THE HISTORY OF EARLY LOW FREQUENCY RADIO ASTRONOMY IN AUSTRALIA. 1: THE CSIRO DIVISION OF RADIOPHYSICS

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Abstract: During the 1950s and 1960s Australia was a world leader in the specialised field of low frequency radio astronomy, with two geographically-distinct areas of activity. One was in the Sydney region and the other in the island of Tasmania to the south of the Australian mainland. Research in the Sydney region began in 1949 through the CSIRO's Division of Radiophysics, and initially was carried out at the Hornsby Valley field station before later transferring to the Fleurs field station. In this paper we summarise the low frequency radio telescopes and research programs associated with the historic Hornsby Valley and Fleurs sites.

Keywords: Australian low frequency radio astronomy, CSIRO Division of Radiophysics, Alex Shain, Hornsby Valley, Fleurs, Tasmania.

1 INTRODUCTION

A revolution began in astronomy in 1931 when the American physicist Karl Guthe Jansky (1905–1950) first detected what he termed 'cosmic static'. With the discovery of extraterrestrial radio emission, a new window was added to the electromagnetic spectrum (see Sullivan, 1983; 2009), and although little interest was shown by most optical astronomers at the time, this new approach to astronomy was followed up during the 1930s and early 1940s by an American radio 'ham', Grote Reber (1911–2002), who also built the world's first dedicated radio telescope (Kellermann, 2005; Reber, 1984; Sullivan, 1984b; 2009).

During WWII, scientists and radar operators from several different nations independently discovered that the Sun was a strong radio emitter from metre to centimetre wavelengths (see Alexander, 1946; Hey, 1946; Reber, 1944; Schott, 1947; Southworth, 1945; cf. Orchiston, 2005a; Orchiston and Slee, 2002a; Sullivan, 2009: 79-99).

In the years immediately following WWII radio astronomy flourished as it built on these—for the most part—secret wartime solar detections and exploited WWII developments in radar antenna and receiver technology. A number of nations made important contributions to radio astronomy at this time, but undoubtedly the two leading ones were Australia and England. It is notable that both countries boasted long traditions in ionospheric research and intensive wartime research on radar (Hey, 1973; Sullivan, 2009).

In Australia, for a short time there were small solar radio astronomy research groups based at Mt Stromlo Observatory and the University of Western Australia in Perth (for Australian localities mentioned in the text see Figure 1) (Orchiston et al., 2005), but most of the post-war effort in this new research field was mounted by the CSIR's (later CSIRO) Division of Radiophysics (henceforth RP), which from 1946 through into the early 1960s maintained a large number of field stations and remote sites, mainly in and around Sydney (see Orchiston and Slee, 2005a; Robertson, 1992). Their distribution is shown in Figure 2. Two of these field stations, Hornsby Valley and Fleurs, were involved in low frequency radio astronomy—that is, research conducted at frequencies below 30 MHz. Key individuals involved in the RP low frequency research were Alex Shain, Charlie Higgins and one of the authors of this paper, Bruce Slee.

During the 1950s and early 1960s a second centre of Australian low frequency radio astronomy emerged in Tasmania to the south of the Australian mainland (see Figure 1). Because of its privileged position with respect to the South Magnetic Pole, Tasmania was one of the very few locations on the Earth where extraterrestrial radio emission down to 1 MHz or even lower could sometimes successfully reach the Earth's surface during sunspot minima. Tasmanian research primarily was in the care of two individuals, that aforementioned U.S. pioneer of radio astronomy from the 1930s, Grote Reber, and Graeme Ellis (1921–2011) from the Physics Department at the University of Tasmania.

