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RECOLLECTIONS OF TWO AND A HALF YEARS WITH 'CHRIS' CHRISTIANSEN

Rodney D. Davies
Jodrell Bank Observatory, Macclesfield, Cheshire SK11 9DL, U.K.
E-mail: rdd@jb.man.ac.uk

Abstract: I spent the period February 1951 to August 1953 in W.N. (Chris) Christiansen's group in the C.S.I.R.O.'s Division of Radiophysics in Sydney and at the Potts Hill field station. This was a particularly fruitful period of Chris' scientific career. It included the first detection of the 21-cm hydrogen line in the Southern Hemisphere and strong confirmation of the detections made at Harvard and Leiden. This, incidentally, became my own research area at Jodrell Bank beginning two years later. For Chris this was but an interruption to his group's major effort of building a solar grating interferometer. During the period from early 1951 to late 1953 we were intensely busy building, commissioning and operating this new solar instrument. I was involved in most phases of this work, admittedly in a junior capacity—ranging from digging the post holes for the supports of the 32 antennas of the east-west array through to identifying the main source of radio emission with the H-alpha plages associated with sunspots using the Mt Stromlo spectroheliograph that I operated at Potts Hill. This was an exciting time to be at Radiophysics; being a member of Chris' group was inspirational to myself and the other young team members as I shall describe in this short paper.

Keywords: W.N. (Chris) Christiansen, CSIRO Division of Radiophysics, Potts Hill, solar grating interferometer, H-line emission, solar bursts.

1 SOME BACKGROUND

During World War II Australia and the United Kingdom had a number of co-operative links in their radio and radar development programmes. These links led to appreciable transfer of personnel between the two countries after the War when the potential contribution of radio to the astronomical spectrum was realized.

Upon graduating in 1935, E.G. (Taffy) Bowen joined the Radio Research Station at Slough and was immediately recruited by Robert Watson Watt's team at the Bawdsey Research Station on the East Coast where they had already clearly demonstrated the strategic importance of radar in the future war effort. Bowen was soon to become the leader of the air-borne radar group. Hanbury Brown joined this group in 1937. At the outset of WWII young scientists from a range of disciplines—although mainly physics—were directed to radar research. Among these were A.C.B. (Bernard) Lovell, who developed the 3-cm air-borne radar used by Coastal Command for submarine detection, and Martin Ryle, who worked on other aspects of radar. J.S. (Stanley) Hey was in the Army Operational Research Group dealing with problems of anti-aircraft defence and assessing the performance of radar systems (and in the course of his radar work he detected radio emission from the Sun and later fluctuating noise from the constellation of Cygnus). At the end of hostilities they, along with a large number of other scientists, returned to academia. Bernard Lovell went back to Manchester and Martin Ryle to Cambridge, each establishing a thriving radio astronomy research group; Stanley Hey returned to the Royal Radar Establishment (RRE) at Malvern and headed a radio astronomy group there until 1969. L.G.H. (Len) Huxley, a wave-guide specialist, had acted as leader of the Radar School at RRE during the War; in 1949 he was appointed Professor of Physics at Adelaide University in South Australia.

In immediate pre-War Australia, the Radiophysics Laboratory was established by the Council of Scientific and Industrial Research[1] in the grounds of the University of Sydney with the aim of developing radio and radar for use in the Pacific area and wherever Australian service personnel operated during the War. The staff members were mainly Australian graduates. Several had research experience overseas. J.L. (Joe) Pawsey, for example, did his Ph.D. at Cambridge. At the end of the War a major decision had to be made about the future role of the Laboratory. The fact that extraterrestrial radio waves had been found by staff members during operational activities[2] played a not inconsiderable part in the final assessment of the possibilities. In 1946 Taffy Bowen was appointed Chief of the Radiophysics Division, succeeding D.F. (David) Martyn (a cousin and the dead spit image of our family doctor in Wilmslow, Cheshire) and F.W.G. (Fred) White. The UK ex-servicemen, J.G. (John) Bolton and J.P. (Paul) Wild both had extensive radio and radar experience and were recruited to the team. W.N. (Chris) Christiansen joined Radiophysics from Amalgamated Wireless (Australasia) Ltd. in 1948.

