History of Australian Astronomy

The beginnings of radio astronomy in Australia

J. P. Wild

Introduction
My lecture this evening is dedicated to my late friend and fellow astronomer, Harley Wood, who died on 26 June 1984 at the age of 72. It is a fine thing that the ASA has decided to give the name of Harley Wood to an annual public lecture at the time of the society’s Annual General Meeting. For besides making a monumental contribution to the astrometry of the southern skies, Harley became a leader, a kind of organizer and father figure, among Australian astronomers. He played a leading part in the formation of this society and was its foundation President. He will also be specially remembered by a small group of us, about half a dozen, who met regularly in the charming old building of Sydney Observatory to plan the 1973 IAU General Assembly held in Sydney, the first time ever in Australia. Harley chaired not only the local organizing committee, but the ladies’ committee too. My wife still recalls the gentle, but firm way in which Harley once admonished her for addressing a remark across the table without going through the Chair. Harley was totally approachable and totally positive at all times: you could always count on his support for any sensible initiative. He had many friends and no enemies that I have heard of. And unlike so many of his profession, there was no hint of the egotist or the prima donna. I count it a privilege to have been his contemporary and colleague.

Harley witnessed from very close quarters the whole drama of the beginnings of radio astronomy in Australia — our subject this evening — and was one of the very few optical astronomers who took the embryo science seriously. He himself has given an enlightened account of this piece of history (Wood 1966).

Tonight I speak on the subject, not as an objective historian, but through the recollections of one who was a young research scientist at the time, one who considers himself to have been very lucky to have lived through this period and been totally involved. The period I shall deal with is the first seven years, 1945-52. Part of my lecture stems from a brief memoir written 15 years ago (Wild 1972) and I shall quote freely from contributions to Woody Sullivan’s book on the early years of radio astronomy. A complete list of Australian publications on radio astronomy during the years 1946-52 is given in Appendix 1.

1945
Today radio astronomy is an integral and sophisticated part of astronomy, providing detailed information on the Universe as we see it from our planet with comparable and sometimes greater sophistication than optical astronomy. But, its beginnings were very humble indeed. The Australians who first embraced the new science knew nothing at all about astronomy, nor did they imagine they were going to make any serious contribution to astronomical knowledge.

It all started in 1945, a year of transition for many research laboratories around the world as new programs were sought to replace wartime activities. One such laboratory was the CSIR Radiophysics Laboratory in Sydney, which had been immersed in radar development problems throughout the war. Now, under the vigorous direction of its newly-appointed Chief, Dr E. G. (Taffy) Bowen, it looked out for new fields to conquer.

Taffy put it this way (Bowen 1984):
“What were the ingredients which led in 1946 to the development of radio astronomy?

The first and by far the most important of these was the decision by the Chairman of CSIR, Sir David Rivett, that at the conclusion of World War II, CSIR would be devoted only to peace-time research, and that defence research would be carried out by other agencies. This meant that a highly developed laboratory with a superlative staff became available for a wide range of researches and practical developments in a peace-time environment.
The next ingredient was that the staff, about two hundred strong, was already highly skilled in electronic research and development. They ranged from professors of physics to practical engineers from industry.

Many of them had spent months, if not years, at the best overseas laboratories and were saturated with the most recent electronic techniques. In view of later events, it is also rather remarkable that there was not a single astronomer on the staff, nor, for that matter, anyone who had done a university course in astronomy.

Next in importance to the people was the store of special components of all kinds which had accumulated during the way years—magnetrons, klystrons, pulse-forming networks, pulse-counting circuits—the whole paraphernalia of a new electronic era.

Another important factor was morale.

Our policy was to try anything that gave promise of useful scientific or practical application; if successful, we poured in manpower and resources. Radio astronomy was to become one of the most productive of these."

Pawsey and the Sun

It was just at this critical time that a British report—kept secret during the war—was received about a remarkable phenomenon discovered three years before. For several successive days in February 1942 radar sets throughout Great Britain had been jammed by a new kind of noise which defied counter-measures. The discovery, made by Dr J. S. Hey, was that the jamming was being generated not by the Germans, as was at first suspected, but by the Sun.

