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Under the Radar

The First Woman in Radio Astronomy: Ruby Payne-Scott

Springer

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Cover illustration: Starry Night, after Van Gogh′ by Fiona Hall the daughter of Ruby Payne-Scott and Bill Hall. This 'Reconstructed painting' from 1981 shows electrical power cords as they swirl in the night sky. From page 43, *Fiona Hall* by Julie Ewington (2005). 'The Reconstructed paintings are also notable for the obvious pleasure Hall took in multiple slippages of meaning between historical templates and contemporary life.' Used by permission of Fiona Hall.

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To
Libby, Lyn

Foreword

It is rare for a complete biography of an Australian scientist, particularly of an Australian woman scientist, to be published. It is rarer for such a book to be co-authored by an American.

Although scientists have written discourses on the history of their discipline, it is most unusual for a scientist to write a full length biography of a colleague in his field. It is also uncommon for a man to write about an Australian woman scientist; most of the work on Australian women scientists has been done by other women. However, these authors, both distinguished researchers in the field of radio astronomy, became so interested in the history of their discipline and in the career of the pioneer radio astronomer Ruby Payne-Scott that they spent some years bringing this book to fruition.

Until relatively recently, Ruby Payne-Scott had been the only woman scientist mentioned briefly in histories of Australian science or of Australian radio astronomy. This book will be an invaluable resource for anyone interested in these disciplines. Being scientists themselves, the authors explain Payne-Scott's scientific work in detail; therefore, the value and importance of her contributions can, for the first time, be recognised, not only by historians but also by scientists.

After a brilliant academic career, with an M.Sc. in physics (the highest qualification then available at any Australian university), Ruby Payne-Scott worked as a science teacher, one of the few professional positions available to Australian women in the 1930s, and especially in depression. However, the Second World War opened up opportunities for women science graduates. She was one of the first of the scientific staff members appointed to the new Radiophysics Laboratory of the Council for Scientific and Industrial Research (CSIR) from which radio astronomy developed, and notably the first woman scientist in the Laboratory.

She was part of a pioneering group of radar scientists during the Second World War, led by J.L. Pawsey, whose scientific distinction and leadership qualities have been referred to by all writers in the field. Although it was mainly due to him that radio astronomy developed in Australia from 1944, she was one of the key people contributing to Australia's pre-eminence in the world in radio astronomy for many

decades. Pawsey valued her judgment and experience so highly that when she was absent from a meeting, he would often not make a final decision until she had been consulted. She became the overall advisor to the group on scientific issues, engineering planning, and mathematics, and she also made major contributions to the development of radio astronomical techniques.

By 1951, when she left the discipline, she had been promoted to the highest research category short of the leader and was being paid the second highest salary on the scientific staff. Her standing was confirmed later by a member of this distinguished group who himself became an important radio astronomer but who disliked Payne-Scott; nevertheless, he considered her, as the authors record, to have been "one of the best physicists at Radiophysics – no, one of the best physicists in Australia".

In telling Payne-Scott's story, the authors highlight the inferior position of women in the work force at that time. Married women could not become permanent employees in the public service. The practice of requiring women to choose between marriage and their careers inevitably deprived Australia of unknown talent.

Payne-Scott had to suffer the indignity of keeping her marriage secret from CSIR for some five years. When the marriage was discovered, she fought vehemently against the injustice of this regulation but was forced to become a temporary employee, losing all her superannuation entitlements in the process. She finally resigned in 1951 when pregnant with her first child, as there was no maternity leave at that time.

The War years provided some measure of equal pay for women. After the War, the old discriminatory practices returned. Payne-Scott, together with other colleagues, campaigned unsuccessfully for the recognition of the principle of equal pay.

"Women's rights" was not the only issue about which she felt strongly and for which she argued publicly and vigorously. During the War, it was natural that the type of work which the group was engaged in was classified; but after the War, she was bitterly opposed to secret research in the CSIR. She believed that it was impossible to do good research in the atmosphere of limitations imposed by a sponsoring body, particularly when that body was the military. She wrote to CSIR: "Frightened men do not produce great research".

