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THE HISTORY OF EARLY LOW FREQUENCY RADIO ASTRONOMY IN AUSTRALIA. 2: TASMANIA

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Abstract: Significant contributions to low frequency radio astronomy were made in the Australian state of Tasmania after the arrival of Grote Reber in 1954. Initially, Reber teamed with Graeme Ellis, who was then working with the Ionospheric Prediction Service, and they carried out observations as low as 0.52 MHz during the 1955 period of exceptionally low sunspot activity. In the early 1960s, Reber established a 2.085 MHz array in the southern central region of the State and used this to make the first map of the southern sky at this frequency. In addition, in the 1960s the University of Tasmania constructed several low frequency arrays near Hobart, including a 609m × 609m array designed for operation between about 2 MHz and 20 MHz. In this paper we present an overview of the history of low frequency radio astronomy in Tasmania.

Keywords: Australian low frequency radio astronomy, Tasmania, Grote Reber, Graeme Ellis, CSIRO Division of Radiophysics.

1 INTRODUCTION

In the 1940s and 1950s, Australia was a major contributor in the emerging field of radio astronomy (see Robertson, 1994; Sullivan, 2009). Apart from small short-lived solar research groups based at Mt Stromlo Observatory, near the nation's capital, Canberra, and at the University of Western Australia in Perth (Orchiston et al., 2005) the major role was played by the CSIRO's Division of Radiophysics, which was based in Sydney. Between 1946 and the early 1960s the Division operated a number of field stations and remote sites in the Sydney area (see Orchiston and Slee, 2005), two of which, Hornsby Valley and Fleurs, made major contributions to low frequency radio astronomy (see Orchiston et al., 2015b).

In the early 1950s the American radio engineer Grote Reber, who had constructed the world's first purpose-built radio telescope in Wheaton (Illinois) in 1937, was working with a sea interferometer atop Mt. Haleakala on the island of Maui in Hawaii (see Reber, 1955) when he developed an interest in carrying out radio astronomical research at low frequencies and making observations in the southern hemisphere (Reber, 1949). He had gathered ionospheric data from many places around the world in order to find locations that offered the best prospects.

For low frequency work, consideration of ionospheric conditions is very important. There is a frequency limit below which celestial radio waves cannot penetrate the ionosphere: upon moving downwards from 10 MHz to lower and lower frequencies, transmission becomes steadily poorer until a limit is reached at around 1–2 MHz under the best conditions. The lower limit is dependent on several factors, the most important of which is the observer's location. The lower the atmospheric ionisation, the greater the transmission. It is now well known that there is a mid-latitude ionospheric 'trough' of least ionisation—sufficiently far from the geographic and geomagnetic poles—that offers the lowest usable frequencies for radio astronomy. However, other important factors combine to produce low ionisation: low solar activity, time of day, and the season of the year. The ideal conditions under which to observe are at or near solar minimum, during winter, and at night.

During the early 1950s, Graeme Ellis, who was then working for the Commonwealth Observatory Ionospheric Prediction Service, performed ionospheric research near Hobart (see Ellis, 1954). Reber (1954) was prompted to contact Ellis after reading a paper by Ellis (1953). As a result of their correspondence, Reber (1977; 1982) decided to carry out low frequency radio astronomy in Tasmania, as it was clear from

Ellis' paper and other ionospheric data from around the world that Tasmania offered excellent conditions for the observation of cosmic radiation at low frequencies.

Reber then moved to Tasmania, and between 1955 and 1967 he carried out low frequency observations at Cambridge, Kempton and Bothwell, initially in collaboration with Ellis (for Tasmanian localities mentioned in this paper see Figure 1).

After working in Queensland and New South Wales, Ellis returned to Hobart in 1960 to take up the Chair of Physics at the University of Tasmania, thus beginning two and a half decades of low frequency radio astronomical research at the University. Observations by Professor Ellis (Figure 2) and a succession of Honours and Ph.D. students were carried out at Hobart Airport (Llanherne), Penna and Richmond to the east and north-east of Hobart (Figure 3), and they made good use of the mid-1960s minimum in solar activity (as indeed did Reber).

The aim of this paper is to provide readers with an overview of the low frequency radio astronomy that was carried out in Tasmania by Grote Reber and by Graeme Ellis and his associates from 1955. Details of the research conducted at Bothwell, Cambridge, Kempton, Llanherne, Penna and Richmond will be published in later papers in this series.

