*Journal of Astronomical History and Heritage*, 8(1): 33-38 (2005.)

# THE IMPACT OF F.F. GARDNER ON OUR EARLY RESEARCH WITH THE PARKES RADIO TELESCOPE

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**Abstract:** Frank Gardner, who died in 2002, aged 78, was one of the driving forces in the early years of the Parkes Radio Telescope, and it is hard to separate Frank from any of the early discoveries. An inventive receiver engineer who turned radio astronomer with the commissioning of the Parkes Telescope, Frank was a pioneer in radio polarization and spectral line observations. The present authors both benefited greatly from their association with him. In this paper we outline those early scientific discoveries and tell some of the tales that reveal his character.

**Keywords:** Frank Gardner, polarization and spectral line studies, Parkes Radio Telescope

## 1 'FF' GARDNER, RADIO ASTRONOMER EXTRAORDINAIRE

Dr Francis Fredrick Gardner (Figure 1) was born in Sydney in 1924 and died in 2002. He graduated from the University of Sydney in Science in 1943 and with First Class Honours in Electrical Engineering in 1945. Quiet and unassuming, he worked on ionospheric research at the Cavendish Laboratory from 1947 to 1949 graduating with a Ph.D. from Cambridge University. Returning to Australia, he joined the CSIRO's Division of Radiophysics in 1950, and continued in ionospheric research until 1957 when he turned his attention to developing low-noise amplifiers for the Parkes Radio Telescope. From 1962 until his retirement in 1989, and for a few years afterwards, Frank Gardner (henceforth 'FF', as he was affectionately known) carried out research with the Parkes Radio Telescope that produced cutting-edge results in fields as diverse as the polarization of radio emission and interstellar chemistry.

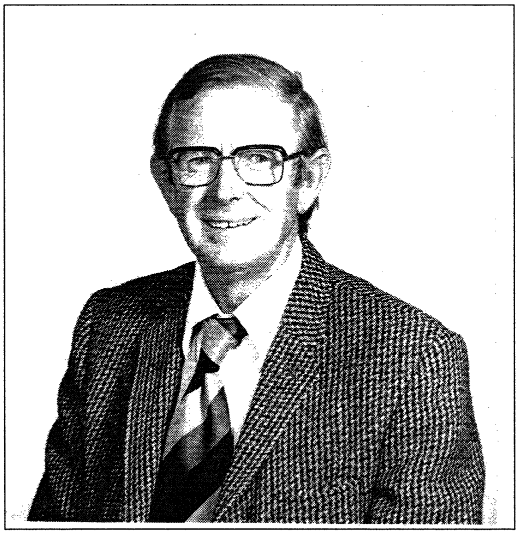

Figure 1: Dr Frank Gardner (courtesy: ATNF Historic Photographic Archive).

## 2 THE EARLY YEARS AT RADIOPHYSICS

The first author (DKM) first met FF in 1951. The latter needed someone to climb the antenna mast at CSIRO's Camden field station and attach further wires, dipoles or other equipment. DKM asked FF to make sure that the transmitter was switched off and he stuttered "y-y-yes, it's off", so DKM climbed the dizzy heights and nearly fell off when the first tingle hit him! "Who *is* this idiot ...?" he thought. He did not realise that FF was simply displaying his keen sense of humour!

DKM joined FF in 1958 when he and Gib Bogle were developing a maser receiver for the Parkes Radio Telescope (see Milne et al., 1994: Figure 1), and they worked closely together for the next four years. They built an operational maser, one of the world's first, and tested it briefly on the 11-m radio telescope at Potts Hill (see Figure 2). However, they realized that handling liquid helium at Parkes was going to be beyond them at that time, and so they abandoned the project in favour of a 20-cm nitrogen-cooled parametric amplifier (see Gardner and Milne, 1963). At that stage, this was only the fourth receiver built specifically for the Parkes Radio Telescope (see Brooks and Sinclair, 1994: Table 1). During this period DKM came to respect FF as a brilliant engineer, and he learnt much from their association. In retrospect, he feels that FF may also have benefited on the practical side from his presence.