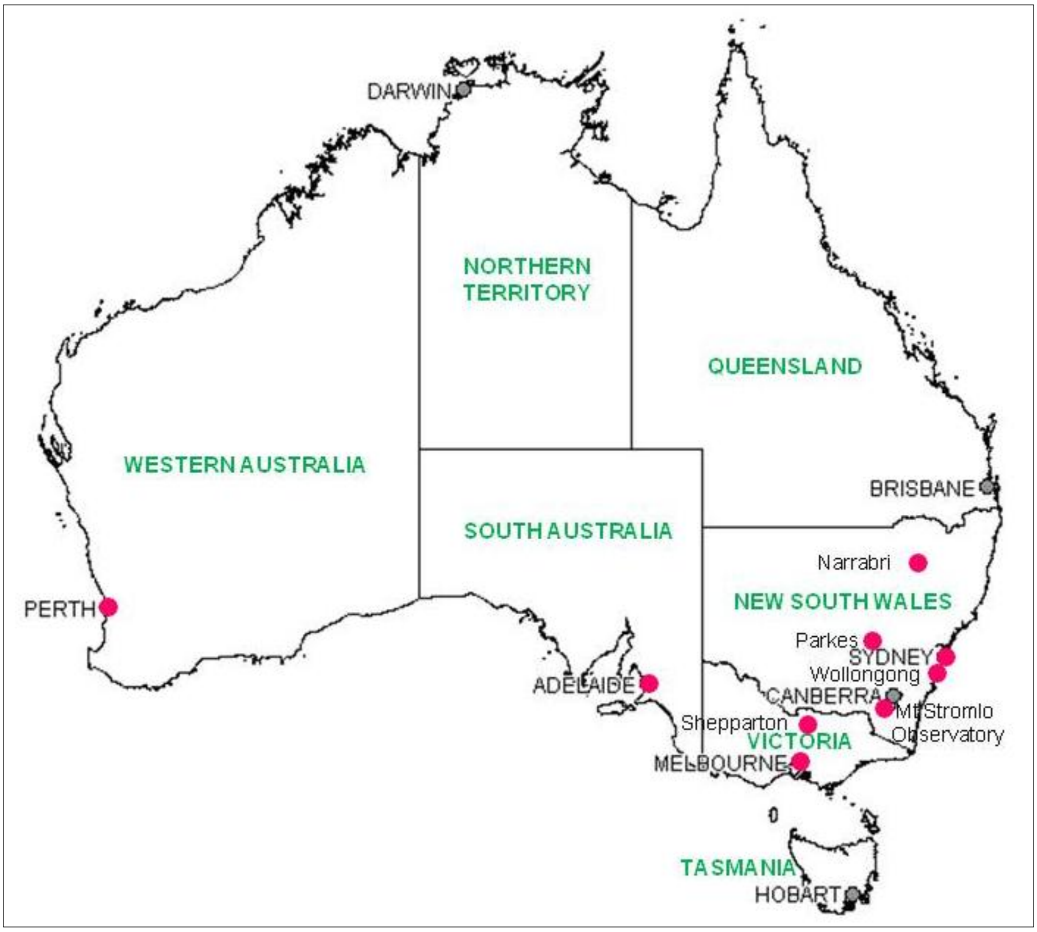

Figure 1: A map of Australia showing States and Territories and their capitals, with mainland localities mentioned in the text shown in red.

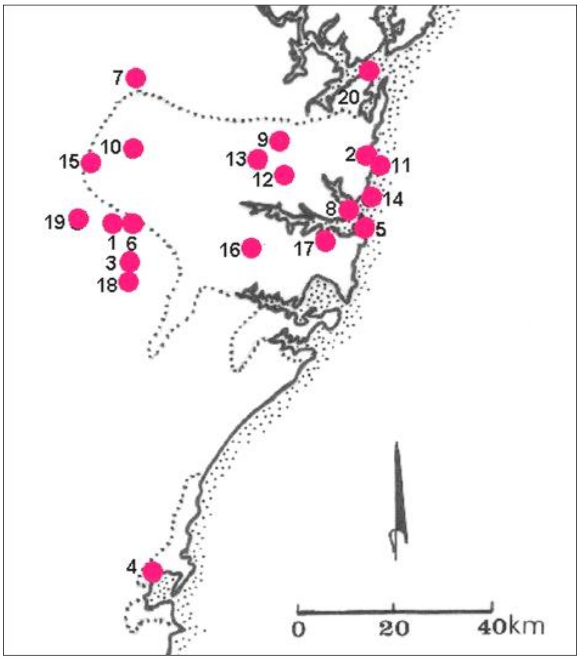

Figure 2: This map shows field stations and remote sites in the Sydney and Wollongong areas used by the CSIRO's Division of Radiophysics at one time or another between 1945 and 1965. The Hornsby Valley and Fleurs field stations where low frequency research was carried out are indicated by sites 9 and 6, respectively. The upper dotted boundary shows the approximate present-day extent of suburban Sydney and the lower dotted boundary of 'greater Wollongong'.

While the RP low frequency research was merely part of a wide-ranging campaign that extended in frequency from about 9 MHz to 24 GHz (see Orchiston and Slee, 2005a), the choice by Reber and Ellis to focus exclusively on low frequency radio astronomy was intentional, and was motivated by Tasmania's special geographical location.