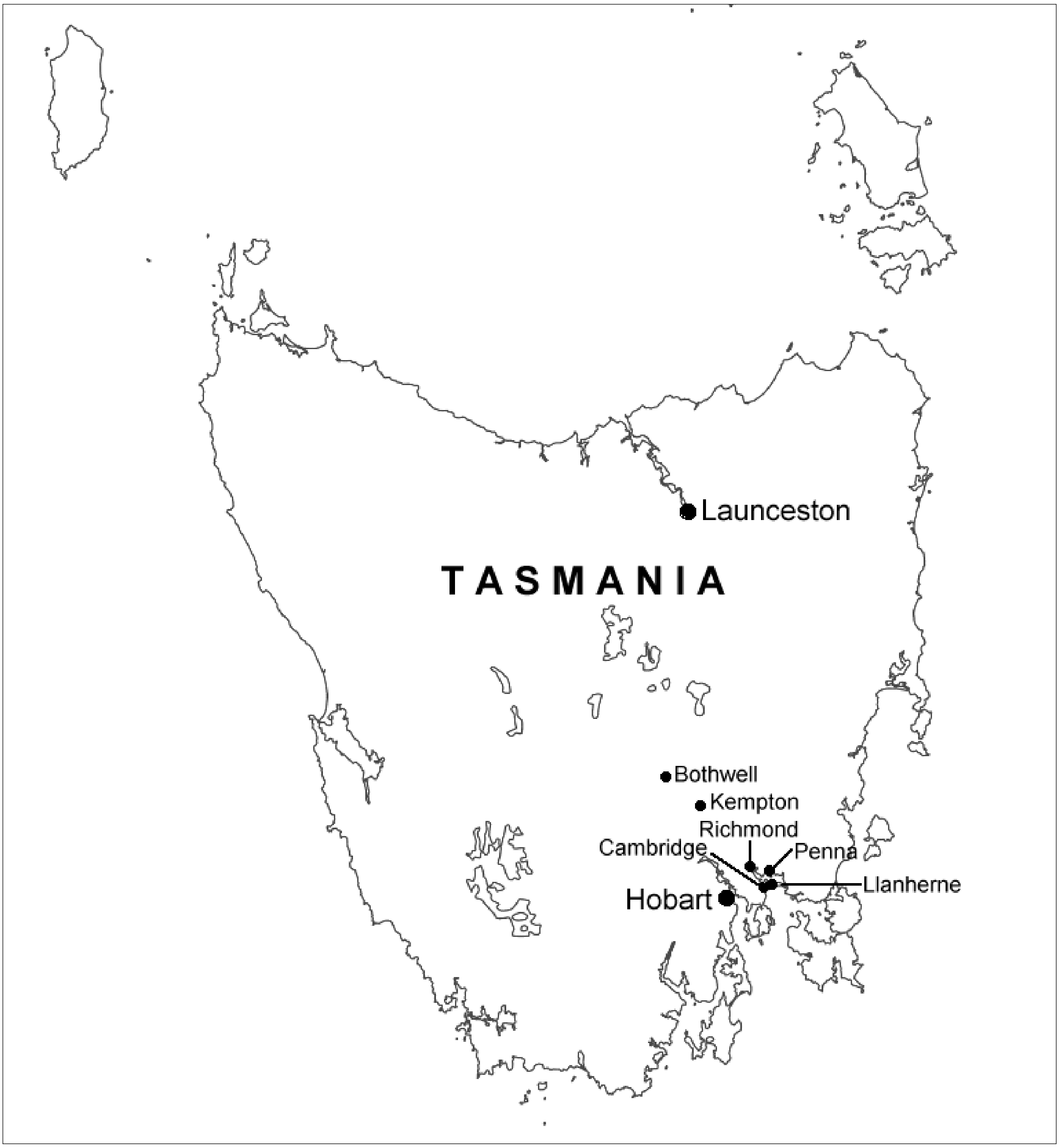

Figure 1: The island of Tasmania, showing the low frequency radio astronomy locations mentioned in the text.

Figure 2: Graeme ('Bill') Ellis in about 1970 (photograph: University of Tasmania).