This report was seized upon by Joe Pawsey, the outstanding physicist on Dr Bowen's staff and the mainspring of much of the Laboratory's wartime success in radar. Impatient now to see the new phenomenon for himself, Pawsey and one or two colleagues descended upon Sydney's network of coastal radar stations and with the cooperation of service personnel went in search of the solar emissions. At Collaroy, North Head and Dover Heights the aerials looked horizontally over the sea and so could point to the Sun at sunrise (over water) and sunset (over land). The idea was to receive the signals with the actual radar-receiving equipment augmented by equipment hastily put together in the laboratory. They first detected the solar radiation on 3 October 1945 and found it to be highly variable; after three weeks of observation they were able to report to Nature that the variations of intensity showed a correlation with sunspot activity. This was the first of the Laboratory's radio astronomy publications, which are now counted in thousands.

The next important step was made the following February. Pawsey, in collaboration with Lindsay McCready and Ruby Payne-Scott, performed a historic though simple observation by which he directly demonstrated that the emissions were being radiated from the actual vicinity of sunspots. This experiment needed extremely high angular resolution far beyond that of a single aerial. However, the aerial of each radar station was located on high cliffs and Pawsey realised that as the Sun slowly rose above the horizon the recorded signal would show a fringe pattern owing to the interference between direct and reflected rays. The accuracy of position finding was sufficient to establish the sunspot origin of the radiation. With this observation Pawsey may be said to have introduced the technique of interferometry to radio astronomy (although Martin Ryle at Cambridge was independently developing two-aerial interferometry at much the same time).

It was Pawsey and his colleagues, reporting this work in the Proceedings of the Royal Society, who went to the very heart of interferometry by pointing out that if you record a brightness distribution using a pair of aerials separated by a given baseline, the oscillatory record obtained corresponded to one Fourier component of the distribution; and that if you record with many different bases, even at different times, it would be possible to synthesize the complete distribution: he had stated for the first time the basis of what is now known as aperture synthesis.

Pawsey was extraordinarily lucky to have carried out this observation during a period when one of the largest spot groups in recorded history was present on the Sun's disk. Had the sunspot activity been weak Australian radio astronomy might never have grown its wings.

At much the same time Pawsey recognized that there were three components to the Sun's radio emission: a basic million-degree thermal component, corresponding to the million-degree corona; an enhanced continuum component from sunspots; and intense sudden bursts, sometimes occurring with solar flares.
**Discrete Sources**

Bowen recognized the scientific potential of this work and an increasing number of the Laboratory's staff were diverted to the field from other, less flourishing, projects. They worked in small groups of two or three under Pawsey's general direction. Observations were not confined to the Sun, but were extended to mapping radiation from the Galaxy. As long ago as the early 1930's Karl Jansky had discovered that the Milky Way was a broad extended source of radio emission. Also in 1946 Hey's group in England had noted that when they pointed their aerial beam in the direction of the constellation of Cygnus they received a fluctuating signal; they inferred the presence of a discrete, compact source in the sky, though they could not locate it with any accuracy. It fell to two of Pawsey's young colleagues, John Bolton and Gordon Stanley, to substantiate the existence of the source in Cygnus. Using Pawsey's method of cliff-top interferometry at Dover Heights field station they located the source accurately and demonstrated that it was indeed of very small angular dimension—less than eight minutes of arc, in fact. This was in 1947 (published in 1948) and during the same year Bolton, Stanley and Slee increased the number of sources to six. Next year Bolton and his colleagues made the first identification of a radio source, Taurus A, with an optical object—the Crab Nebula—and then discovered that two other sources, Virgo A and Centaurus A, were peculiar galaxies beyond our own galactic system.

These discoveries of discrete radio sources and the first identification with optical objects perhaps represent the finest hour of Australian radio astronomy. More than that, the demonstration that the Crab Nebula emitted intense, surely non-thermal, radiation was in my opinion the beginning of the revolution that was to change the face of astronomy over the second half of the twentieth century. Certainly radio astronomy in Australia had come to stay.

With these first identifications, especially the identification with the Crab Nebula, came the first intimate link between the radio investigator and the classical astronomer. Bolton (1973) has described how this link was forged through Harley Wood, a walking encyclopedia and always available for consultation.