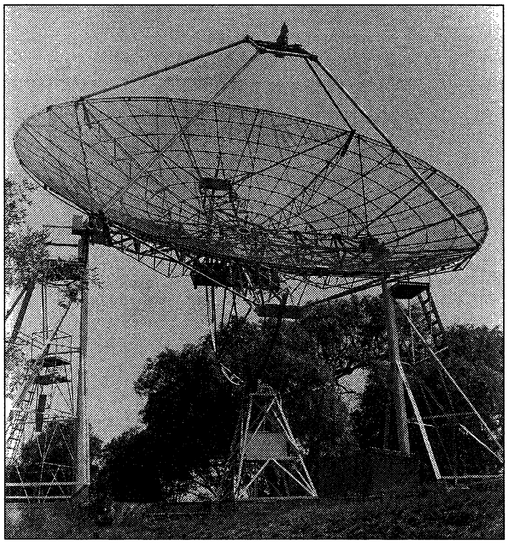

Figure 2: The 11-m transit radio telescope at Potts Hill field station (courtesy: ATNF Historic Photographic Archive).

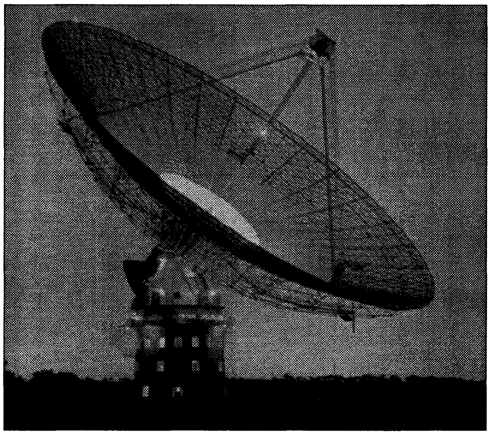

Figure 3: The 64-m Parkes Radio Telescope (courtesy ATNF Historic Photographic Archive).

FF was sometimes referred to as 'Bushranger Gardner' after his notorious nineteenth century namesake, and DKM saw his opportunism in action around 1960. The Radiophysics Laboratory had only one signal generator, which Norm Labrum had been using for several days. So, one morning when DKM met FF on the train two stations down from where he and Labrum normally embarked, FF said, "Grab the sig gen as soon as we get to the Lab." DKM protested that Labrum was still using it, to which FF replied: "No, he won't be in for another half hour; he missed the train!" Later, when FF and DKM were working at Parkes, Dick McGee had a locked cupboard in which he kept his personal 'goodies' like attenuaters, matched terminations, cables and cable gender changers. The first thing FF always did upon arriving at the Radio Telescope was to find McGee's 'well-hidden' key and help himself to anything he needed! It is no wonder that he was sometimes referred to as 'Fearless Frank' rather than 'FF'.

One of the authors (JBW) also tells the tale of how FF returned to Sydney halfway through an observing run with his 'personal' cold load reference in his pocket and without informing his observing collaborator, JBW, of the removal of this piece of equipment from the observing system. This left JBW observing with a less effective skyhorn as a reference, and wondering why the system performance had deteriorated suddenly (see Whiteoak, 1994: 78, 80)!

## 3 OBSERVATIONS WITH THE PARKES RADIO TELESCOPE

Once observations started in earnest with the Parkes Radio Telescope (Figure 3), like other research staff, FF was more or less forced to become a 'radio astronomer'. However, he took very quickly to the art of 'observing' with the Radio Telescope and its associated activities. The authors believe that his love of chocolate may have played a part in his rapid transformation into an avid observer. In the early days at Parkes chocolate was included in the supper basket, and pity the poor observer who replaced FF at midnight or 1 a.m. for the 'grave-yard shift' only to be met by empty wrappers and a totally contented radio astronomer—complete with chocolate-coated grin!