The aim of this paper is to provide readers with an overview of the low frequency radio astronomy that was carried out at Hornsby Valley and Fleurs between 1949 and the mid-1960s. Details of the research conducted at these two field stations will be published in later papers in this series.

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

2 THE DIVISION OF RADIOPHYSICS

2.1 Hornsby Valley Field Station

The Hornsby Valley field station (Orchiston and Slee, 2005b) was established in 1946 on farmland in a picturesque valley surrounded by low tree-covered hills (see Figure 3). At the time, this radio-quiet site lay just beyond Sydney's most northerly suburbs.

The first scientists to carry out research at this new field station were Frank John Kerr (1918–2000) and Charles Alexander ('Alex') Shain (1922–1960), but their interest was in radar astronomy, not radio astronomy, and in the Earth's upper atmosphere, not in extraterrestrial emission. During 1947–1948 they used a rhombic aerial to receive 17.84 and 21.54 MHz signals broadcast from Shepparton in Victoria by Radio Australia that were bounced off the Moon. These experiments provided information about the ionosphere, but what interests us is their astronomical conclusion: the nature of the echoes showed that the Moon's surface was 'rough' rather than smooth. This project was Kerr's sole exploration at low frequencies, and he then moved to the Potts Hill field station (Site 16 in Figure 2) where he concentrated on H-line work (Kerr, 1984; Wendt et al., 2011) before accepting a Chair in Astronomy at the University of Maryland.

The departure of Kerr left Hornsby Valley in the capable hands of Alex Shain and Charlie Higgins (Figure 4). Charles Alexander Shain was born in Melbourne on 6 February 1922, and after completing a B.Sc. degree at the University of Melbourne he served briefly in the military before joining the Division of Radiophysics in November 1943 (Orchiston and Slee, 2005b). During WWII he worked on the Division's radar program and immediately after the war he championed low frequency radio astronomy in Australia. When Shain died prematurely on 11 February 1960 Australia lost one of its radio astronomy pioneers. Deputy Chief of the Division of Radiophysics, Dr Joe Lade Pawsey (1908–1962), described Shain as "... a wonderful colleague in the laboratory, imaginative, well balanced, exceedingly unselfish, and a real friend to all." (Pawsey, 1960: 245). Assisting Shain was Technical Assistant Charles ('Charlie') S. Higgins (Figure 4), who came to Radiophysics with a background in radio engineering.

During 1949 and the early 1950s Shain and Higgins plotted a new course for the Division of Radiophysics by developing Hornsby Valley into the Division's forefront low frequency radio astronomy field station (Higgins and Shain, 1954; Shain, 1951; Shain and Higgins, 1954).

Figure 3: This panoramic view of the Hornsby Valley field station shows low frequency aerials, instrument huts and (far left) a farm house (courtesy: CASS RAIA: B2802-10).

Figure 4: Alex Shain (left) and Charlie Higgins (right) (both images are cropped close-ups that were taken from CASS RAIA: B2842-133).

They

> ... built 9.15 and 18.3 MHz horizontal arrays that were distinguished by their simplicity: ordinary posts were used to support the dipoles, with the ground serving as a reflector [see Figure 5] ... The most ambitious of these radio telescopes was an array of 30 horizontal half-wave dipoles, and by moving the beam electronically a strip of sky extending from declination –12° to –50° could be surveyed. These Hornsby Valley antennas were used to produce the first [contour] maps of Galactic emission at low frequencies [e.g. see Figure 6]. (Orchiston and Slee, 2005a: 132).

After completing the 9.15 MHz sky survey, Shain and Higgins planned to embark on a major new low frequency radio astronomy project, but Shain (1952) concluded that the Hornsby Valley site was unsuitable for larger arrays, and he favoured moving to the Division of Radiophysics field station at Badgerys Creek (Site 1 in Figure 2) on the western outskirts of suburban Sydney. For various reasons this did not happen, and instead it was the nearby Fleurs field station (Site 6 in Figure 2) that benefited from the eventual close down of the Hornsby Valley field station in 1955.