Meanwhile, collectively this paper and the preceding paper in this issue of *JAHH* (Orchiston et al, 2015b) will provide a useful national overview of developments in early low frequency radio astronomy in Australia (cf. Orchiston et al., 2015a).

2 SITES AND OBSERVATIONS

2.1 The Llanherne Area

The majority of the low frequency research performed by the University of Tasmania radio astronomers took place in the vicinity of Hobart Airport, which is also called Llanherne Airport (see Figure 3).

In the early 1950s, Graeme Ellis was performing ionospheric work near Cambridge Airport, a few kilometres to the west of Llanherne Airport (which began operations in 1956). Shortly before Grote Reber arrived, the ionospheric station was moved to Mount Nelson, south of Hobart, but some equipment remained at the Cambridge site (Reber, 1982). In 1955, this and other equipment was used for observations at a number of frequencies between 0.52 MHz and 2.1

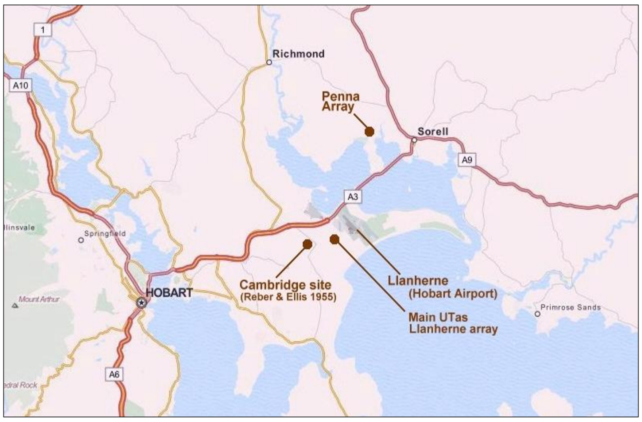

Figure 3: A map showing the locations of the Penna and Llanherne arrays. As this map shows, Reber and Ellis' earlier Cambridge array was located close to the site of the Llanherne array, near Hobart Airport.

MHz (Reber and Ellis, 1956), with the higher frequencies revealing a clear celestial component. Previously, the lowest frequency at which galactic emission had been detected was 9.15 MHz by Higgins and Shain (1954) near Sydney. Subsequently, Ellis and Newstead (1957) used interferometers operating at 10.05 and 18.3 MHz to detect a number of discrete sources, probably from the same location.

However, the University's most significant radio telescope, termed the Llanherne Low-Frequency Array, was closer to Llanherne Airport. It covered an area 609m × 609m, and was composed of 64 east-west rows of broadband dipoles (see Figure 4). Construction commenced in 1967 and it was in full operation by 1972 (Ellis, 1972). It was used during the mid-1970s to map the radio sky at a range of frequencies between 3.7 MHz and 16.5 MHz (e.g. see Cane, 1975; Cane and Whitham, 1977; Ellis, 1982). The array was visible from the road to Llanherne Airport, and a popular misconception was that it was a field of poles for growing hops!

As the work of mapping the sky progressed, it became increasingly clear that the plane of the Milky Way was exhibiting an absorption feature due to an ionised layer (Figure 5), and an important early paper by Hoyle and Ellis (1963) supported this view.

From the early 1960s, Llanherne also was the site for several other low frequency installations, including a small array erected for galactic observations at 4.85 and 9.7 MHz (Waterworth, 1962); an array of crossed dipoles for polarisation studies of Jovian decametric emission (Dowden, 1963); a 39m × 39m array constructed for further work in this field (see Whitham, 1976) and also used for solar work (Klekociuk, 1982); two log-periodic antennas that were designed for solar observations at minimum frequencies of 8 MHz and 24 MHz, respectively, with which they noted frequency splitting using a 24–28 MHz spectrograph (Ellis and McCulloch, 1966); and an array of eight 180-m dipoles constructed for a 1.6-MHz survey of the Galaxy (Ellis and Mendillo, 1987; see Figure 6).

Another major area of low frequency research by the University of Tasmania radio astronomers was on Jovian decametric burst emission. These bursts were first observed by the U.S. radio astronomers Burke and Franklin in 1955, and although Tasmanian observations began in the 1960s, including early observations at Penna (see Section 2.2 below), a major series of observations was carried out between 1972 and 1979 using the Llanherne Low-Frequency Array (Ellis, 1979; 1982; Whitham, 1976). Much theoretical work was performed on the source of the emission (e.g. see Ellis and

Figure 4: The Llanherne Low-Frequency Array in the 1970s (courtesy: Hilary Cane).