The Australian Security Intelligence Organisation kept files on her that have only recently been made available to researchers. A subsequent media release by the National Archives of Australia, headed "The Secret Life of Ruby Payne-Scott", states that she was "passionate about both the independence of scientific research and human rights. These sentiments were deemed a security risk."

The work of pioneering Australian women scientists is gradually being recognised. CSIRO offers OCE Science Team Career Awards. One of these is the OCE Payne-Scott Career Award for researchers returning from family-related career breaks. The life and work of a feisty, brilliant woman is finally being recognised.

Nessy Allen

Preface

Ruby Payne-Scott (1912–1981): Remarkable Scientist and Champion for Women's Rights

Almost 60 years after her retirement in 1951, why is the life of Ruby Payne-Scott of significance to us? She was a unique scientist working in one of the first major solar radio astronomy groups after the end of World War II. This fortunate circumstance was due to the experience she gained working on radar at the major Australian laboratory during World War II. Payne-Scott was a pioneer Australian scientist leading the charge for equality of women in the work place.

In 1997, Dick McGee and I began a discussion about the possibility of writing a short biography of Ruby Payne-Scott. Dick had known her for a brief period in the early 1950s when he joined the radio astronomy group in Sydney, Australia. We first envisaged an article for the *Publications of the Astronomical Society of Australia*, similar in scope to our previous collaboration published in a conference proceedings in 1996, *The Discovery of the Radio Source Sagittarius A (Sgr A)*. As we collected material and carried out initial interviews in Australia, the complex nature of this study of Payne-Scott's life became evident. A year after a trip of several weeks' duration to Australia that I made in early 1999,[1] McGee began to write the first draft. He reported to me at that time that he had been increasingly impressed with the scope of Payne-Scott's contributions to solar radio astronomy. Gradually over the next few years, we both became convinced that a longer version of the Payne-Scott story was required.

New themes developed as Dick and I learned more about her remarkable life: her battles over discrimination against women, her success as a scientist and educator, her membership in the Communist Party of Australia (CPA), her remarkable family and her passion for bush-walking. In particular, her pioneering work in the new field

[1]I gave the SAFA (Sydney Association for Astrophysics) lecture on 9 February 1999, on the topic of Ruby Payne-Scott; a number of her former colleagues were in the audience, who provided helpful comments after the lecture.

of solar radio astronomy (including a major role in the invention of radio aperture synthesis) had not been fully appreciated. Also we met many of her friends and colleagues, who opened up new facets of her life. Payne-Scott's children, Peter and Fiona Hall, were especially helpful in revealing the character of their mother in numerous interviews and visits in both the US and Australia.

We also discovered that Payne-Scott had largely been neglected in treatments of the early years of radio astronomy. Numerous accounts of the history of post World War II science in Australia did provide a cursory glance at her career, often with some distortion. An example is the mistaken assertion by Collis in his history of CSIRO (*Fields of Discovery,* 2002) that: "... in 1951 [Payne-Scott] was forced by public service rules to leave her job when it was discovered she had been secretly married since 1944. Married women were not allowed to hold permanent staff position." Dick and I correct this common misconception in Chap. 4.

An example of neglect can be found in the comprehensive and influential, popular book *The Changing Universe* published in 1956 by the *Scientific American* author John Pfeiffer. He did an admirable job of visiting radio astronomers in the US, the UK, France, and the Netherlands. He corresponded with a number of prominent radio astronomers in Australia. Many of the pioneering results from the Australian group were summarised in the chapter "The Sun in Action", including a description of the remarkable Type II outburst of 8 March 1947, with a whimsical cartoon of the effects of solar outbursts on terrestrial communication. This result was published by Payne-Scott, Yabsley, and Bolton (see Chap. 7). No mention of Payne-Scott appears in the Pfeiffer volume, even though most of her Australian colleagues are named.