Before examining low frequency radio astronomy at the Fleurs field station, there is one final twist to the saga of the Hornsby Valley research that deserves to be told. Terrestrial interference was a common problem encountered by all low frequency radio astronomers because of the frequencies at which they worked, and Shain and Higgins tended to regard it as rather a nuisance and a distraction during their galactic observations at 9.15 and 18.3 MHz. However, when the U.S. radio astronomers Bernard Flood Burke (b. 1928) and Kenneth Linn Franklin (1923–2007) reported the discovery of decametric burst emission from Jupiter in 1955 Shain and Higgins were forced to reflect on this. Shain (1955; 1956) then examined some of those periods of 'intense static' that he and Higgins remembered recording at 18.3 MHz in 1950 and 1951 (e.g. see Figure 7), and he found that these were indeed Jovian bursts.[1] With the benefit of hindsight, this serendipitous 'pre-discovery' proved to be one of the Division of Radiophysics' most notable 'missed opportunities'.

Figure 5: The low frequency radio telescopes at Hornsby Valley consisted of posts that were used to support the dipoles, with the ground serving as a reflector (courtesy CASS RAIA: B2802-5).

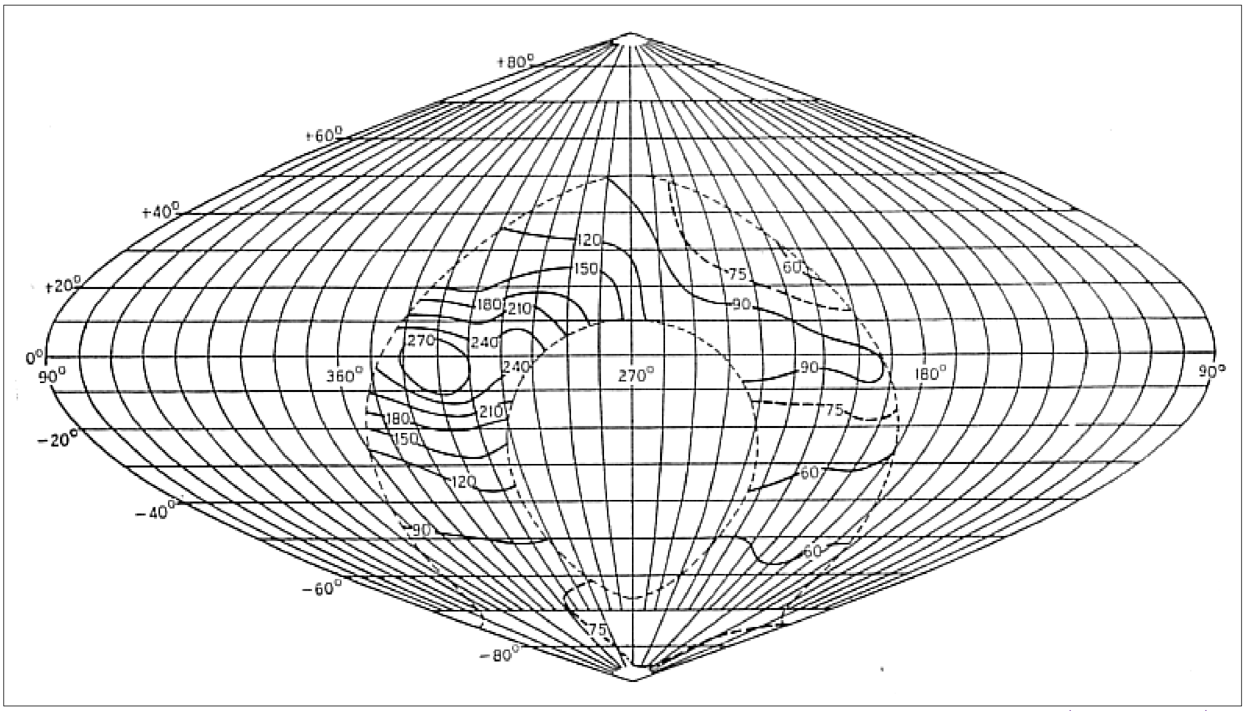

Figure 6: A galactic coordinate isophote plot of continuum emission at 18.3 MHz. The conspicuous source near l^{I} = 330° and b^{I} = –2° is Sagittarius A (after Shain 1954: 152).