In 1947 I left the family farm at Mallala in the Adelaide Plains, some 40 miles north of Adelaide, to study physics at Adelaide University. In May 1948 A.P. Rowe was appointed Vice-Chancellor of the University. He had been Director of the RRE in England during the War, and was a strict disciplinarian according to Hanbury Brown (who had been subject to his strict rule). Rowe found the freedom expected by university staff unmanageable and he retired to Malvern, but one of the positive outcomes of his Vice-Chancellorship was the appointment in 1949 of Len Huxley as Professor of Physics at the University. In 1960 Huxley became Vice-Chancellor of the Australian National University in Canberra.

In Adelaide, Huxley established a flourishing research environment in the Physics Department, and his undergraduate lecture course on waveguides was to be extremely useful to me in later life, particularly as I was able to make good use of his textbook entitled *Waveguides*. Apart from myself, after graduation two of Huxley's other students, Alan Weiss and Bob Duncan, also were appointed to the Radiophysics Laboratory. It is sad to reflect that these two colleagues are no longer with us.

In 1951 the Radiophysics Laboratory began recruiting new Scientific Officers directly from the universities. The intake in early 1951 included R.X. (Dick) McGee, J.A. (Joe) Warburton and myself, and we were all appointed to the Radio Astronomy Group under Pawsey's leadership. As part of our induction period we spent a few weeks at the different field stations—at Dover Heights with John Bolton and at Potts Hill with Chris Christiansen. I also remember that Pawsey was keen to improve our electronic skills. He did this by having us build and test 30 MHz IF amplifier units, a skill that in my case, at least, was to prove very useful in subsequent years. After our induction, Joe Warburton and I were allocated to Christiansen's group (Davies, 2005) and we joined the bus which made the daily trip from the Radiophysics Laboratory out to Potts Hill, a 40-minute drive away.

Pawsey, as Assistant Chief of the Division of Radiophysics, was a constant presence in the radio astronomy researches. He not only supervised the construction projects but also constantly fed the research groups with ideas for consideration. This happened at the weekly radio astronomy meetings and during his visits to the field stations.[3] These visits were also accompanied by a supply of lamingtons, cake cubes covered with chocolate and coconut, which I acquired a taste for. As well as working with Chris, Joe had me analyzing the large stacks of paper recordings of solar bursts (Davies, 1954). Interpretation of this material took me into the domain of J.H. (Jack) Piddington, the Division's leading theorist, so in a sense I had three masters, but Chris was the senior one, and he managed this situation with wisdom.

At Potts Hill, priorities during the first few months of 1951 were (a) construction of the 32-element solar grating array and (b) confirmation of the existence of the 21-cm line of neutral hydrogen. Unbeknown to me at the time, I had joined Chris' group at a high point in its history, and this was to be the beginning of a formative period in my own research career.

2 H-LINE WORK AT POTTS HILL

A detailed account of the early 21cm H-line research at Potts Hill has recently been published by Wendt, Orchiston and Slee (2008b), but I will now set down my own recollections of these pioneering southern hemisphere observations, which were to have more significance than I realized at the time for my future work at Jodrell Bank two years later.

At the end of March 1951 F.J. (Frank) Kerr was at Harvard[4] and he sent Joe Pawsey a letter saying that 'Doc' Ewen and Edwin Purcell had detected 21cm hydrogen line emission from the Galactic Plane. Before publication, they were waiting for confirmation by the Leiden group. At the end of April Pawsey sent a note to Purcell saying that his group would attempt a confirmation in the southern sky; Purcell replied that he was prepared to wait a short time before publication in order to allow this further confirmation. It was agreed that Chris would undertake this challenge with the assistance of Jim Hindman, and that they would construct a receiver system and attach it to the 18 × 16-ft radio telescope that was used for solar monitoring at Potts Hill (Figure 1).[5]

In my first weeks at Potts Hill the work by Chris and his technical staff to construct a 1420 MHz receiver was progressing apace. As a result, the solar work took back stage, except for the daily recording of the solar flux density. The development of a technique for measuring narrow spectral lines required considerable expertise. Firstly, the superheterodyne receiver had to have a narrow enough bandwidth (~50 kHz) to resolve the spectral line. Furthermore, the frequency stability of the local oscillator had to be better than this value over time scales of days; this was a particular challenge given the signal generators of the time. The frequency of the receiver was then swept through the spectral line frequency in a carefully-controlled manner.

