Journal of Astronomical History and Heritage 7(2):118-121 2004

The 1948 solar eclipse and the genesis of radio astronomy in Victoria

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Abstract
In the early years of radio astronomy, solar eclipses played a critical role in establishing the sources of solar radio emission. During the half decade from 1945, Australia emerged as a leading nation in radio astronomy, with most of the observations made at sites that were concentrated in and around Sydney. Radio astronomy in the state of Victoria was launched when a small group of Sydney scientists successfully observed the partial solar eclipse of 1948 November 1 from Rockbank, near Melbourne.

Keywords: *Solar radio astronomy, solar eclipses, Victoria*

1 INTRODUCTION

Although radio astronomy has a history that extends back a little over seventy years, it only blossomed following the development of radar in WWII. Young radio engineers from the CSIRO's Division of Radiophysics (henceforth RP) in Sydney carried out the first investigation of solar radio emission towards the end of 1945, and this was soon followed by studies of galactic and extragalactic sources (Sullivan, 1988).

Two years after the end of WWII, Australia was one of the world leaders in radio astronomy, and most of the observations were made at RP field stations in suburban Sydney (see Orchiston and Slee, 2005). However, there were also small research teams at Mount Stromlo Observatory near Canberra and at the University of Western Australia in Perth, and a solar eclipse in 1948 November prompted the RP group to establish temporary observing stations at Rockbank in Victoria and Strahan in Tasmania. These were the earliest radio astronomical investigations undertaken in these two Australian states, and this paper describes the instrumentation used at Rockbank, the observations, and their interpretation.

2 SOLAR EMISSION AND THE ECLIPSE OF 1948 NOVEMBER 1

By 1948, radio emission from the Sun was known to comprise three distinct components: (1) thermal emission from the 'quiet' Sun, (2) on-going enhanced emission associated, in general, with optically-active regions, including sunspots, and (3) intense short-term burst emission that was also associated with optically-active regions. Because of the poor resolving power of radio telescopes at this time, it was difficult to establish the *precise* relationship between photospheric and chromospheric features observed optical and radio-emitting regions, and one approach to this dilemma was to monitor the change in radio emission recorded in the course of a solar eclipse. In 1947, Covington showed that fluctuations in the level of solar emission as the Moon proceeded across the Sun during the 1946 November 23 partial solar eclipse were correlated with the masking and reappearance of different sunspot groups.

The partial eclipse of 1948 November 1 provided Australian radio astronomers with their first opportunity to carry out such an investigation, and staff from RP planned radio observations at 9,400, 3,000 and 600 MHz (Christiansen et al., 1949a, 1949b; Minnett and Labrum, 1950; Piddington and Hindman, 1949), and photographic coverage with the 15-cm (6-in) Cooke guide scope attached to the 45.7-cm (18-in.) Hoskins reflector at Sydney Technical College (see Figure 1).

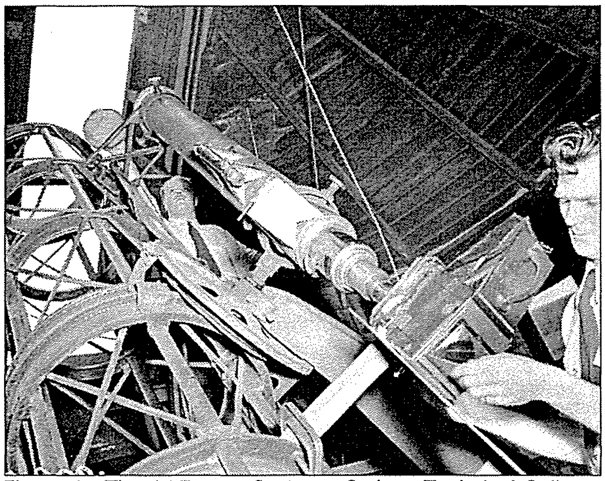

Figure 1. The 45.7-cm reflector at Sydney Technical College, and the 15-cm guide scope that was used for photographic monitoring of the 1 November 1948 partial solar eclipse (ATNF Historic Photographic Archive: B1899-7).

There were three clear research objectives associated with the 600 MHz observations:

(1) To determine the precise positions of enhanced regions of solar emission in the corona. It was reasoned that this should be possible by using three widely-spaced radio telescopes and knowing the path of the Moon's shadow across the solar disk at each site during the eclipse;
(2) To determine whether limb-brightening existed at a frequency of 600 MHz, as postulated by Martyn (1946); and
(3) To determine whether radio-emitting regions in the northern and southern hemispheres of the Sun exhibited opposite senses of circular polarization, as also predicted by Martyn.