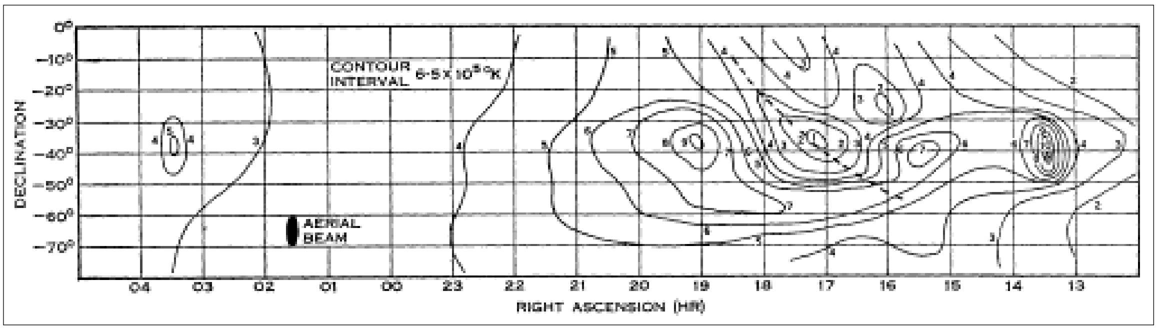

Figure 5: A contour map of 4.7 MHz emission, showing a conspicuous absorption trough, indicated by the dashed line (after Ellis, Green and Hamilton, 1963: 549).

McCulloch, 1963; Ellis, 1974; 1980; Whitham, 1978).

A significant observation made at Llanherne during the later years of low frequency work took place using a newly-constructed antenna to observe through an artificial 'hole' in the ionosphere created by the space shuttle *Challenger* on 5 August 1985. At this time, successful observations of the Galaxy were made at 1.7 MHz (Ellis et al., 1986).

2.2 Penna

Nearby Penna (see Figure 3) was the site of an important early array, used mainly for mapping the sky at frequencies of 4.7 MHz and 10.02 MHz (Ellis and Hamilton, 1966; Ellis and McCulloch, 1966; Hamilton and Haynes, 1968). The Penna installation was a 1200m × 300m array