Finally, there is an example of neglect in the modern era, the plaque shown in Fig. P.1; this comprehensive display at Dover Heights in Sydney (Rodney Reserve) is the site of the major astronomical discoveries made in the era 1946–1948 by the Radiophysics Laboratory (RPL) group. This plaque and a replica of the 100 MHz Yagii antenna were unveiled on 20 July 2003 by Her Excellency, the Governor of New South Wales, Professor Marie Bashir.[2] Although there is a brief description of the solar radio work at this site on the plaque, the text describes the work done by the men at Dover Heights: Bolton, Pawsey,[3] Stanley, Slee (at the ceremony), and McGee, with an emphasis on the radio sources discovered at this site (Taurus A, Virgo A, and Centaurus A). The absence of any mention of Payne-Scott on the plaque is surprising. A number of visitors to the Dover Heights monument since

[2]I was the master of ceremonies, and talks were given by Paul Pierce, Mayor of Waverley Council, Woody Sullivan of the University of Washington in Seattle, and Ron Ekers of the CSIRO Australia National Telescope Facility.

[3]Pawsey was appointed to the CSIR RPL in London in October 1939 and started work in Sydney on 2 February 1940. During the War, he was a major leader in the development of radar in Australia. After the War, he was the Deputy Chief of RPL after E.G. ("Taffy") Bowen became Chief in May 1946. When Pawsey began radio astronomy in 1944 at RPL, Payne-Scott became the leader of the first scientific efforts, while Lindsay McCready was the leader of the engineering efforts. Pawsey was one of the inventors of the new phrase "radio astronomy" in early 1948.

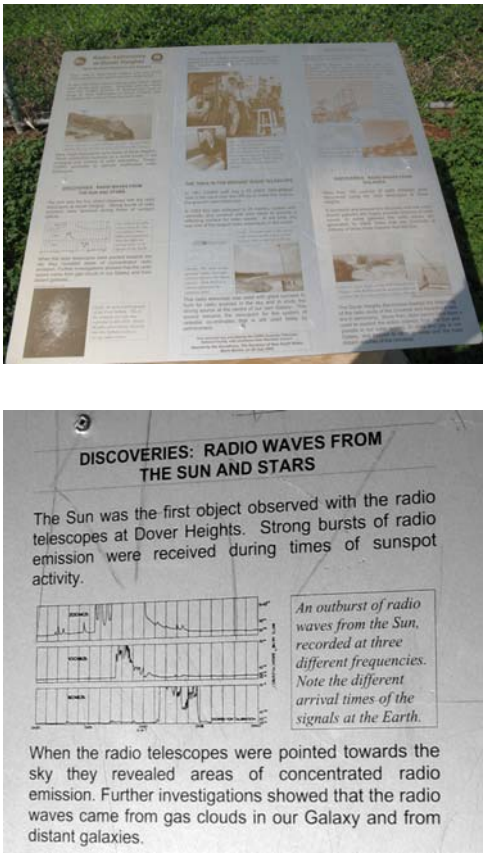

Fig. P.1 Radio astronomy display at Dover Heights (Rodney Reserve), Sydney, New South Wales, Australia. The plaque was constructed by the Australia Telescope National Facility, CSIRO to commemorate the pioneering radio astronomy done at this site from 1946 to 1954. The opening of the scientific memorial was by Her Excellency, the Governor of New South Wales, Prof. Marie Bashir, 20 July 2003. The 25th General Assembly of the International Astronomical Union was being held in Sydney during this period (13–26 July, 2003). Photo by Goss. (**a**) shows the entire plaque; the solar radio astronomy is described in a single panel shown in (**b**). Photo by Goss

2003 have pointed this absence out to me. The printed program for the unveiling ceremony did include a mention of Payne-Scott, although not a photograph.[4]

Only two recent publications deal with Payne-Scott in detail: Claire Hooker in her 2004 book, *Irresistible Forces: Australian Women in Science*, has a thorough