Australia's only rivals in this field were the Cambridge group under Martyn Ryle, a group that held its cards close to its chest; the rivalry between the two groups would sometimes break out into acrimony in years to come. Years later John Findlay, then at Cambridge, wrote (Smith 1986):

"But what kind of stars could they be? The four identifications published by Bolton, Stanley and Slee in 1949 scarcely seemed to help; they seemed to be a mixture of galactic and extragalactic objects" (my italics).

That was written in 1986 by the Astronomer Royal, Sir Francis Graham-Smith (1986).

If John Bolton had given Australia radio astronomy a flying start in the field of discrete sources, it fell to Bernard Mills to make the next significant steps. These are his own words (Mills 1984):

"Nowadays it is difficult to appreciate the abysmal ignorance of the nature of radio sources prevalent around 1950. We were struggling with inadequate instruments to make physical sense of some completely new and unexpected phenomena. There were but two types of instrument, interferometers comprising pairs of low directivity antennas (or the equivalent single antenna on a cliff-top overlooking the sea) and single small-size antennas operating at low frequencies with poor resolution. Accordingly, the sky appeared to be populated by randomly distributed 'point sources', which produced interferometer patterns, and a broad band of rather featureless emission concentrated to the plane of the Milky Way. This purely instrumental result seemed to correspond to the general appearance of the visible sky and led to models comprising dark 'radio stars' distributed through the Galaxy much like the visible stars. The Cambridge group, under the leadership of Martin Ryle, strongly espoused this view.

My own realization that it was likely to be incorrect came when, in early 1950, I put into operation a three antenna interferometer with two spacings of 60 m (20X) and 270 m (90X). This was my first major project ... .

From almost the first observations with the interferometer the results were surprising. 'Point sources' detected by the close pair of antennas often seemed to bear no relation to those detected with the wider spacing, and when this occurred, the apparent flux densities on the close spacing were usually larger. Obviously sources of large angular size were involved, sources which were being resolved at a spacing of 90X. Further indications that the 'radio star' hypothesis might be incorrect came from identifications which Bolton had suggested with three nebulae . . . ."

Mills showed, in fact, that the increasing numbers of radio sources being found belonged to two populations, one galactic, the other extragalactic. Measurements of angular size of the extragalactic sources then became a vital challenge; this was achieved simultaneously around 1952 by Mills in Australia, Graham Smith at Cambridge and Hanbury Brown at Jodrell Bank. Then it became clear 'radio stars' were not stars at all, but nebulae, whether galactic or extra galactic. The only known radio star proper was the Sun.

**Some Personal Recollections**

While these fruitful investigations of galactic and extragalactic investigations were progressing, several groups were studying different aspects of the radio Sun. I was involved in one such investigation and I would like now to give my personal recollections of this work.
During the latter stage of the war John Bolton and I both served in the Royal Navy as radar officers, he in the light carrier Unicorn, I in the battleship King George V (which incidentally entered Tokyo Bay on VJ+1 day and attended at the signing of the surrender). Both ships used Sydney as their rear base; both of us became betrothed to Sydney girls whom we were to marry at ceremonies a mere month apart. John and I had never met in the Navy, but we had similar backgrounds: both born in Sheffield, both educated at Cambridge in wartime haste. (At one stage later we were joint vice-captains of the Radiophysics cricket team!) And in 1946, both still in the Navy, we applied for the same job at the CSIR Radiophysics Laboratory. John was on the spot in Sydney (where he was demobbed); I was still in England teaching radar at 'HMS Collingwood', where Taffy Bowen on a visit to the UK interviewed me. John got the job. I was still determined to join Radiophysics and wrote accordingly to Bowen who referred my letter for reply to some bloke named Pawsey. Pawsey offered me a job as Assistant Research Officer—to work on test equipment in the Test room. I seized the opportunity and on being demobbed on an icy February day in 1947, I sailed for the sunshine of the antipodes in RMS Asturias. The astute and kindly Fred Lehany was my first boss who became a friend for life, but I was bored with and ineffective at my test room job. One day Joe Pawsey and Fred took me out to the radio astronomy field station at Middle Head. While there I was able to do something useful—improve the noise factor of a receiver by some 4 dB. I believe it was that flukish incident which led to Pawsey's offer to let me join the 'solar noise group' (the term radio astronomy had not been invented). That was about February 1948.