Two different types of antennas were used for the 600 MHz observations: a former experimental radar antenna located at the Potts Hill field station in Sydney, and two simple 3-m (10-ft) diameter altazimuth-mounted parabolic antennas at the Rockbank and Strahan observing sites. Figure 2 shows one of these two antennas undergoing testing at the Georges Heights field station (see Orchiston, 2004) prior to the eclipse.

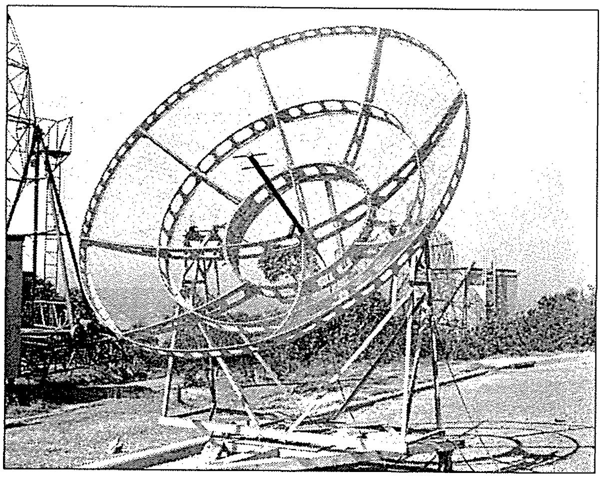

Figure 2. The Rockbank or Strahan portable radio telescope at Georges Heights on 31 August 1948 (ATNF Historic Photographic Archive: B1511)

The custom-made wire-mesh dish had a beam width of 15°, and featured crossed dipoles, as required for the polarization measurements (but note that these are not shown in Figure 2). The receiver consisted of

> … a quarter-wave transmission-type cavity-resonator, followed by a conventional crystal converter, 30 Mc/s. intermediate-frequency amplifier, and diode second detector … After rectification, the signals passed into a D.C. amplifier which was connected to a recording milliammeter.
>
> With the small aerials used at Rockbank and Strahan, the ratio of signal power from the uneclipsed sun to the internal noise power at the receiver input was between 0.10 and 0.15, so that great care was required for accurate measurement of the power flux density from the sun during the course of the eclipse. (Christiansen *et al.*, 1949a: 508).

3 THE ROCKBANK OBSERVATIONS

At Rockbank, the eclipse began at 1639 local time, maximum phase was reached at 1741 when 72% of the Sun disk was covered, and the event ended at 1838, just sixteen minutes before sunset (Christiansen, Yabsley and Mills, 1949a: Table 1). Photographs taken in Sydney on the day revealed the presence of six groups of sunspots, but their total area was small, amounting to only ~0.085% of the total area of the visible disk of the Sun. A table listing the elevation and azimuth of the Sun was used initially to point the antenna at the Sun, and it was then moved manually every few minutes. Tracking sessions using this technique on days prior to the eclipse showed that errors in radio intensity measurements caused by slight misalignment of the antenna would amount to less than 1%.