[4]A photograph of the two element 100 MHz Yagi at Dover Heights was included in the published program for the event of Sunday 20 July 2003: "...this was first used by Ruby Payne-Scott, Don Yabsley and John Bolton to study solar radio emission." There is no mention that Payne-Scott was a major player in the first ever radio astronomy interferometer observation as the sun rose on 26 January 1946. The location of this ground breaking event is not certain but was at either Dover Heights or Collaroy.

treatment in Chap. 10, "The Sun, Ruby Payne-Scott and the Birth of Radio Astronomy." Woody Sullivan, in his monumental study, *Cosmic Noise: A History of Early Radio Astronomy* (2009), has described her work in detail in a sub-section of his Chap. 13, "The Radio Sun: Payne-Scott's work."

During the initial years of the twenty-first century, a number of newspaper articles and a radio and a television program about Payne-Scott appeared in Australia with Dick's and my participation. The positive response encouraged us to continue our quest for details of Payne-Scott's life.[5] Dick and I followed the trail using interviews, letters and the Division of Radiophysics Archives in Marsfield (Sydney), the National Archives of Australia (NAA) in Canberra and Sydney (Chester Hill), and Professor Woodruff ("Woody") T. Sullivan III's remarkable archive of Australian radio astronomy in his home in Seattle, Washington. We were forced to learn some solar radio astronomy, a field that neither of us had worked in as professional radio astronomers (McGee since the late 1940s and I since the early 1960s). I relied on colleagues Tim Bastian (National Radio Astronomy Observatory) and Don Melrose (University of Sydney) for advice on many aspects of solar physics, in particular Payne-Scott's contributions. After some time, the nature of her scientific life began to emerge; fortunately, much of the records from the time that Payne-Scott worked at the Council for Scientific and Industrial Research (CSIR, 1941–1949) and the new Commonwealth Scientific and Industrial Research Organisation (CSIRO, 1949–1951) were maintained in a *written* form after this interval of 50–60 years.[6] In the course of our interviews, Dick McGee and I re-discovered the well-known effect discussed by Isaacson in his biography of Einstein published

[5]The most successful and influential event was an Australian Broadcasting Corporation (ABC) Radio National Saturday broadcast on Valentine's Day 2004. The broadcast was in the long running series, "The Science Show", by Robyn Williams, directed in a thorough fashion by Pauline Newman Davies. Elizabeth (Betty) Hall, McGee, Claire Hooker, Fiona Hall, Carolyn Little and I were interviewed. The world wide web distribution of the transcript has led to numerous helpful comments to the authors. By contrast, the television program in the *Rewind* series on 7 February 2005 by the ABC was a disappointment. In spite of a heroic effort by the director, Laurie Critchley, the original concept for the "History Detectives" series fell victim to internal infighting within the ABC. The final version is a watered-down presentation that does not capture the essence of Critchley's original production. In particular the fascinating interview with Bruce Slee at Dover Heights (Sydney) was cut as well as a humorous interview with McGee at his home in Eastwood, Sydney. I have film copies of these un-broadcast interviews on DVD.

[6]The NAA has an extensive collection of RPL material in the series C3830 (727 entries, Sydney). The series C4659 (12 entries) contains correspondence of J.L. Pawsey. An especially important series is NAA: C3830, F1/4/PAW/1 Part 1 (US) and Part 2 (Europe), containing correspondence during the trip that Pawsey took to the US, Canada, and Europe in 1947–1948. From the NAA in Canberra, Payne-Scott's personnel record was obtained (NAA: A8520, PH/PAY/002) as well as a redacted Australian Security Intelligence Organisation (ASIO) file (NAA: A6119). In addition, the service record in World War II of her brother, Henry Payne-Scott (Service Number 20769, NAA: A9301), was obtained from the NAA in Canberra. Woody Sullivan provided a number of copies of RPL files that he found during his visits to Australia. A few key items were found in his files that were not located in Australia in the NAA. Eventually, we will deposit the Payne-Scott archive that we have collected with the National Radio Astronomy Observatory Archives in Charlottesville, Virginia, under the direction of Ellen Bouton.

in 2007: "... remind us of the caution needed when writing history based on dimming recollections." Dick McGee and I discovered numerous inconsistent statements about Payne-Scott; wherever possible, we rely on contemporary records in place of recalled memories of her colleagues.