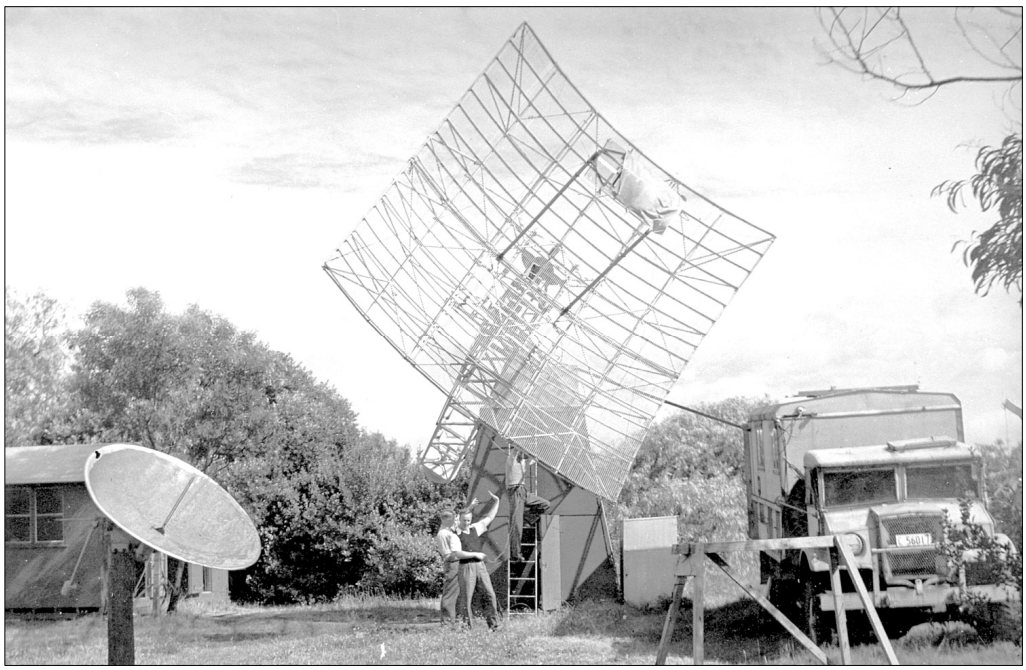

Figure 1: The 16 x 18-ft telescope at Potts Hill in use during the first detection of HI in the Southern Hemisphere. Chris Christiansen is on the left, Jim Hindman is on the ladder and Joe Warburton is in the foreground. A cm-wavelength antenna is on the left (photograph by the author).

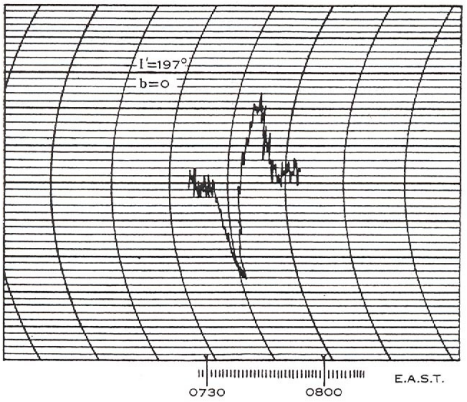

Figure 2: A spectrum of HI in the Anticentre region taken during the survey of the southern sky (after Christiansen and Hindman, 1952).

In what was a real *tour-de-force* Chris and his team pulled together a viable H-line receiver in two months and confirmed the Harvard detection. I was essentially an onlooker in this effort, my part merely being to make sure that the pen recorder kept inking properly during observations and to note the local oscillator frequency. A brief report of the confirmation was submitted by Pawsey (1951) to *Nature* and published alongside the Harvard (Ewen and Purcell, 1951) and Dutch (Muller and Oort, 1951) papers. It is interesting to note the respective submission dates of the three contributions: Ewen and Purcell on 14 June, Muller and Oort on 26 June and Pawsey on 12 July.