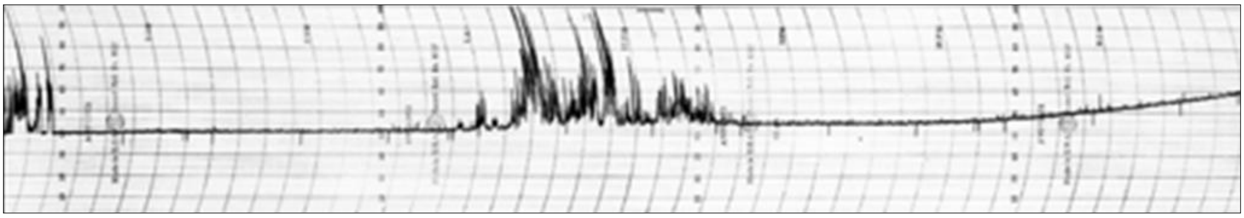

Figure 7: An example of 18.3 MHz Jovian bursts noted on the 1950–1951 Hornsby Valley chart records (CASS RAIA: B3719-13).

2.2 Fleurs Field Station

One of the last field stations to be set up by the Division of Radiophysics prior to the erection of the 64-m Parkes Radio Telescope was Fleurs, about 40 km west-south-west of central Sydney. This occupied an area of flat land between South Creek and Kemps Creek near an old WWII air strip (Orchiston and Slee, 2002b). Between 1954 and 1963, Fleurs was one of the Division's leading field stations and would become home to three innovative cross-type radio telescopes: the Mills Cross, the Shain Cross and the Chris Cross (Figure 8). All of these were to play important roles in furthering international radio astronomy (Orchiston and Mathewson, 2009; Orchiston and Slee, 2005a; Robertson, 1992).

However, when Shain arrived at Fleurs in 1955, he was not interested in using the existing radio telescope there, the Mills Cross, which operated at 85.5 MHz. Instead, he wanted to follow up his investigation of the 18.3 MHz Jovian bursts recorded at Hornsby Valley back in 1950. To do this he arranged the construction of three new small-scale low-frequency radio telescopes: a 19.6 MHz two-element E-W interferometer and 14 MHz and 27 MHz single in-line arrays of four and eight half-wave dipoles respectively. During 1955 and 1956 he and Frank Frederick Gardner (1924–2002; see Milne and Whiteoak, 2005) used these antennas to explore the rotation period of the source of the Jovian decametric emission. As a result of their study they concluded that the bursts resulted from plasma oscillations in an ionized region of the Jovian atmosphere (Gardner and Shain, 1958).

While this Jupiter research was in progress, Shain also was busy overseeing the construction of the field station's second large cross-type radio telescope. Appropriately named the 'Shain Cross', this had N-S and E-W arms of 1105 m and 1036 m, operated at 19.7 MHz, and had a beamwidth of 1.4° (Shain, 1958b). Although this new radio telescope evolved out of the Hornsby Valley arrays, it also drew on the innovative cross-type radio telescope concept invented by Shain's Radiophysics colleague Bernard Yarton Mills (1920-2011; see Mills, 1963). As at Hornsby Valley, the design was simple: a series of dipoles was strung between what looked like telegraph poles, again with the ground serving as a reflector (Figure 9).

Initially Shain used the Shain Cross to survey emission along the Galactic Plane, in the process discovering a conspicuous dip in the chart records (Figure 10), which indicated that "… absorption of 19.7 Mc/s radiation is occurring in a