One of the authors (JBW) generally took the late shift, and recalls another interesting feature of the shared observing. FF regarded very seriously the changeover time, and expected the second shift observer to always be on time. Even if the second observer was as much as a few seconds late he would invariably be met by FF, rushing down the stairs on his way back to the observers' quarters.

Be that as it may, FF's first research program at Parkes was with John Bolton, and involved surveying the sky simultaneously at wavelegths of 75-cm and 20-cm and at declinations ranging from from –20° to –60°. About 2,000 discrete sources were detected (Bolton, Gardner, and Mackey 1964).

When the source survey was completed, FF joined forces with JBW to investigate linear polarization (see Whiteoak, 1994). By the late 1950s it had been accepted that the non-thermal component of Galactic and extragalactic radio emission was caused by synchrotron emission. It was therefore expected to display a fairly high degree of linear polarization, but initial attempts to detect this polarization were unsuccessful. However, in the early months of 1962 linear polarization was detected at 3-cm for the radio galaxy Cygnus-A and the Crab Nebula supernova remnant (SNR) (Mayer, McCullough and Sloanaker, 1962). Then, later in 1962, polarization of the extended Galactic Plane radio emission was reported by workers in Holland (Westerhout et al., 1962) and England (Wielebinski and Shakeshaft, 1962). Before the Parkes Radio Telescope was operational, preliminary planning of future research projects included a search for linear polarization (which at that stage had not been detected). Thus, an important task for the fledgling Parkes Radio Telescope became the investigation of the polarization of discrete sources and the extended Galactic radio emission.

The first Parkes polarization measurements were made by FF, Jim Roberts and JBW in March 1962 with a dual 20/75-cm wavelength system. Both receivers were crystal mixers, fed from two pairs of orthogonal dipoles, and the receiver outputs were fed to a two-pen chart recorder. This system had only a short tenure, with the installation of the Gardner-Milne 20-cm parametric amplifier in April 1962. In December, an 11-cm paramplifier, developed by Brian Cooper's team, was also available for use (see Brooks and Sinclair, 1994: Table 1). The much improved sensitivity of these two receivers, coupled with the advantages of an alt-azimuth mounted radio telescope, made polarization measurements relatively easy, and polarization observations at Parkes began in earnest.

In their initial observations, FF and JBW looked at the brightest radio sources and concentrated more on the 75-cm wavelength, but they did not detect any polarization. In retrospect, they could not have made a worse start since at that wavelength the brightest sources proved to be the least polarized, and depolarization increases markedly with wavelength. Matters improved when they reduced their 20-cm data and detected linear polarization from seven discrete sources, including the radio galaxy 3C270 (8% polarized) and the very extended SNR Vela-X—which exhibited a high degree of polarization in several directions (see Gardner and Whiteoak, 1962; 1963).

It would be churlish to omit an incident that occurred shortly before Easter 1962. A 10-cm receiver had just been installed on the Radio Telescope and was being tested by Brian Cooper. Ron Bracewell was visiting Parkes at this time and took advantage of some spare telescope time to pre-empt the scheduled observations of the brightest radio galaxy, Centaurus-A, and discover a remarkably high degree of polarization from this galaxy (see Bracewell, 2002; Bracewell, et al., 1962). This object became the subject of further *ad hoc* observations when Marc Price used unscheduled time over Easter to observe the polarization at several wavelengths and towards three directions in the Galaxy. He found that at each position the polarization angle varied as wavelength squared. This variation is consistent with the Faraday Rotation of polarized radiation in a magneto-ionic environment, and Price had discovered Faraday Rotation in the interstellar medium (Cooper and Price, 1962). The Faraday Rotation was similar at each position, suggesting that the magnetic field distribution was widespread and uniform either in our Galaxy or in Centaurus-A.