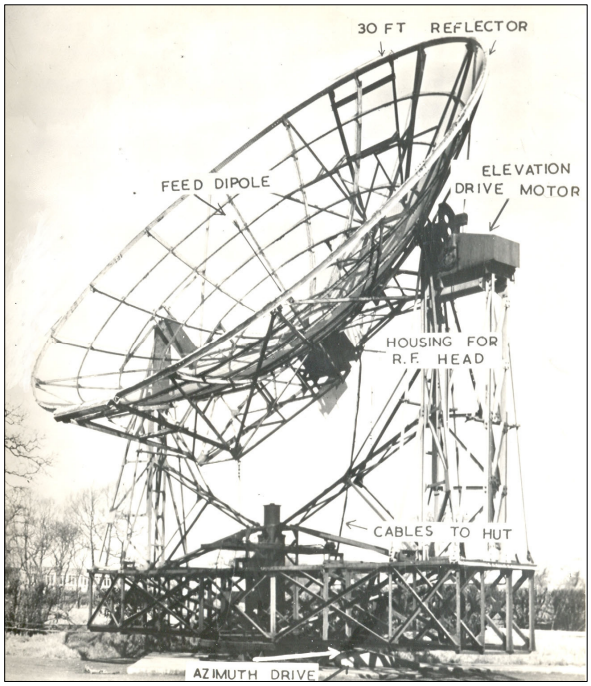

Figure 3: The 30-ft telescope at Jodrell Bank used for the first HI observations in 1954. This antenna was originally sited on the south coast of England during WWII where it was used for anti-aircraft surveillance (after Davies, Ph.D. thesis, University of Manchester, 1956).

Following the first detection at Potts Hill, Chris and Jim made a broad survey of the H-line in the southern sky using the 18 × 16-ft radio telescope (sometimes referred to as the 25 m^2 telescope). Its elevation range was increased to allow the H-line survey to cover the declination range -50^o to $+50^o$. Between June and September 1951 the survey was completed by taking spectra along lines of declination separated by 5^o; the beam width was 2.3^o. This work is described in Christiansen and Hindman (1952). A typical spectrum in the Galactic Anticentre region, where the line is narrow and bright, is seen in Figure 2 as recorded in the frequency-differencing mode. All the spectra were recorded on paper charts and were analyzed by hand. The next phase of the Radiophysics H-line research was with a dedicated 36-ft transit radio telescope that would be constructed at Potts Hill under the leadership of Frank Kerr upon his return from Harvard in 1952.

I was not to know at the time that within a little more than two years I too would also be building a hydrogen line system, but this time at Jodrell Bank. It is interesting to note the similarities between these two first detection projects. My fellow Ph.D. student, D.R.W. (David) Williams, and I used a 30-ft paraboloid (Figure 3) which Bernard Lovell had acquired from the Services upon his return to Manchester. It had been used on the South Coast of England to detect hostile aircraft as they crossed the Channel. Our workshops built an altazimuth drive for it so that it could be used for radio astronomy. David and I built a control system which allowed us to track positions on the sky. My experience at Radiophysics stood me in good stead in building a front-end receiver system and the narrow-band spectrometer, again with its output going to a chart recorder. Figure 4 shows a typical spectrum from those days, obtained in the Cygnus region. Our first observations led to the detection of H-line absorption in front of the brightest radio sources, thereby allowing a determination of their distances (see Williams and Davies 1954). Following this work I used the 30-ft telescope to made an H-line survey of the northern sky, as seen from Jodrell Bank, which clarified the existence of the local Gould Belt system in hydrogen (Davies, 1960). The beam width was 1.55^o. Line observations with the 250-ft Lovell Telescope began in 1958.

3 THE 32-ELEMENT GRATING INTERFEROMETER

After Chris' H-line diversion he returned to solar work, and the construction of the first of two solar grating arrays at Potts Hill (see Wendt, Orchiston and Slee, 2008a). This was a 32-element E-W interferometer (Figure 5), and from early 1951 I worked with the team on the construction of the interferometer elements. This included digging the post holes for the mounts that supported each of the 6-ft dishes, and we soon became qualified posthole diggers (Ph.D.s), although I had actually obtained my first degree in this field on our family farm in South Australia! By the second half of 1952, Chris, Joe Warburton and I were making regular observations of the Sun with the completed array. As soon as this interferometer was fully operational, I also began making regular observations with a spectrohelioscope in order to obtain H-alpha images of the solar disk. The spectrohelioscope was on loan from the Commonwealth Observatory in Canberra, and was supervised by R.G. (Ron) Giovanelli from the National Physical Laboratory (which was also based in the grounds of the University of Sydney). It would appear that the move of the spectrohelioscope to Potts Hill occurred in late 1952. My recollections are that it was set up in a hut next to the 16 × 18-ft parabola used for the H-line observations. Our paper