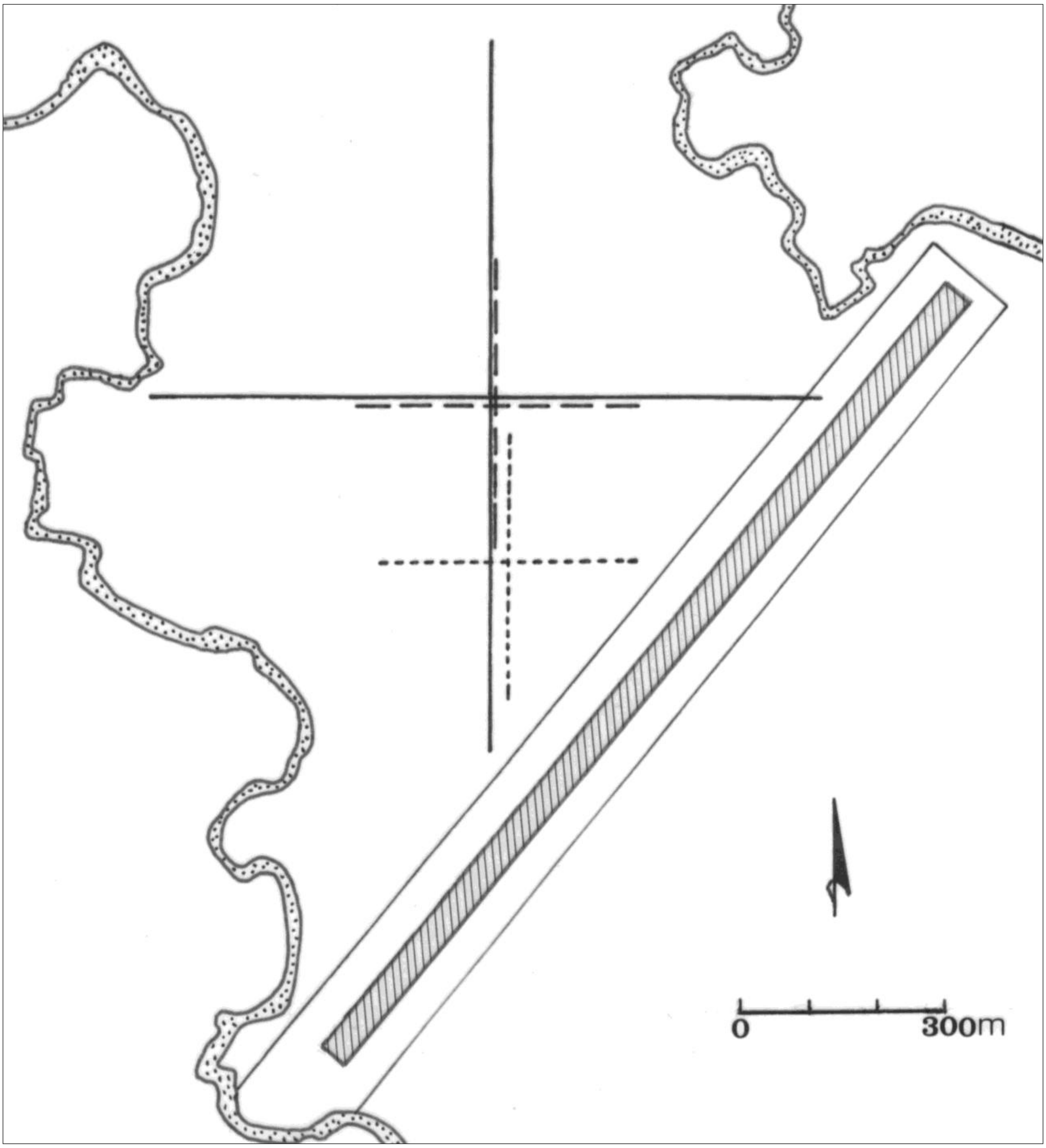

Figure 8: Plan of the Fleurs field station showing the WWII airstrip, South Creek and Kemps Creek and the three cross-shaped radio telescopes, the largest of which was the Shain Cross (map: Wayne Orchiston).

band of HII regions near the galactic plane." (Shain, 1957: 198). Meanwhile, the resulting isophote map of the region showed that some of the emission from the Galactic Centre source, Sagittarius A, also was absorbed by these HII regions. In contrast, Shain (1958a) found that the discrete sources Centaurus A and Fornax A were in emission. This promising line of research came to an unexpected end in 1960 when Alex Shain succumbed to terminal cancer, and it was left to Shain's Radiophysics colleagues Max M. Komesaroff and Charlie Higgins to publish a more detailed analysis of the 19.7 MHz Galactic Plane survey (see Shain et al., 1961).

Had he not died, Shain's plan was to also use the Shain Cross to carry out simultaneous 19.7 MHz and optical observations of Jupiter. Instead, it was Bruce Slee and Charlie Higgins who would take up the Jovian challenge.

Owen Bruce Slee (Figure 11) was born in Adelaide on 12 August 1924, and was one of those who independently detected solar radio emission during WWII while serving as a radar operator. After the war he joined the Division of Radiophysics as a Technical Assistant, and worked with John Bolton (1922–1993) and Gordon Stanley (1921–2001) on 'radio stars' at the Dover Heights field station (Site 5 in Figure 2), before transferring to Fleurs field station and

Figure 9: A view looking south along the N-S arm of the Shain Cross. To the left is part of the south arm of the Mills Cross and a broadside array that was used to investigate the angular sizes of discrete sources (courtesy: CASS RAIA: B3868-19).