The origin of the Faraday Rotation was the next question to be addressed, and FF and JBW embarked on a project to determine the 'rotation measure'—a rather unimaginative term that they coined as a measure of the Faraday Rotation in terms of radians per metre squared—for a sample of polarized extragalactic radio sources. The initial investigation showed a marked decrease in rotation measure with Galactic latitude, being highest near the plane of the Galaxy (Figure 4). This was consistent with the Faraday Rotation taking place in the interstellar medium within our Galaxy. It was expected that the Rotation would be enhanced in directions along spiral arms, where the magnetic field would be along the line of sight, but this effect was not well established in these early data (Gardner, 1964).

As already mentioned, polarization of the Galactic background emission had already been detected by radio astronomers in Europe, and similar observations were now commenced by JBW, FF, and Roberts at Parkes. Scans across the Galactic Plane were made at different feed angles, switching the receiver against a cold load. The technique was fairly insensitive, and the project was abandoned in late 1962 when JBW left to work in the USA. Research on the background polarization was taken up again in 1963 by Don Mathewson and DKM. Beginning initially as a continuum and polarization survey of the Magellanic Clouds, the program became a full-sky survey when the observers followed strong polarized emission extending in all directions well away from the Clouds and showed that it was consistent with a magnetic field aligned along the local spiral arm of our Galaxy (Mathewson and Milne, 1964).

By this time an observational method had evolved whereby the antenna feed at the focus of the radio telescope was rotated through 360° in a direction towards the polarized emission, then in an adjacent reference direction devoid of polarization. The receiver output was recorded on a chart, and markers registered every ten degrees of feed rotation. Each rotation produced a 'wonky' sinusoid signal—'wonky' because instrumental effects during the rotation contributed modulations with periods of both 180° and 360°. It took a little under 2.5 minutes to rotate the feed a full turn forward and reverse, so by rotating at positions with right ascension advanced by two minutes each observation, the observations were performed at similar hour angles (that is, similar elevations in the sky) and suffered similar instrumental rotational effects. An unpolarized reference position was also observed and the polarization intensity and feed angle of maximum intensity were extracted for each position by subtracting the off-source rotations; using tracing paper and pencil. Finally, because the Parkes Radio Telescope had an alt-azimuth mount, the feed angles had to be tranformed to position angles on the sky using computed parallactic angles. This method proved to be quite satisfactory and was really only superseded by scans at selected feed angles once two-channel receivers with polarization switching or polarization correlation were installed.

During 1962 DKM helped FF observe, in the process learning the vagaries of polarization measurements, and then became involved with producing the Parkes 20/75-cm radio source catalogue extending from declination –60° to the South Celestial Pole, working with Marc Price (see Price and Milne, 1965). But DKM wanted a project that he could call his own, and FF suggested that he follow up the Gardner-Whiteoak discovery of strong polarization in Vela-X. DKM began observations in November 1962; this object offered a challenge because of its relatively large size (~5°) and because its identification as a supernova remnant was questionable. From this time on, SNRs became DKM's main field of research (see Milne, 1994).

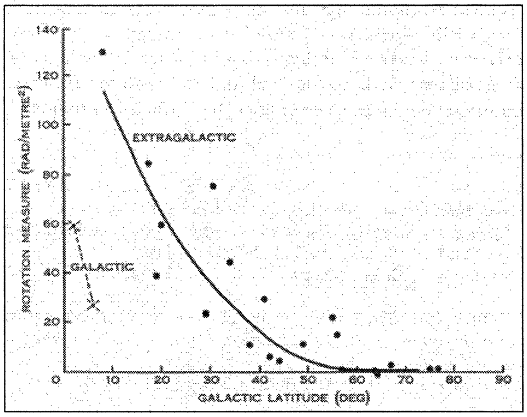

Figure 4: Plot of rotation measure vs Galatic latitude for Galactic and extragalactic sources (after Gardner,1964: 144).