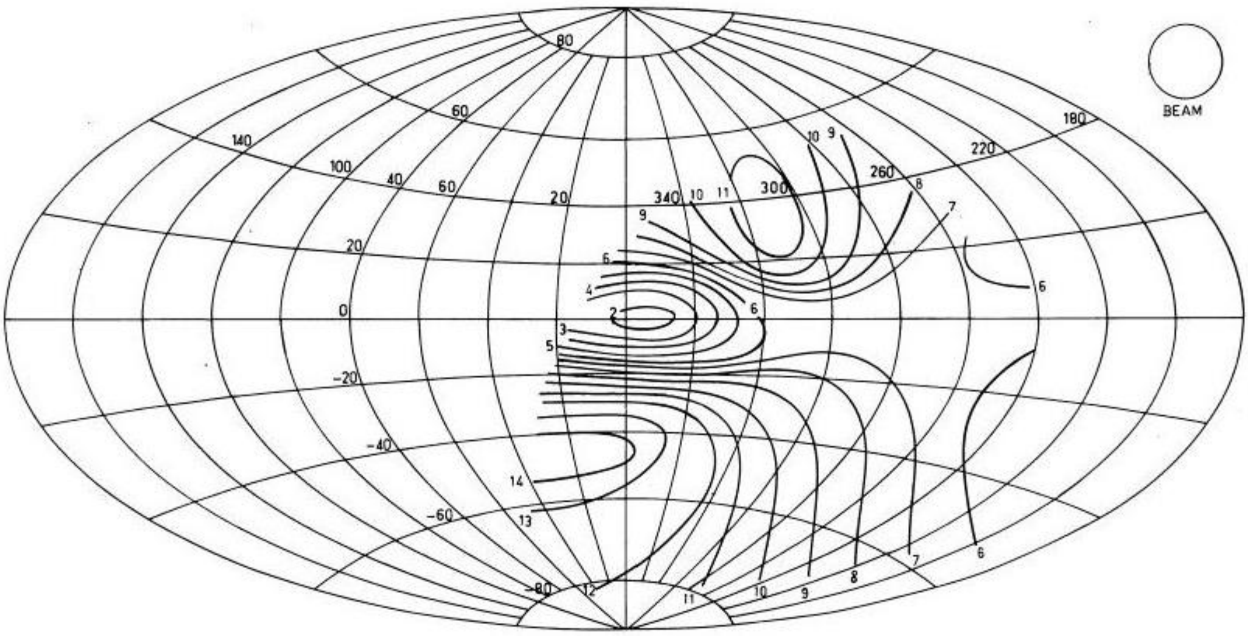

Figure 6: A 1.6 MHz isophote map of the sky (after Ellis and Mendillo, 1987).

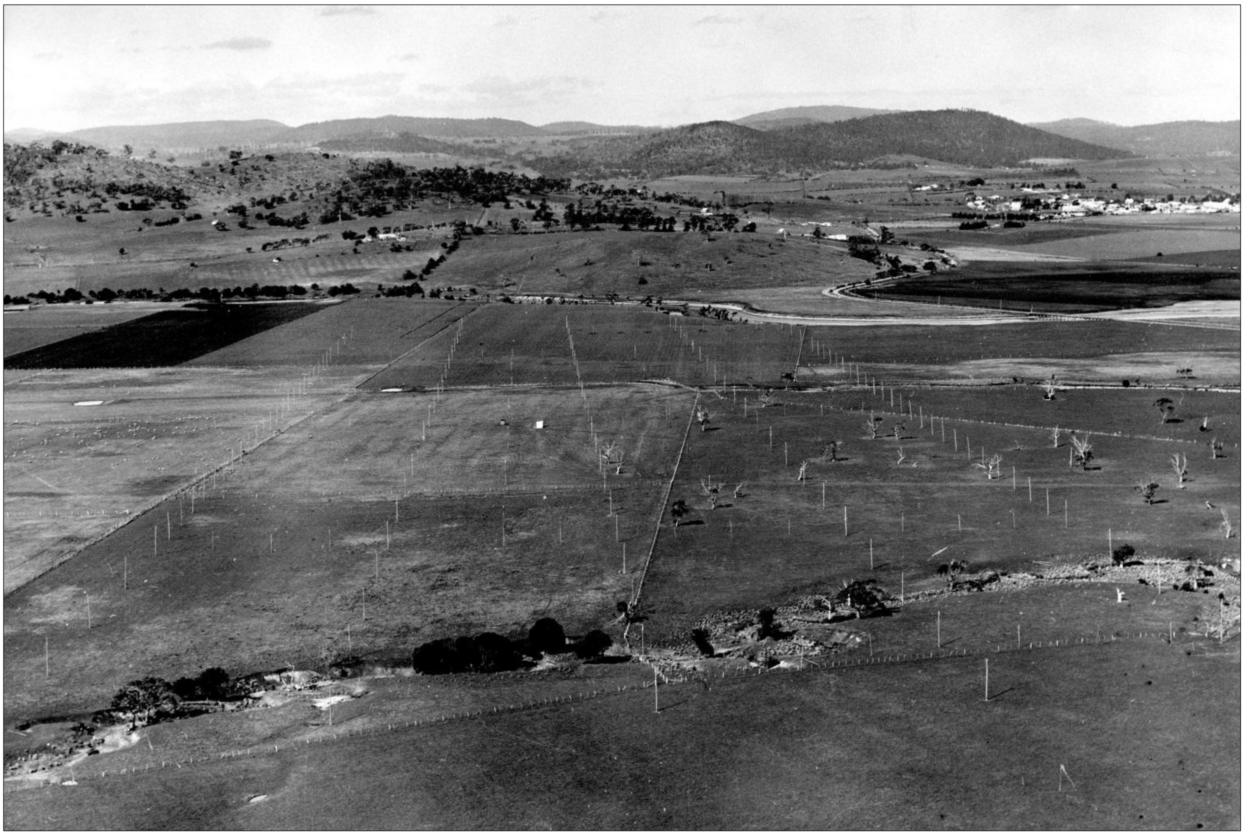

Figure 7: The Penna array in the 1960s (courtesy: University of Tasmania).

consisting of half-wave dipoles initially designed to operate at 4.85 MHz (see Figure 7). During early testing at the site, before the main construction period, Ellis succeeded in observing Jupiter at 4.7 MHz (Ellis, 1962). The full array began operation in June 1962 (Green, 1963) and was destroyed in the tragic bushfires of 7 February 1967, which cost more than 60 lives and caused major destruction in the southern half of the State.