Of all researchers working on the history of Australian radio astronomy, we owe a huge debt to Sally (Sallie) Atkinson BEM,[7] who had been at RPL since the early days of World War II (she and Payne-Scott appear on the staff list at RPL in June 1942 for the first time). Atkinson had been Secretary to E.G. Bowen from 1946 to 1971, the year of the retirement of Bowen. She had been Honorary Archivist of RPL from 1971 until about 1992. McGee and I visited and corresponded with Sally several times in the 1990s (up to 1999). She had carried out the monumental task of organizing the RPL archives before they were transferred to the NAA (files from 27 November 1940 to April 1988). During W.T. Sullivan III's two visits to RP in March 1978 and April 1981, Atkinson provided hundreds of files for his inspection. In fact, many of the documents in the NAA have in Atkinson's handwriting "Hold for WTS" or "W.T. Sullivan".[8]

Ideally, Dick or I would have interviewed Payne-Scott in the 1960s–1970s. Since this did not occur, we only have Sullivan's attempted telephone interview with her on 3 March 1978, 3 years before her death. Sullivan was in Australia, beginning the interviews for his book on the history of radio astronomy. On this date, she stated to Sullivan that her memory was failing and that she was not very coherent; after 30 min of conversation, Sullivan reluctantly agreed. She told Sullivan that she had been trained as a physicist and had worked on engineering projects and in addition carried out scientific research. She credited a large component of her success to the excellent workshop at RPL and to Alec Little for his major contributions to their joint project at Potts Hill (swept-lobe interferometer, Chap. 9). She especially praised Joe Pawsey: "he seemed to have a vision of what to do next. He was terribly enthusiastic – you were lucky to get home for dinner when he showed up at the end of the day." Payne-Scott did describe the marriage crisis of 1950 (both professional and non-professional women had to resign their permanent employment status on marriage, Chap. 4); she stated that there was considerable surprise among some colleagues and a few showed indignation because they thought that she had been disloyal and dishonest. On a subsequent visit to Australia 3 years later, Sullivan rang the Hall home on 30 March 1981. A man, likely Bill Hall, answered. Sullivan was told that Payne-Scott was in a nursing home and had no memory of the past. She died 2 months later.

Since 1999, I have given lectures about the life of Payne-Scott at the Raman Research Institute, Bangalore, India; at the National Centre for Radio Astrophysics (Tata Institute) in Pune, India; at Agnes Scott College, Atlanta, Georgia; at the Adler Planetarium, Chicago, at the University of Sydney (twice), at the National

[7]British Empire Medal (Civil) awarded 1978 for "Recognition of service to the public service with CSIRO".
[8]Woodruff T. Sullivan, III. In 2008, Atkinson celebrated her 95th birthday.

Radio Astronomy Observatory, Socorro, New Mexico and Charlottesville, Virginia, at the University of Adelaide, at the University of Wisconsin, Madison, and at James Cook University, Townsville, Australia. My research and thoughts about this topic have benefited greatly from the interactions with the audience at each lecture.

Throughout this book, we use much of the radio astronomy terminology of the late 1940s and early 1950s. However, we have decided to use the modern MHz (mega Hertz, one million) instead of the previous terms used in 1950, Mc/s (Mega Cycles per second). In addition, in most cases, we use the modern terms for the types of solar radio bursts and outbursts. As Wild (1985) has written: "Before the 'origin of the species' could be identified there had to be an exercise in taxonomy." This exercise was quite important in clarifying the perception of these new phenomena. We introduce the newer terms for solar bursts in the relevant Chaps. 7–9. Also we use the unit of radio astronomy intensity-Jansky: or 10^{-26}W $M^{-2}Hz^{-1}$. We do not use the often-quoted solar flux unit, favoured by solar radio astronomers – s.f.u. or 10^4 Jansky (Jy). For the CSIRO and the CSIR Division of Radiophysics, we use the term RPL (Radiophysics Laboratory), which was common during World War II and the immediate post War period; RP became the common designation later in the 1950s.