Pawsey suggested one of two projects for me to start on: to join Bolton at Dover Heights (the great discoveries of sources and identification had just been made) or to work with Lindsay McCready on developing a solar spectrum analyzer to investigate solar bursts). Both were exciting projects and I chose the latter mainly because I believed I would have far more independence (complete as it turned out) in the gentle and unobtrusive, yet experienced and competent, hands of Lindsay McCready.

The challenge was marvellous. Nobody had any idea what caused the Sun occasionally to break out into radio storms or generate sudden intense bursts of radio emission, some simple 'isolated bursts', others extremely complex 'outbursts'. The first important clue had been obtained a year earlier when Payne-Scott, Yabsley and Bolton, recording at three field stations, had found that certain phenomena could be identified with terrestrial aurorae. And the type III bursts which showed a rapid downward drift in frequency. These were ready-made for spectral analysis of the noise from the Sun and they were quickly pressed into service. In the inventive hands of Lindsay McCready and Paul Wild, a 'radio spectrometer' evolved which was to dominate the field of solar studies for the next twenty years. This was another instance of a device, designed for the first place for military use, repaying a massive debt to fundamental science'.

I am flattered by the general tenor of these remarks, but for the sake of the record it should be said that military spectrum analysers were not up to the job and played no part either in implementation or in concept (which was self-evident).

By February 1949 Bill Rowe and I had established a make-shift field station on a cattle stud farm near Penrith railway station to which we travelled each day by train. We observed the Sun by pointing the rhombic aerial towards it with the aid of a pole, ropes and a winch, adjusting it every 20 minutes. Inside the darkened 'laboratory' (an ex-army trailer) we took 20 minute turns to watch the display for solar bursts to turn on (originally to wind by hand!) the movie camera. Sometimes weeks would go by with nothing happening; at other times the bursts came copiously. We recorded for just 4 months, March—June 1949, then closed down the field station and I buried myself in a darkened room to analyse the results.

From this study three characteristic types of burst emerged, and our classification, types I, II and III remain to this day the international standard. Of special interest were the type II bursts which showed a gradual downward drift in frequency. These corresponded to disturbances moving out through the solar corona at speeds of order 1000 km s⁻¹, just the right kind of speed to account for the time delay between solar flares and terrestrial aurorae. And the type III bursts which showed a rapid downward drift in frequency. After eliminating other hypotheses we were left only with the interpretation that these also were outward moving disturbances, but at a much greater speed than the type II's—100 000 km s⁻¹ or one-third the velocity of light. Few people believed in such an unheard-of phenomena, until 20 years later they were detected directly by spacecraft. Thus began a new line of investigation which proved a great stimulus for the evolving science of plasma physics and solar-terrestrial physics, as well as solar physics.

**Pawsey's Group**

The years 1946-1950 saw the diversification of Pawsey's scattered group. Working on the Sun and Moon were seven small groups: Lehany and Yabsley, and later Christiansen and Hindman, on
decimetre waves, Piddington and Minnett on centimetre waves, Payne-Scott and Little on metre-wave interferometry, McCready and I on metre-wave spectroscopy, Kerr and Shain on lunar echoes, Westfold and Smerd (sometimes joined by Professor Jaeger of the University of Tasmania) on the theory of radio emission, and Pawsey and Yabsley on temperature measurements of the solar atmosphere. Working on galactic and extragalactic problems were Bolton, Stanley, Slee, and (later) Westfold using cliff interferometry at Dover Heights, Mills and Thomas, using two-aerial interferometry, and Shain, studying decametre waves. No fewer than six field stations were in use during these years. By 1951-2, each one of these groups had produced publications of a definitive nature which in retrospect can be seen to have played a major part in laying the foundations of the new science. I am sorry I cannot do justice here to all this work.

