwittingly being the 'founding father' of Japanese radio astronomy, Koichi Shimoda quickly lost interest in solar observations and chose not to pursue a career in this exciting new field of research. In the early 1950s there were four small research groups active in solar radio astronomy in Japan: Tokyo Astronomical Observatory had a broadside array and two Yagi arrays at Mitaka; Nagoya University a small radiometer at Toyokawa Observatory; Osaka City University a small radiometer at an on-campus site; and the Radio Research Laboratories of the Ministry of Posts and Telecommunications a broadside array at Hiraiso (see Ishiguro et al., 2012 and Ishiguro and Orchiston, 2013; and Figure 1 for relevant localities). Yet by this time Shimoda was already happily employed as an Assistant Professor by the University of Tokyo and was involved in re-search on microwave spectroscopy. It was ironic, therefore, that

> The microwave spectroscopy research led by him made an outstanding contribution to the radio astronomy in Japan. In addition, at the early stage of maser and laser research in the

> 1950s and 1960s, he made achievements in building the basis of the maser and laser study together with C.H. Towns [sic.; see Shimoda et al., 1956; 1957] and other scientists. After that, he proceeded to the study of laser spectroscopy and developed a wide variety of researches ranging from the basic research of Stark Spectroscopy and double resonance to laser-applied technology.
>
> Prof. Shimoda has passionately devoted himself to his research as well as the science and physics education. He served as the chairman of the Physics Education Society of Japan for 16 years until 2 years ago [i.e. until 2006] and he has published numerous educational text-books and study guide. Furthermore, he has produced a large number of leading researchers and educators in the field of physics.
>
> In May 2007, there was a celebration of his eighty-eighth birthday. The highlight of the celebration was Prof. Shimoda's lecture. Three experiments were performed with scientific demonstrations and explanations based on his own ideas. They were performed in front of the people who came for the celebration: the first experiment was a magnetic levitation experiment using permanent magnets only (floated body was completely motionless), the second was an interference experiment using laser and optical fiber, and the third was an automatic Sink-Float experiment [actually it was a self-moving Cartersian diver]. All the experiments were both surprising and amusing. Prof. Shimoda's never-ending affection and curiosity toward physics and his passion for enlightenment left a strong impression on the participants. (Tsubono, 2009).

While he did not follow developments in solar radio astronomy, the above quotation indicates that Shimoda did maintain an active interest in international radio astronomy, and in this context he was one of those who contributed to the detection of interstellar methylamine using the TAO's 6-m millimetre radio telescope (see Kaifu et al., 1974).

In 2008 Professor Shimoda's lifelong contribution to research, education and the training of future Japanese physicists was formally recognized at a national level when he was selected as one of the 'Persons of Cultural Merit' by the Japanese Ministry of Education.

5 CONCLUDING REMARKS

In his 1984 review paper, Tanaka claimed that Japanese solar radio astronomy began in 1949, but he was not aware that Kiochi Shimoda from the University of Tokyo attempted to observe the 9 May 1948 partial solar eclipse at 3,000 MHz using a simple radiometer that he assembled. Nor is Shimoda's experiment mentioned in Woody Sullivan's (2009) *Cosmic Noise. A History of Early Radio Astronomy.*

However, Shimoda's solo pioneering efforts were soon eclipsed as small groups of solar radio astronomers emerged in the early 1950s at Hiraiso, Osaka, Toyokawa and Mitaka (in Tokyo). The Tokyo Astronomical Observatory group at Mitaka and the Nagoya University group at Toyokawa both followed up on Shimoda's work by carrying out successful observations of solar eclipses during the 1950s (see Hatanaka et al., 1956; Tanaka and Kakinuma, 1958; and Nakajima et al., 2013). These investigations followed a world-wide trend at that time when radio observations of solar eclipses were used successfully to pinpoint the locations of radio-emitting regions and examine the distribution of emission across the solar disk at different frequencies (Castelli and Aarons, 1995). However, by the late 1950s solar eclipses had become much less important as the availability of grating interferometers and position interferometers allowed these types of investigations—and others—to be carried out on a regular basis. No longer would radio astronomers have to wait for the next solar eclipse in order to continue their research programs.

6 NOTES

1. This is the second paper in a series reporting the results of an international project conducted under the auspices of the IAU Working Group on Historic Radio Astronomy, which aims to document the early history of Japanese radio astronomy. The first paper in the series (Ishiguro et al., 2012) provided an overview of early Japanese radio astronomy, and the present paper is the first in a series that will examine in detail different aspects of these early investigations.
2. At that time Shimoda did not know of Arthur E. Covington's radio observations of a partial eclipse in 1946, or that the Russians and John P. Hagen had observed a total solar eclipse in 1947.
3. In the immediate post-War years the US Army had banned the construction by the Japanese of any type of radar system, but fortunately there was no prohibition on the construction of receivers.
4. In addition to references listed in this Section and in Table 1, a poster paper on early Australian *and* French solar eclipse observations was displayed at the 2007 Winter Meeting of the American Astronomical Society in Seattle (see Orchiston et al., 2007).
5. Hey (1955) mistakenly associates Sander's observations with the 23 November 1946 eclipse, but Sullivan (2009: 115, 290) shows that he actually observed the 9 July 1945 eclipse.
6. Here we merely list the French teams that were active during this eclipse and used it to determine the shape and size of the solar

corona at 169 MHz, and the Belgian team that conducted research in collaboration with their French colleagues. Sullivan (2009: 290) provides information on the other six teams that also observed this eclipse.

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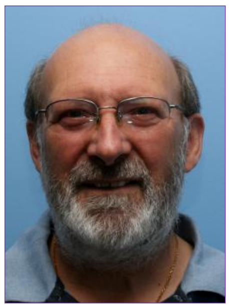

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