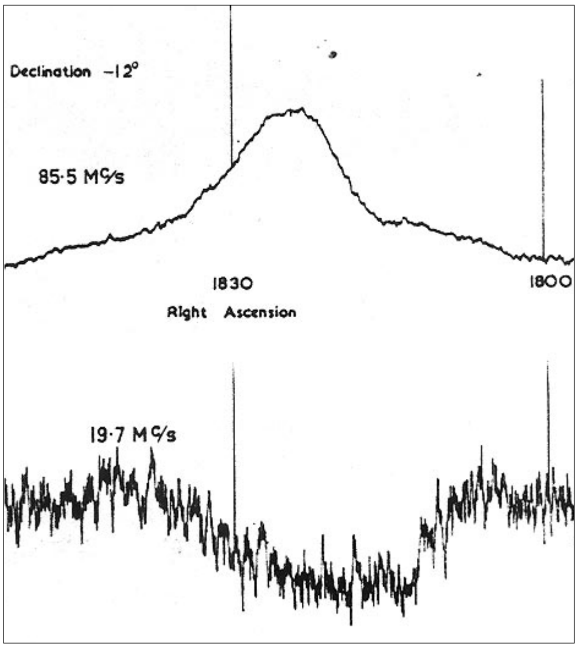

Figure 10: The Galactic Plane shown in emission at 85.5 MHz (Mills Cross) and absorption at 19.7 MHZ (Shain Cross) (after Shain, 195x: xxx).

Figure 11: Bruce Slee in the Control Room at the Parkes Radio Telescope in the 1960s (courtesy: CASS RAIA).

working with Bernie Mills on the Mills Cross. After studying evenings and obtaining a B.Sc. Honours degree he joined the Division's research staff and ultimately was awarded a D.Sc. for his international contributions to radio astronomy. Over the years, Slee made extensive use of the 64-m Parkes Radio Telescope, the Culgoora Radioheliograph (in its guise as the 'Culgoora Circular Array') and the Australia Telescope Compact Array near Narrabri—amongst other instruments—to investigate a wide range of astronomical objects and phenomena (see Orchiston, 2004; 2005c). He is a co-author of this paper, and as a CSIRO Astronomy and Space Sciences Research Associate continues to carry out research in astrophysics and on the history of Australian radio astronomy.

During the early 1960s Slee and Higgins erected small arrays of 19.7 MHz dipoles at Fleurs, and three remote sites at various distances to the north and south of Fleurs in order to carry out long-baseline interferometry of Jupiter. Their objective was to expand on the research done earlier by Shain and Gardner on the size of the source of the Jovian decametric emission (Slee and Higgins, 1963). Initially they found the source of the emission to be 10–20″ in diameter (Slee and Higgins, 1966), but later realised that the source was very much smaller (Slee and Higgins, 1968), and was

> ... due to an interplanetary diffraction pattern scattering by solar wind turbulence, which drifted across our baseline at the speed of the outward flowing solar plasma of a few hundred km/sec. (Slee, 2005: 105).[2]

It was also at this time that Slee and Higgins used the Shain Cross for one final research project: between September and December 1961 they used the N-S arm in a search for 19.7 MHz radio emission from selected flare stars (Slee, Solomon, and Patston, 1963). They were successful as Figure 12 illustrates, and along with Jodrell Bank's Sir Bernard Lovell (1913–2012), they pioneered the detection of radio emission from stars other than the Sun.

3 CONCLUDING REMARKS

The years following WWII saw Australia emerge as one of the international leaders in the new field of radio astronomy. Low frequency investigations were carried out in two quite separate geographical regions: the Sydney region, through the CSIRO's Division of Radiophysics, and far to the south in the island state of Tasmania, by staff from the University of Tasmania and the U.S. radio astronomy pioneer, Grote Reber (who conducted independent research).