(Christiansen, Warburton and Davies, 1957) states that the first scans with the E-W grating array were obtained on 20 June 1952.

During my daily observations of the Sun with the spectrohelioscope the active areas were plotted on a Stonyhurst Disk. This enabled the solar coordinates to be determined and compared with the positions of the 21cm radio plages. Active regions seen with the spectrohelioscope included sunspots and H-alpha plages; the latter were brightenings around sunspots, but sometimes they also were seen before sunspots appeared in a region and/or after they had disappeared. The discovery that radio emission was closely linked to the chromospheric plages rather than photospheric sunpots was my great excitement at Potts Hill. It was during these daily observations that I observed the ascending prominence of 26 February 1953 which is reported in Davies (1953). I still remember the reprimand that Joe Pawsey gave me for not staying on at Potts Hill that day so that I could follow the prominence until sunset, or at least until it moved behind the trees on the horizon. Instead I took the bus back to the Radiophysics Laboratory rather than staying at my post and then hitch-hiking back to Sydney!

I made these daily observations until I left the Radiophysics Division in August 1953, when I was appointed to a lectureship at Manchester University and began my researches at Jodrell Bank. After I left, Chris and Joe continued observing with the E-W grating array until December 1953. When analysis of our observations were undertaken in 1955-1956 for the Christiansen, Warburton and Davies (1957) paper, we used the more extensive optical data available in the *Quarterly Bulletin of Solar Activity*, which contained good quantitative information on chromospheric plages supplied by M. and Mme. D'Azambuja.[6] As far as I know, no further systematic observations with the spectrohelioscope were made at Potts Hill after I left; by then, this instrument had served its purpose in allowing us to correlate the radio 'hotspots' on the Sun with the chromospheric plages. However, it was used later in connection with Paul Wild's solar burst work at Dapto (e.g., see Giovanelli and Roberts, 1958).

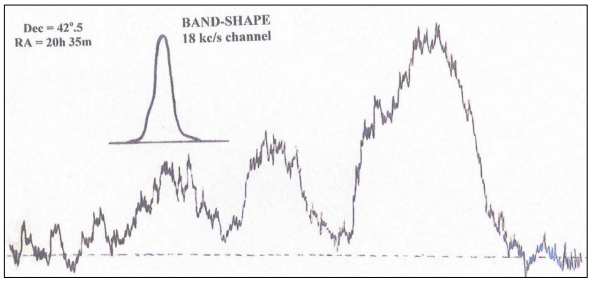

Figure 4: An HI spectrum taken with the 30-ft telescope on the Galactic plane in the Cygnus region showing the 3 spiral arms in this direction. The radio source Cygnus A was found to have HI absorption in all three arms, and was therefore concluded to be extragalactic (after Williams and Davies; 1954, and Davies, Ph.D. thesis, University of Manchester, 1956).

4 SOLAR BURST OBSERVATIONS AT POTTS HILL

When I arrived at Potts Hill in 1951 two monitoring programmes were in progress. Ruby Payne-Scott and A.G. (Alec) Little were recording radio emission from solar bursts with a 97 MHz three-element interferometer located on the edge of the reservoir (Figure 6). They were also measuring the linear polarization of the burst emission. Ruby soon resigned from Radiophysics in order to start a family, and Alec then worked with Bernie Mills on the prototype Mills Cross which they built at Potts Hill over the next year or so (see Mills and Little, 1953).

Figure 5: The 32-element solar grating interferometer at Potts Hill photographed on completion in late 1952. The first serious solar observations began in February 1953 (photograph by the author).

Figure 6: View showing two of the three 97 MHz crossed Yagis comprising Ruby Payne-Scott and Alec Little's solar interferometer. The second Yagi can be discerned behind the colourful garden display maintained by the Water Board (photograph by the author in 1951).