DKM's next observational contact with FF was when the latter laid a map on the desk showing a double-arc source and asked: "Is this one of your SNRs?" DKM's response was to immediately ask FF where it was located in the sky, since FF—in typical Gardner fashion—was very cagey and had not even put any co-ordinates on the map. After some banter FF wrote "$14^h\ 59^m$, –41°" somewhere on the map, and DKM immediately said, "It's got to be the A.D. 1006 remnant." And indeed it was (see Figure 5). This object (Gardner and Milne, 1965) was only the fourth SNR to be identified with its progenitor supernova (see Stephenson and Green, 2002), and the Parkes measurements showed the associated magnetic field to be radial, as would be expected for a young expanding SN shell.

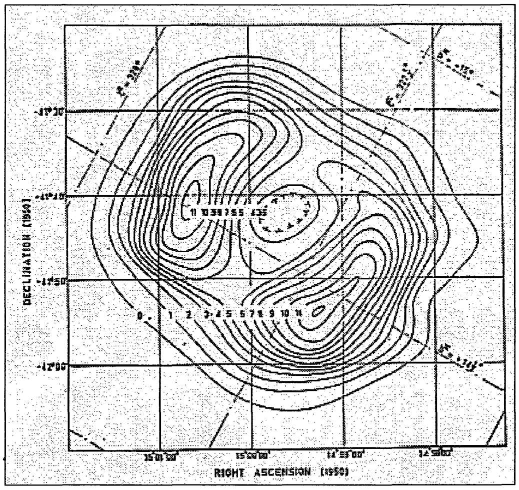

Figure 5: The first radio isophote map of the 1006 SNR (after Gardner and Milne, 1965).

When the first radio spectral lines from an interstellar molecule (the hydroxyl radical, OH, with lines at 1665 and 1667 MHz) were finally detected by US radio astronomers in 1963, FF realised the importance of the result as a probe of interstellar molecular clouds, and decided to diversify his research interests. He and several colleagues rapidly improvised a receiving system and confirmed the existence of the lines using Parkes observations of the dense molecular clouds near the centre of our Galaxy (Bolton et al., 1964a, 1964b; Robinson et al., 1964). Further observations of the clouds yielded the two weaker lines (at 1612 and 1720 MHz) of the OH ground-state quartet (Gardner et al., 1964). FF participated in the initial OH project long enough to collaborate in observations of other molecular clouds which showed that anomalous relative intensities of the four OH lines were due to disturbed populations of energy levels associated with the line production, rather than to other causes (McGee et al., 1965).

In April 1968 a 6-cm receiver on loan from the US National Radio Astronomy Observatory (NRAO) was installed at Parkes, and FF invited DKM to join him, Peter Mezger and Tom Wilson in surveying recombination lines in HII regions (Wilson et al., 1970). DKM recalls that FF had to talk him into joining the collaboration, the argument being that DKM could take over for further study all the objects that showed no recombination lines and hence were possibly SNRs. Mainly through this work, DKM was able to considerably increase the number of known SNRs.

The US receiver had been loaned to the Division of Radiophysics specifically for the Parkes recombination line survey, but a communication from an NRAO radio astronomer—who shall remain nameless—advised that the Radiophysics scientists could do whatever they liked with the receiver. This was in 1969, when NRAO radio astronomers had just detected the first spectral lines from interstellar formaldehyde in molecular clouds, at a wavelength of 6-cm. FF immediately realized the potential of the Greenbank receiver for this type of research, and he tuned the system to the formaldehyde frequency. He and JBW then began a love affair with interstellar chemistry that was to continue with the Parkes Radio Telescope and overseas instruments until FF's retirement in the late 1980s.

There was a twist to the initial Parkes observations, however, in that FF and JBW noted that the spectral line was so strong towards some molecular clouds (Figure 6) that it should also be possible to detect the 6-cm transition of the $^{13}C$ isotopomer (see Whiteoak and Gardner, 1969). The $^{13}C/^{12}C$ isotope abundance ratio is a rather important quantity in the study of Galactic nucleosynthesis. The observers planned a new observing run, but word of this intention somehow reached the USA and the Radiophysics Laboratory was instructed to immediately return the receiver to the NRAO! Not to be outdone, FF planned an impromptu observing run with an old Radiophysics 6-cm receiver. However, this project was also suddenly vetoed a few days before it was to due to commence, and it was not until 1971 that the $^{13}C$ isotopomer was observed at Parkes (Whiteoak and Gardner 1972). By this time, it had been well and truly detected at the NRAO.