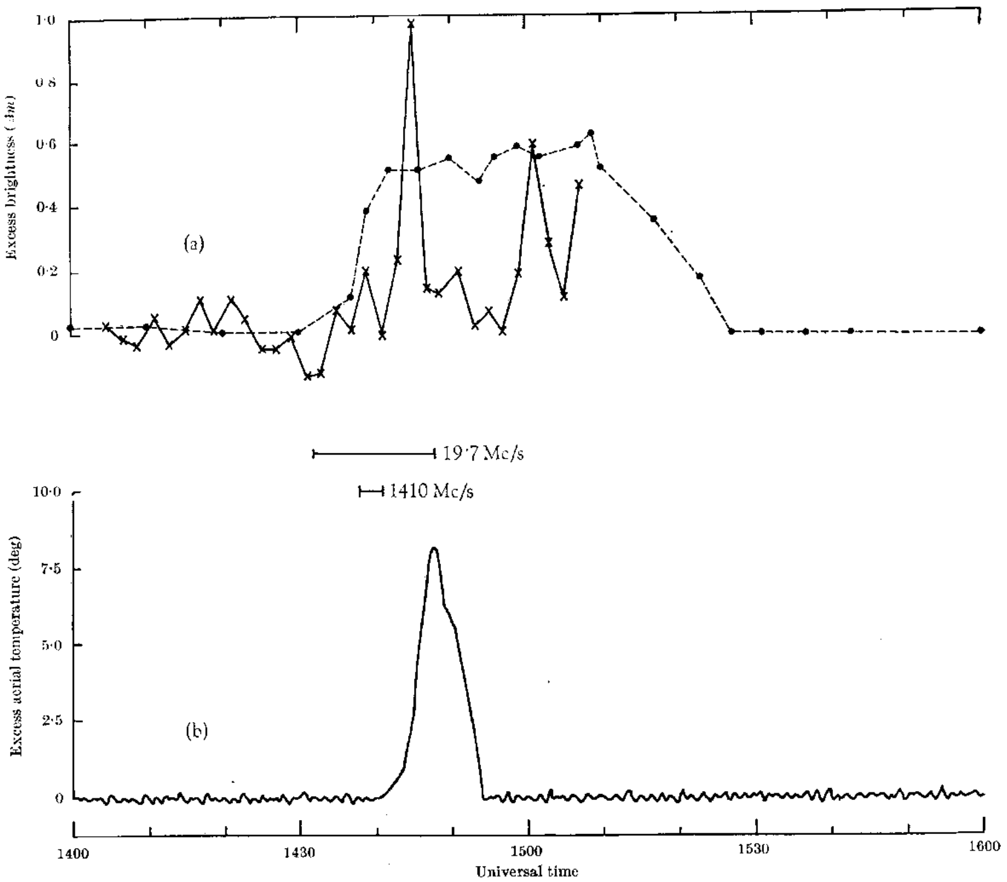

Figure 12: Optical (a) and radio (b) flaring of V371 Orionis on 30 November 1962. In (a) the solid line shows the optical light curve derived from Baker-Nunn photographs while the dashed line indicates the magnitude variation based upon visual observations by amateur astronomers. In (b) the smoothed line is the emission recorded at 410 MHz using the 64-m Parkes Radio Telescope, and directly above are the time intervals when radio emission also was recorded at 19.7 MHz and 1410 MHz using the Shain Cross at Fleurs and the Parkes Radio Telescope respectively (after Slee, Solomon, and Patston, 1963: 993).

The investigation of Jovian decametric burst emission at Hornsby Valley and later at Fleurs and three remote sites to the north and south of Sydney was a major research investigation of the Division of Radiophysics, whereas the galactic research conducted at these two field stations was merely part of a much larger program that involved other field stations and remote sites in and near Sydney and extended in frequency from 9 MHz to 1,200 MHz.

Details of the low frequency research conducted at Hornsby Valley and Fleurs will be presented in later papers in this series.

4 NOTES

1. In fact, at first Burke and Franklin also thought that their Jovian bursts were some form of interference (see Franklin, 1983).
2. We now know that the Jovian bursts originate in Jupiter's magnetosphere and are broadened by scattering caused by irregularities in the solar wind.

5 ACKNOWLEDGEMENTS

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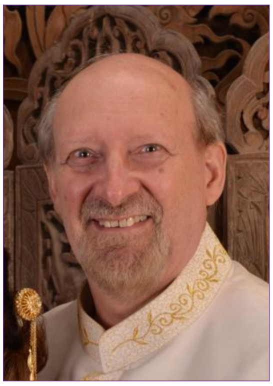
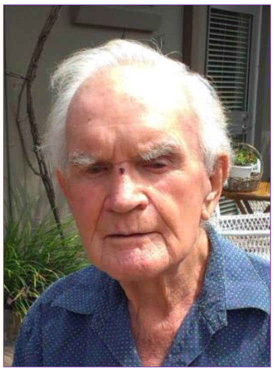


Professor Wayne Orchiston was born in New Zealand in 1943 and works as a Senior Researcher at the National Astronomical Research Institute of Thailand and is an Adjunct Professor of Astronomy at the University of Southern Queensland in Toowooma, Australia. In the 1960s Wayne worked as a Technical Assistant 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 he 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 asteroid 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.

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.



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 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 100-m 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.