Chris and his technical assistants, Jack Harragon, George Fairweather and Charlie Fryar, used the 16 × 18-ft radio telescope to monitor burst activity on the Sun at 600 and 1200 MHz. A double feed system was placed at the telescope focus. Daily flux density measurements were made at the two frequencies. In earlier years, small paraboloids were used to measure solar activity at higher frequencies (for details see Wendt, 2008).

Chris' last paper on solar burst observations was a radio study of large solar disturbances on 17, 21 and 22 February 1950 (Christiansen, Hindman, Little, Payne-Scott, Yabsley and Allen, 1951) covering the frequency range 60 to 9000 MHz. This material included data from the 3-element polarization interferometer operated by Ruby Payne-Scott and Alec Little illustrated in Figure 6. The 600 and 1200 MHz data were from the 16 × 18-ft radio telescope, while the 3000 MHz data were from a small paraboloid located nearby.

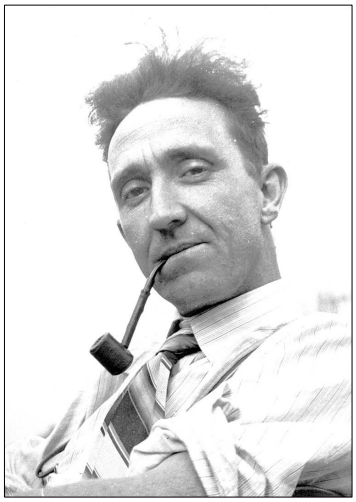

Figure 7: George Fairweather, a valued member of Chris Christiansen's technical staff (photograph by the author).

5 CHRIS THE COLLEAGUE

Chris was very much an 'ideas man'. He clearly enjoyed the research freedom allowed under Joe Pawsey's regime at Radiophysics. He came to Radiophysics from the commercial atmosphere of Amalgamated Wireless (Australasia) Ltd. where he was an aerials specialist, and upon joining Radiophysics he developed and used aerial systems for a wide range of solar observations. By 1951, when I joined his group, he had designed the 32-element solar grating array and was in the throes of building it. At the same time, along with other Radiophysics staff, he was looking at innovative ways of building a really large radio telescope and his idea was to float a huge spherical antenna in a hydraulic spherical bearing. The more conventional altazimuth-mounted paraboloid was to be the ultimate choice. Chris left CSIRO in 1960 for the University of Sydney to develop the Chris Cross at Fleurs into the Fleurs Synthesis Telescope (see Orchiston and Mathewson, 2009).

Chris' research enthusiasm was infectious. He encouraged me in my investigation of the Radiophysics solar burst records, even though this was not directly under his supervision. Looking back, I see that a substantial amount of the data was from the daily observations which he had made. He also welcomed me back into the fold after I had spent some time working with Jack Piddington on the physics of the solar corona, a project that was based on Radiophysics data collected over the years (see Piddington and Davies 1953a; 1953b). Chris and Jack were poles apart in their politics and their outlook on life.

Chris encouraged a strong team spirit at Potts Hill. The technical staff were dedicated to Chris's projects and would give them all their efforts. These activities were sometimes rather gruelling at critical times during the commissioning phases, especially for the 21cm confirmation and the solar grating interferometer. I particularly remember Charlie Fryar, and George Fairweather with his quaint pipe (Figure 7). We always had a break for lunch. A cricket bat was an essential piece of equipment at Potts Hill, and Chris was an accomplished batsman (Figure 8).

Upon reflection, cricket played no small part in the ethos of the Radiophysics establishment, and I enjoyed playing with the Radiophysics team in a (mostly!) friendly league in the Sydney suburbs. During my time the captain was either John Bolton or Paul Wild, depending upon their outside commitments. Interestingly, as soon as I arrived at Jodrell Bank, Bernard Lovell, who was captain of the local cricket team, had me playing on Cheshire turf. It was rumoured that Bernard only appointed people to his staff if they played cricket or the piano; I believe there may have been some truth in this!