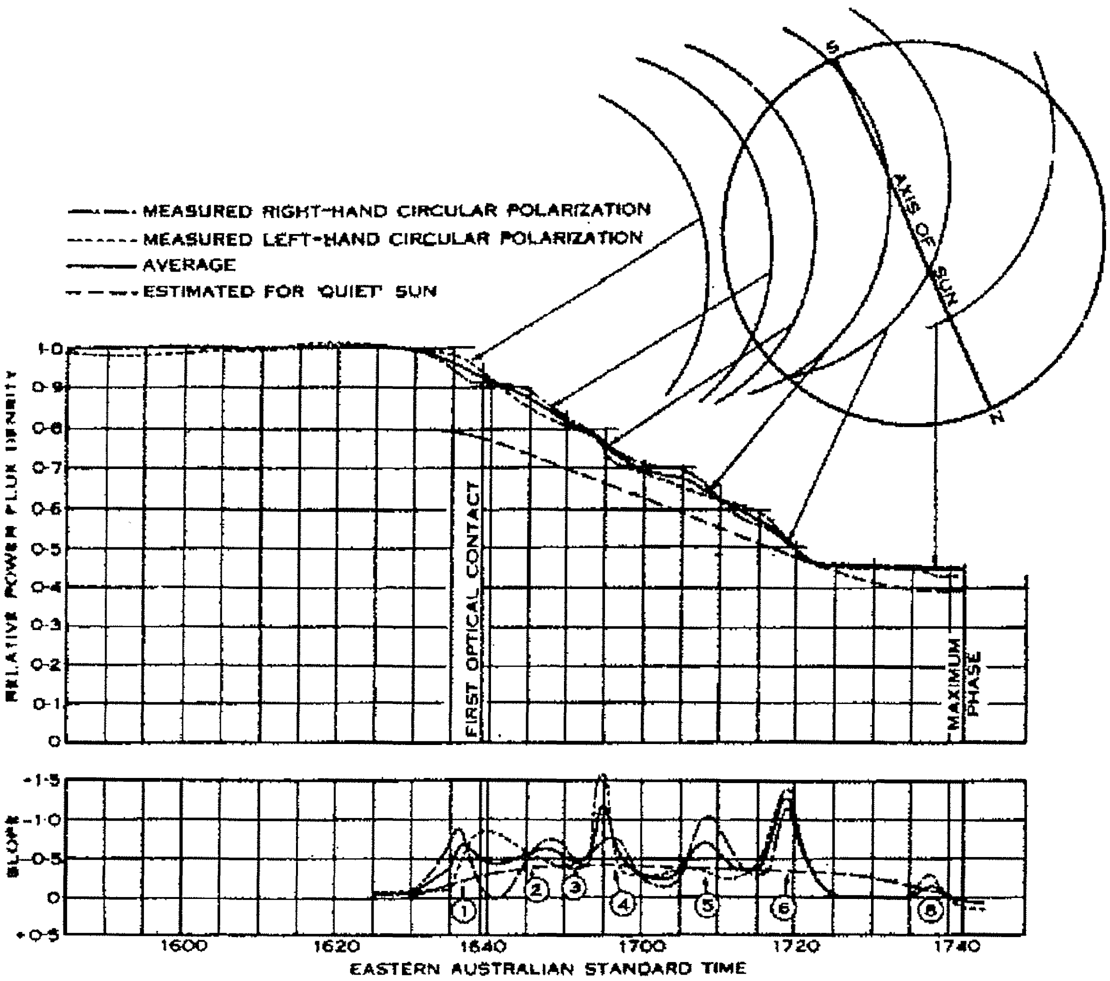

Figure 3. Observation of the eclipse at Rockbank (after Christiansen et al., 1949a: 511).

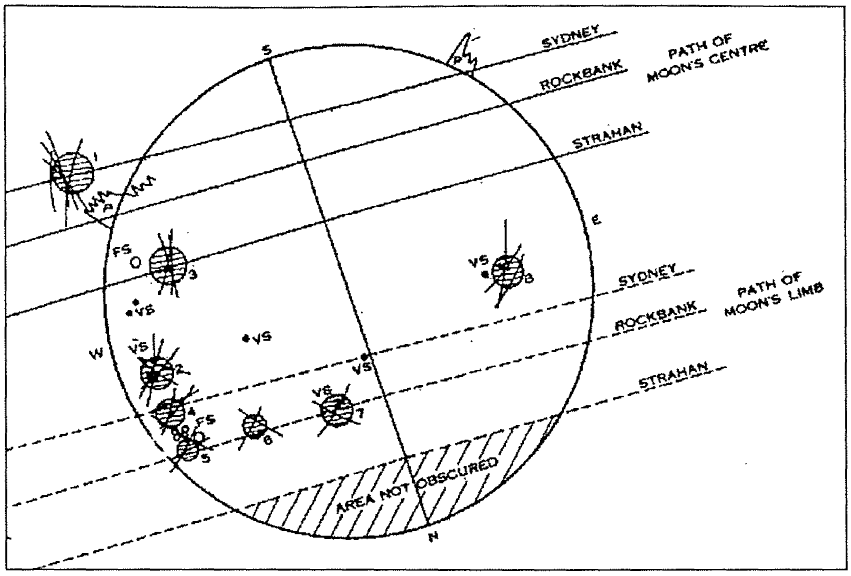

Figure 4. Regions of enhanced solar radio emission at 600 MHz (hatched circles) on 1948 November 1, and sunspots (VS), locations where sunspots were present on the previous solar rotation (FS) and prominences (P) (after Christiansen *et al.*, 1949a: 513).

Figure 3 shows the variation in radio emission received at Rockbank during the first half of the eclipse. Although the plotted curve is unbroken, the original record was discontinuous because the aerial was directed away from the Sun at frequent intervals to calibrate the receiver, and the polarization of the aerial was changed periodically, resulting in a disrupted record of each sense of polarization. The missing segments were interpolated, and it was estimated that "No serious error was likely to be caused by this procedure because the changes were made at close intervals." (Christiansen *et al.*:511). The upper plot in Figure 3 shows the actual trace, while the lower plot has been corrected for the slope and the peaks have been magnified. Both plots show the estimated level of emission from the quiet Sun. The circular arcs at the top right show the positions of the Moon at the occurrence times of the peaks in the lower curve.