2.3 Richmond

Contemporary with construction at Penna was the erection of arrays just north of the nearby town of Richmond (see Figure 3). Observations were carried out using full-wave dipoles at 2.35 MHz, 1.5 MHz and 1 MHz (see Figure 8), and as would be expected the 1 MHz attempts failed to produce much useable information (Bessell, 1963).

Figure 8: The Richmond Array in 1962 or 1963 (courtesy: University of Tasmania).

2.4 Kempton and Bothwell

The two sites used by Reber (Figure 9) after his collaboration with Ellis were three kilometres west of the town of Kempton (about 50 kilometres north of Hobart), and a site farther north called Dennistoun, six kilometres north-east of the town of Bothwell (see Figure 1).

Following his early observations with Ellis close to Hobart in 1955, Reber (1982) returned to Tasmania in early 1956 and erected four low frequency dipoles at the Kempton site over a valley between two hills. The main frequency at which Reber made observations was 0.52 MHz, and he obtained "... nearly continuous records ..." between August 1956 and May 1957 (Reber, 1957). Although atmospherics tended to dominate the reception Reber deduced that there was celestial emission, but later he had his doubts.

Reber then constructed a 2.085 MHz radio telescope at Bothwell (Figure 10), the largest filled-aperture array ever built, a record that still stands. It was constructed in 1961–1962, contained 192 dipoles, and covered one square kilometer—leading to modern-day comments that it was the 'first square-kilometre array'.

Observations were made between 1963 and 1967, straddling the period of the 1960s solar minimum. This instrument was used to produce am important 2.085 MHz map of the sky (Reber, 1968), and this is shown in Figure 11.

In the mid-1970s, Reber converted this Bothwell installation into a 48-dipole array in order to attempt observations at 1.155 MHz. However, this resulted in failure, attributed by Reber as due to the shallower solar minimum during that period (Reber, 1974; 1982; Ellis and Mendillo, 1987).

3 CONCLUDING REMARKS

The three-decade period beginning in the mid-1950s saw considerable activity in the field of low frequency radio astronomy in Tasmania, with the 1960s and 1970s being unquestionably the halcyon years. There is little doubt that this pursuit was considerably influenced by the presence of Grote Reber, in combination with the interests of Graeme Ellis, whose work up to that time had focused on the properties of the ionosphere.

It was understood from an early stage that Tasmania, at a geographic latitude of 43° south and a geomagnetic latitude of 52° south, was one of the best places in the world for low frequency radio astronomy, as it lay directly under the so-called southern ionospheric 'trough' where the ionosphere is most transparent.

Since these pioneering low frequency studies, the University of Tasmania radio astronomers have focused on higher frequencies, especially after the establishment in 1986 of a new 26-m

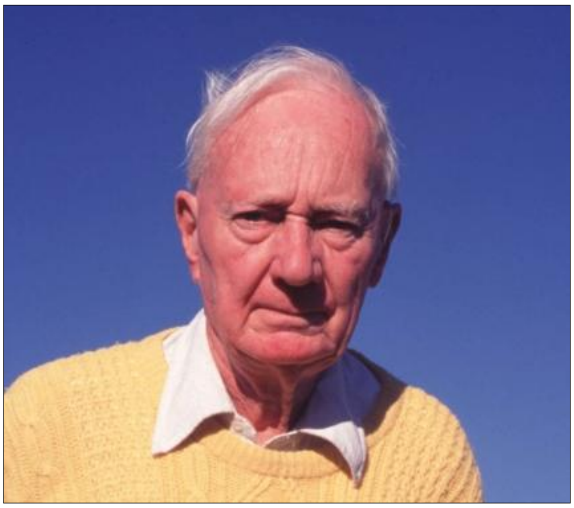

Figure 9: Grote Reber in 1995 (photograph: Martin George).