Chris had a strong social concern which showed itself in a number of ways, including helping developing nations with their scientific growth (e.g. see Wang Shouguan, 2009). This led to the Potts Hill E-W solar grating array being sent to India in 1960, where it was used to stimulate their radio astronomy. Govind Swarup and R. Parthasarathy (1955) had previously converted it to 600 MHz at Potts Hill, so Govind was well placed to recommission it in India (for details see Swarup, 2006; 2008).

6 CONCLUDING REMARKS

Looking back on my time with Chris in the Radiophysics Division of CSIRO, I now realize even more strongly than I could have done at the time that he had assembled a remarkable team and that I was extremely fortunate to start my scientific career in such an environment and under the influence of outstanding colleagues. Chris was internationally-recognized by being elected President of the International Union of Radio Science (URSI) from 1978 to 1981; he was also elected an Honorary Life President. His was one of the early elections to the Fellowship of the Australian Academy of Sciences (FAAS).

The radio astronomy group in CSIRO was one of the most highly-awarded in the subject: of those on the staff when I was there, eight were elected to the FAAS (Bowen, Christiansen, Mills, Minnett, Pawsey, Piddington, Robinson and Wild) and five were elected Fellows of the Royal Society (Bolton, Bowen, Mills, Pawsey and Wild). I also find it amazing that three of the young appointees on the staff during my time in the Radio Astronomy group were subsequently elected FRSs (Govind Swarup, Ashesh Mitra and myself); we owed much to the inspiration of Chris and other CSIRO colleagues.

7 NOTES

1 The Council for Scientific and Industrial Research in 1949 became the Commonwealth Scientific and Industrial Research Organisation (CSIRO).

2 Observations of solar radio emission with a Royal Australian Air Force radar unit at Collaroy in suburban Sydney commenced in October 1945, and are discussed in Orchiston, Slee and Burman, 2006.

3. In the early 1950s, apart from Dover Heights and Potts Hill, the Division of Radiophysics also maintained field stations at Badgerys Creek, Dapto, Hornsby Valley and Fleurs. For an overview of these, earlier and later field stations, and associated remote sites, see Orchiston and Slee (2005), while detailed studies of Dapto and Potts Hill have been presented by Stewart (2009) and Wendt (2008) respectively.

4 Frank Kerr was in the USA at that time in order to study for a Masters degree in astronomy at Harvard. Since many of the early RP staff had radio engineering or radar backgrounds, but no formal knowledge of or training in astronomy, it was Radiophysics policy to send selected staff members to England or the USA for post-graduate training in astronomy (see Sullivan, 2005).

5 This 16 × 18-ft section of a parabola began life as a WWII experimental radar antenna at Georges Heights, overlooking the entrance to Sydney Harbour. It was then used briefly by Lehany and Yabsley for solar research when RP gained access to Georges Heights at the end of the War (see Orchiston, 2004). In 1948 the antenna was relocated to RP's Potts Hill field station and installed on an equatorial mounting in time to be used for observations of the 1 November partial solar eclipse (Christiansen, Yabsley and Mills, 1949a; 1949b). Thereafter it was used extensively at Potts Hill for solar, galactic and extragalactic research. A detailed review of the role that this pioneering radio telescope played in the development of radio astronomy is presented in Orchiston and Wendt (n.d.).

6 Dr and Mrs D'Azambuja referred to chromospheric plages as 'plages faculaires'.

8 ACKNOWLEDGEMENTS

I thank Wayne Orchiston for giving me the opportunity to write this appreciation of Chris Christiansen. It has enabled me to recall fond memories of my time at Potts Hill with Chris and colleagues. Thanks are also due to Wayne for help in preparing this paper.

Figure 8: Lunch-time activity at Potts Hill on an improvised cricket pitch. Chris kept his eye on the ball in more ways than one. Jim Hindman, who was probably bowling, was no mean bowler. Charlie Fryar is keeping wicket (photograph by the author).

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Rodney Davies FRS, CBE, is a former Director of the Jodrell Bank Observatory and Professor of Radioastronomy in the University of Manchester. His research interests are in the field of radio-astronomical techniques, in studies of our Galaxy and nearby galaxies in the hydrogen line. Most recently he has been observing the Cosmic Microwave Background and is currently involved in the ESA Planck mission to observe the CMB. He has published more than 200 papers and 3 books.