The upper curve in Figure 3 shows that radio emission from the Sun began to decrease ~10 minutes before the commencement of the optical event, consistent with the idea that the 600 MHz radio emission originated in the corona. As the eclipse progressed, the declining emission curve was punctuated by a number of minor troughs, best seen in the lower plot. These represented masked localized regions of enhanced solar emission, and their precise positions—projected onto the solar disk—were obtained by plotting the intersections of the appropriate eclipse arcs at the Sydney, Rockbank and Strahan observing sites. These locations are shown in Figure 4, where the numbers correspond to the peaks in the lower plot in Figure 3.

4 ANALYSIS

Calculations showed that the eight localized regions of enhanced emission contributed ~20% of the total solar radiation received on 1948 November 1. These emitting regions were assumed to be approximately circular, and their areas varied by little more than a factor of two, with a mean of ~0.4% of the total area of the visible disk of the Sun. Their effective temperatures varied by more than 10:1, and if we assume a quiet Sun temperature of $\sim 0.5 \times 10^6$ K at 600 MHz, then the brightest localized regions in Figure 4 (numbers 4 and 6) would have had effective temperatures of $\sim 10^7$ K.

Figure 4 shows that peak number 1 was located $\sim 1.7 \times 10^5$ km beyond the solar limb, and above a magnetically-active region in the chromosphere marked by a conspicuous prominence. All other emission peaks were on the solar disk, and in the case of numbers 2, 7, and 8 coincided with sunspot groups. However, peaks 3–6 did not appear to be associated with any obvious photospheric features, although three of these were close to the positions occupied by sunspots groups exactly one solar rotation earlier. Meanwhile, two small sunspots groups in Figure 3 and one large group (near the western limb) were not associated with measurable levels of enhanced solar radio emission.

The second research objective related to possible limb brightening at 600 MHz, and the results were inconclusive:

> … roughly half the (presumed) thermal component of the radiation originated close to, and predominantly outside, the edge of the visible disk of the sun. The details of the brightness distribution could not be derived from the records. The latter were shown to be consistent with two tentative distributions, the first a theoretical one, involving limb brightening … and the second a uniform one over a disk having 1.3 times the diameter of the optical disk of the sun. The existence of limb brightening, therefore, was not proved. (Christiansen *et al.*, 1949b:570).

The polarization analysis proved interesting in that Rockbank was the only site to provide relevant data. Before the eclipse the two modes of circular polarization differed in amplitude by less than 2%, but on 1948 November 1, "The eclipsing of the active areas produced changes that sometimes were confined to one or other circularly-polarized component, or in some cases involved both components." (Christiansen *et al.*, 1949a:521). The changes were of short duration, and the two components quickly returned to equality. This is illustrated in Figure 3, where the most significant variations in the relative levels of left-hand and right-hand circular polarization are associated with active regions 1, 4 and 5. Since the difference in the two polarizations curves was <3% at the maximum phase of the eclipse, this indicated that the general magnetic field strength of the Sun at the poles was <8 gauss. We should note that this is in line with current thinking, but that in 1948 a value of ~50 gauss was assumed.

5 CONCLUDING REMARKS

The Rockbank observations of the 1948 November 1 partial solar eclipse led to a greater understanding of the relationship between optical solar features and areas of enhanced radio emission, and a summary of the overall project was published in *Nature* in 1949 (Christiansen *et al.*, 1949b), with the full account appearing that same year in the *Australian Journal of Scientific Research* (Christiansen *et al.*, 1949a). This pioneering study was the first radio astronomical research project carried out in the state of Victoria.

From a national and international perspective, the Rockbank, Strahan and Sydney observations of the 1948 eclipse marked a watershed in solar radio astronomy, in that they were the trigger that inspired W.N. Christiansen (1984:117) "... to devise some method of viewing the Sun [at high resolution] more frequently than was possible with eclipse observations. This of course meant devising some antenna system of very great directivity." The result was the first solar grating array, an innovative 32-element interferometer operating at 21cm that was constructed at the Potts Hill field station in Sydney during 1951 (see Christiansen and Warburton, 1953).

6 ACKNOWLEDGEMENTS

I am grateful to Drs Don McLean and Bruce Slee (Australia Telescope National Facility) for reading and commenting on the manuscript, and to the Australia Telescope National Facility for supplying Figures 1 and 2.

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