Figure 10: Reber's array, north of Bothwell, in 1975 (courtesy: Grote Reber Foundation).

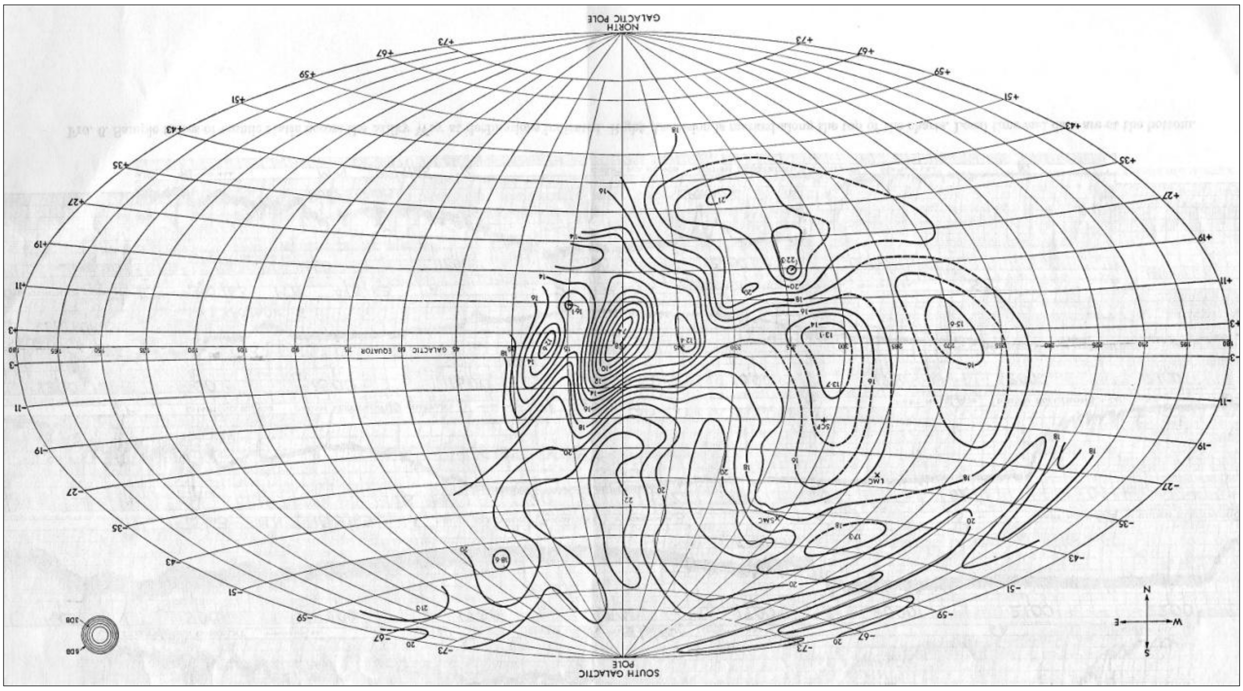

Figure 11: A 2.085 MHz contour map of galactic radio emission (after Reber, 1968: 10).

paraboloid at Mount Pleasant, near Cambridge. Today, there is almost no evidence of the low frequency radio astronomy work performed at the various sites, although some relics at Kempton offer an insight into Reber's work there, and a dilapidated shed at Llanherne brings back memories of Ellis' array.

Details of the low frequency research conducted by Reber and by Ellis and his associates will be presented in later papers in this series.

4 ACKNOWLEDGEMENTS

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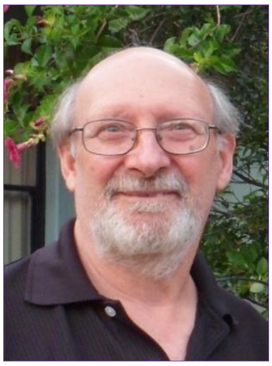
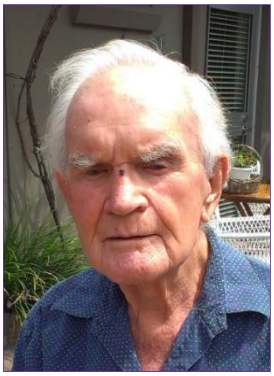
Martin George is the Collections and Research Manager at the Queen Victoria Museum and Art Gallery in Launceston, Tasmania, and also is responsible for the Museum's planetarium and astronomy collections. He is a former President of the International Planetarium Society. Martin has a special research interest in the history of radio astronomy, and is completing a part-time Ph.D. on the development of low frequency radio astronomy in Tasmania through the University of Southern Queensland, supervised by Professors Wayne Orchiston and Richard Wielebinski (and originally also by Professor Bruce Slee). Martin is the Administrator of the Grote Reber Medal for Radio Astronomy, and is a member of the IAU Working Group on Historic Radio Astronomy.