It is interesting to read reflections of some of those who took part during this period. Christiansen (1984) writes:

“The Sydney group directed by E. G. Bowen had as its scientific leader J. L. Pawsey, a physicist/engineer of infectious enthusiasm with the interest and ability to contribute in detail to each of the individual research projects being undertaken. His enthusiasm, combined with the youthfulness of the group and the interest inherent in exploring unchartered territory, produced an air of excitement that few scientific groups seem lucky enough to experience. With the eagerness of the young, the scientists shared new ideas with their colleagues as soon as the ideas were formed. This continual interchange produced a group strength that was much greater than the sum of the strengths of its members.

The field work had a pioneering appearance. Each morning people set off in open trucks to the field stations where their equipment, mainly salvaged and modified from radar installations, had been installed in ex-army and navy huts. At the field stations the atmosphere was completely informal and egalitarian, with dirty jobs shared by all. Thermionic valves were in frequent need of replacement and old and well-used co-axial connectors were a constant source of trouble. All receivers suffered from drifts in gain and ‘system-noise’ of hundreds or thousands of degrees represented the state of the art. During this period there was no place for observers who were incapable of repairing and maintaining the equipment. One constantly expected trouble.

One peculiarity of the Sydney group was the number of field stations. This was partly the result of the taking over of a number of former radar sites, but it continued because maintenance work and observations at the same site by different groups produced mutual electrical interference. Each group sought isolation for this reason, but also because it suited the style of work of most members of the groups”. Christiansen himself made a beautiful contribution to radio astronomy techniques during this period. He invented, designed and constructed the first grating interferometer (equally spaced array) to study the decimetre-wavelength radiation from the Sun. This was perhaps the world’s first high resolution array, albeit of one dimension. Later Christiansen was one of the first to use the rotation of the Earth to obtain two dimensional synthesis.

I have nostalgic memories of that pre-1952 period. It was a time when one could discover new things with simple, often improvised equipment; each little group had its own approach and made its own equipment. With the flow of new discoveries from a brand new science an atmosphere developed — perhaps, though on a humbler scale, something like that at the Cavendish in Rutherford’s time.

Pawsey’s role at this time was quite central. Most people of his group — though perhaps there were a couple who liked to think themselves self-sufficient—looked to him for advice, encouragement and inspiration, which were freely and selflessly given. About once a fortnight the research staff would meet together with Pawsey in the chair. Each person or group would report progress and Pawsey would ask questions and make suggestions. At other times when one ran into problems, half-an-hour’s discussion with Joe tended to be both soothing and rewarding. Then on some days he would arrive unexpectedly at one’s field station, usually at lunch time (accompanied by a type of sticky cake known as the lamington, which he found irresistible); or else infuriatingly near knock-off time. During all such visits one had to watch him like a hawk because he was a compulsive knob-twiddler. Some experimenters even claimed to have built into their equipment prominent functionless knobs as decoys, especially for Pawsey’s benefit.

Frank Kerr (1984) made this comment:

“The inspiration and driving force of all the early Australian work was Joseph Lade Pawsey. He was a brilliant research leader, who always knew the right questions to ask, usually simple ones. He actively led each part of the research program, but had the ability to develop the less experienced members of his group into independent thinkers who then became leading contributors in their respective fields.”

Pawsey always liked the idea of people spending some of their time on what he called ‘wild cat’ experiments, or ‘projects on the wrong job number’, or following hunches. That is why I find the following recollection of John Bolton (1982) strangely out of character:

“Our efforts (to search for non-solar objects) were unfortunately not successful and after a week or two they were cut short by an unheralded visit from Pawsey, who noted that the aerials were not looking at the Sun. Suffice it to say that he was not amused and we were both ordered back to the lab”.

Pawsey himself saw the whole development as one in which simple equipment led to increasingly complex equipment through a step by step process as each stage produced new phenomena that needed to be investigated. He said (Pawsey 1961):

“It should be noted that [this process] can only be followed effectively in a well organized scientific organization in which the scientific direction can very quickly make decisions and supply facilities for the really promising developments. In all too many cases elsewhere the energies of scientists are taken up in advertising the potentialities of their prospective investigations in order to obtain any support at all. The result
is a neglect of the unspectacular preliminary probing investigations which are often such a vital ingredient in success."