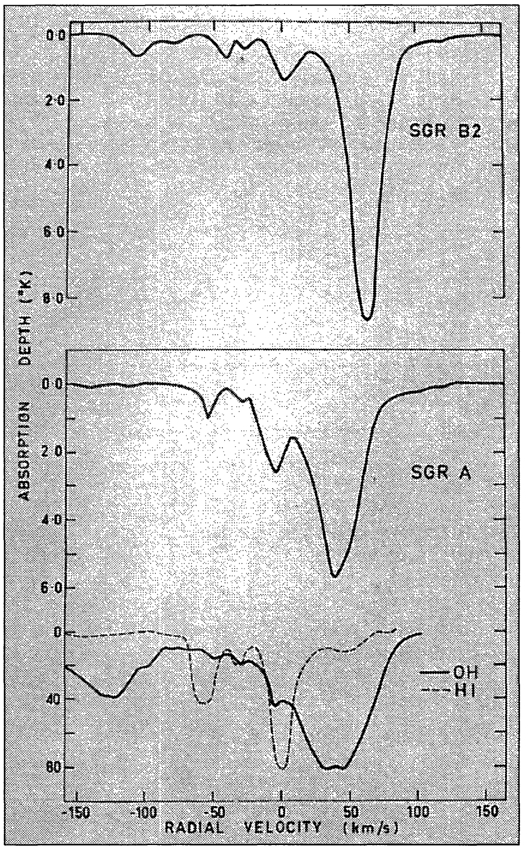

Figure 6: Formaldehyde absorption profiles for Sgr A and Sgr B (after Whiteoak and Gardner, 1969: 283).

A new two-channel 6-cm receiver, built by Brian Cooper's group, was installed at Parkes in late 1970, and a 3.4-cm receiver the following year (Brooks and Sinclair, 1994). At last FF, DKM and JBW had systems operating at frequencies close enough (in wavelength$^2$) to eliminate the ambiguities in large rotation measures, and by rapidly switching between dual orthogonally-polarized channels they were able to scan in polarization. DKM was then joined by John Dickel in an SNR partnership that has persisted to the present day. By the late 1960s, FF and JBW had amassed quite a large sample of rotation measures derived from the polarized radio emission of discrete radio sources (see Whiteoak, 1994). However, the distribution of the rotation measure over the sky was complex, and it was not possible at that stage to identify patterns that could be interpreted in terms of the magnetic field structure of our Galaxy. Accordingly, the two astronomers discontinued their polarization studies and concentrated on their astro-chemistry research (e.g. see Robinson, 1994).

## 4 CONCLUSION

Frank Gardner was always modest, quiet and unassuming (except for his tennis and table tennis styles which had to be classified as 'sneaky'!). He was endowed with dry humour and a sense of fun that made working with him anything but boring. These characteristics were enhanced by by an uncanny 'feel' for microwave engineering, plus a fundamental knowledge of and interest in organic chemistry that was rare within the Australian radio astronomical community. As a result, he played a major rôle in contributing to the list of research successes during the early days of the Parkes Radio Telescope.

## 5 ACKNOWLEDGEMENTS

We are grateful to the ATNF for providing Figures 1-3.

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Dr John Whiteoak is also an Honorary Fellow at the ATNF. At the time of his retirement, in 2001, he was Deputy Director of the ATNF. During his 36 years as a radio astronomer with CSIRO his main research interests involved the linear polarization of radio sources and spectral line studies of the molecular clouds in our Galaxy and other galaxies. He collaborated with Frank Gardner in many projects during a period of some twenty years. He has authored or co-authored over 250 scientific papers and articles. John is a past President of Commission 40 (Radio Astronomy) of the International Astronomical Union.