Professor Wayne Orchiston was born in New Zealand in 1943 and works as a Senior Researcher at the National Astronomical Research Institute of Thailand and is an Adjunct Professor of Astronomy at the University of Southern Queensland in Toowoomba, Australia. In the 1960s Wayne worked as a Technical Assistant in the CSIRO's Division of Radiophysics in Sydney, and forty years later joined its successor, the Australia Telescope National Facility, as its Archivist and Historian. He has a special interest in the history of radio astronomy, and in 2003 was founding Chairman of the IAU Working Group on Historic Radio Astronomy. He has supervised six Ph.D. or Masters theses on historic radio astronomy, and has published papers on early radio astronomy in Australia, England, France, Japan, New Zealand and the USA. He also has published extensively on the history of meteoritics, historic transits of Venus and solar eclipses, historic telescopes and observatories, and the history of cometary and asteroidal astronomy. He is a co-founder and the current Editor of the *Journal of Astronomical History and Heritage*, and in 2013 the IAU named minor planet 48471 Orchiston after him.



Dr Bruce Slee was born in Adelaide, Australia, in 1924 and is one of the pioneers of Australian radio astronomy. Since he independently detected solar radio emission during WWII he has carried out wide-ranging research, first as a member of the CSIRO's Division of Radiophysics, and then through its successor, the Australia Telescope National Facility. After working with Bolton and Stanley on the first discrete sources at Dover Heights, he moved to the Fleurs field station and researched discrete sources with Mills using the Mills Cross, and radio emission from flare stars with the Shain Cross and the 64-m Parkes Radio Telescope. He also used the Shain Cross and a number of antennas at remote sites to investigate Jovian decametric emission. With the commissioning of the Parkes Radio Telescope he began a wide-ranging program that focussed on discrete sources, and radio emission from various types of active stars. He also used the Culgoora Circular Array (*aka* Culgoora Radioheliograph) for non-solar research, with emphasis on pulsars, source surveys and clusters of galaxies, and continued some of these projects using the Australia Telescope Compact Array. Over the past two decades, he also has written many papers on the history of Australian radio astronomy, and has supervised a number of Ph.D. students who were researching the history of radio astronomy. .

Professor Richard Wielebinski was born in Poland in 1936, and moved with his parents to Hobart, Tasmania, while still a teenager. Richard completed B.E. (Hons.) and M.Eng.Sc. degrees at the University of Tasmania. In his student days he met Grote Reber and was involved in the construction of a low frequency array at Kempton. After working for the Postmaster General's Department in Hobart he joined Ryle's radio astronomy group at the Cavendish Laboratory, Cambridge, and completed a Ph.D. in 1963 on polarised galactic radio emission. From 1963 to 1969 Richard worked with Professor W.N. (Chris) Christiansen in the Department of Electrical Engineering at the University of Sydney, studying galactic emission with the Fleurs Synthesis Telescope and the 64-m Parkes Radio Telescope. He also was involved in early Australian pulsar research using the Molonglo Cross. In 1970 Richard was appointed Director of the Max-Planck-Institute für Radioastronomie in Bonn, where he was responsible for the instrumentation of the 100m radio telescope at Effelsberg. In addition, he built up a research group that became involved in mapping the sky in the radio continuum, studying the magnetic fields of galaxies, and pulsar research. Further developments were the French-German-Spanish institute for mm-wave astronomy (IRAM), and co-operation with the Steward Observatory, University of Arizona, on the Heinrich-Hertz Telescope Project. Richard holds Honorary Professorships in Bonn, Beijing and at the University of Southern Queensland. He is a member of several academies, and has been awarded honorary doctorates by three universities. After retiring in 2004 he became involved in history of radio astronomy research, and is currently the Vice-Chairman of the IAU Working Group on Historic Radio Astronomy.