In the early days none of us knew anything about astronomy or solar physics. We spoke a different language from the astronomer. We owed a lot to Dr C. W. Allen at Mount Stromlo and Harley Wood at Sydney Observatory for teaching us some of the rudiments. Indeed Allen became so interested that he himself used our equipment to take solar observations on the mountain. Dr D. F. Martyn, one-time Chief of Radiophysics then seconded to Mount Stromlo, was another who, for a time, become deeply involved, making important contributions. But, until the arrival of Bart Bok in 1957, few local astronomers could be bothered with a new-fangled radio observations.* It was different when eventually, one by one, we began to travel and attend international conferences and meet the people with great names. Then suddenly we found ourselves treated with respect—as equals; the fact that we were wearing long trousers could be tolerated with a new-fangled radio observations. It was unavoidable that bit by bit the radio astronomer, like his optical counterpart, sought ‘observing time’ to carry out an investigation tailored to the available instrument. It thus became increasingly important to devise radio telescope systems that had both extremely high resolution and extremely high flexibility. The answer has now emerged: earth rotation aperture synthesis—and what a marvellous answer!

The evolution of aperture synthesis has been described from a Cambridge viewpoint in a charming memoir by Peter Scheuer (1984). But, Australia too had played a notable part in this. Its principle was first stated by McCready, Pawsey and Payne-Scott; its theory was first given in detail by Bracewell and Roberts, and Christiansen was one of the first to exploit the Earth’s rotation to synthesize an image. Yet the first to put the whole thing together and, by using the newly emerging electronic computer, make the technique work was Martin Ryle and his colleagues at Cambridge; it was a great personal triumph for Ryle and earned him a Nobel prize.

Did Australia miss an opportunity? Well, when the international visitors of the 1952 URSI conference came to visit the Radiophysics Laboratory, they saw CSIRAC one of the first electronic computers ever built, the handiwork of Pearcey and Beard. The main problem with CSIRAC was that nobody wanted to use it for any grand purpose. How marvellous it would have been if we had been smart enough then to bring our radio astronomy skills and computing skills together to be the first cab off the rank with true aperture synthesis and perhaps to found a national computing industry at the same time.

Never mind! We can now look forward to a resurgence of radio astronomy strength with the impending completion of the Australia telescope which will be one of the two most powerful aperture synthesis telescopes in the world.


* Bowen recalls the famous remark of Richard Woolley, Commonwealth Astronomer, Director of Mount Stromlo: ‘In ten years’ time radio astronomy will be forgotten’. I was present among the small group that heard this remark in reply to a question by Ron Bracewell. Soon Woolley was to become Astronomer Royal. On taking up this position he made another much publicised statement: “Space research is utter bilge”. Sputnik was to fly shortly.

Epilogue

But, before I completely stop let us very briefly reflect on where this exciting early phase of Australian radio astronomy led. The next two decades were dominated by the struggle to build radio telescope systems of higher and higher resolution by greater and greater ingenuity. It led, for instance, to the Mills Cross and the Parkes telescope. It led necessarily to much greater investment in single projects; but the price one had to pay was lack of the flexibility, available in the early days, to throw together new equipment to investigate the latest discovery. It was unavoidable that bit by bit the radio astronomer, like his optical counterpart, sought ‘observing time’ to carry out an investigation tailored to the available instrument. It thus became increasingly important to devise radio telescope systems that had both extremely high resolution and extremely high flexibility. The answer has now emerged: earth rotation aperture synthesis—and what a marvellous answer!

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Appendix 1

Australian Publications on Radio Astronomy During the First Seven Years (1946-1952)

CSIRO Division of Radiophysics

1946

1947

1948

1949

1950


1951


1952

R. N. Bracewell, ‘Radio Stars or Radio Nebulae?’, The Observatory, 72, p. 27.


W. N. Christiansen and J. V. Hindman, ‘21-Centimetre Line Radiation from Galactic Hydrogen’, The Observatory, 72, p. 149.


Mount Stromlo Observatory (Then Commonwealth Observatory)


* On secondment from Radiophysics Laboratory.

CSIRO Division of Physics


University of Sydney