Dick McGee and I are aware of the advantages and disadvantages of *scientists*' attempting to write history, in contrast to historians of science. The geologist William Glen[9] (1988) has discussed this issue in detail:

> [Scientists] suggest that history [of science] written by historians which is based on critical examination of the scientific ideas themselves, will be wanting. The historians, on the other hand, through the methods and techniques of history, social studies and philosophy – tools not often possessed by scientists – can show scientists how their discipline has come to be, how it is bedded in society, and how it derives its esteem and support for being. Practicing scientists can seldom understand their intellectual past and predecessors as historians do. Historians only rarely come to know all that scientists understand about the ideas, methods, instruments, and practice of science. Scientists and historians have much to offer each other; fully furnished history requires contributions from both.

Dick and I hope that we have brought the understanding of scientists to the study of this remarkable physicist, Ruby Payne-Scott.

Now, after more than half a century has passed, we can attempt to re-interpret the fascinating and complex life of Ruby Payne-Scott from a new point of view. As J.D. North has suggested (*The Measure of the Universe: A History of Modern Cosmology*, 1965):

> The past, as elicited by the historian, is not something which was simply "there" and now awaits description. It is a product of the minds of both author and reader, and hence of the circumstances under which it was written and read. Different individuals may, of course, ask the same questions and answer them differently.

[9]I am grateful to Ron Bracewell (1921–2007) for introducing me to Glen in Palo Alto, California, in January 2007.

Dick McGee and I hope that the readers will ask additional questions about the life of Ruby Payne-Scott.

A word to our readers: non-scientists may possibly want to skip Chaps. 5–9; these deal with the details of Payne-Scott's scientific achievements concerning War time radar and the initial years of solar radio astronomy in Australia in the era 1944–1951. A short summary of Payne-Scott's astronomical work is presented in Chap. 1. Some of the appendices are also technical in nature; Appendices C–G, L and M are intended for readers with a background in physics or astronomy.

Numerous individuals have contributed to this study of the life of Ruby Payne-Scott. Her children, Peter Hall and Fiona Hall (Chap. 12), were especially helpful; Betty Hall (Dr. Elizabeth Hall), a lifelong friend of Ruby and Bill Hall (Ruby's husband), was crucial to our understanding of Payne-Scott; she is not related to Bill Hall! Harry Wendt of Vaucluse (Sydney) played an important role in helping me to find my way through the labyrinth of the National Archives in Sydney; he provided me with numerous copies of relevant files. Harry has recently received a Ph.D. degree from James Cook University with a thesis on a history of Potts Hill and Murray Bank field stations of RPL. Alison Muir of the School of Physics, Sydney University, provided the title of the book during a conversation in early 2007. Claire Hooker has provided assistance and insight for many years and gave us her Payne-Scott archive. Woody Sullivan has provided inspiration and assistance for years. Barnaby Norris at the Australia Telescope National Facility has helped considerably with the photo-archive from the Division of Radiophysics. My son, Andrew M. Goss, historian at the University of New Orleans, has provided advice and comments on the writing of history. The detailed editing of this volume has been carried out by my daughter-in-law, Pax Bobrow. Finally, I thank Nessy Allen (retired, School of Science and Technology Studies, University of New South Wales) for writing the foreword to this book. She is an expert on "women in science", and in particular on "women scientists in Australia".[10] In addition, she has provided copious suggestions for improvements to the text of our book. Numerous chapters have been improved thanks to her meticulous editing.

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[10]Her important comparative study of Rachel Makinson (Chap. 11) and Joan Freeman (Chap. 11) was published in 1990: "Australian Women in Science – A Comparative Study of Two Physicists", *Metascience*, Vol. 8, No. 2, pp. 75–85.

Tim Bedding, Vicki Drazenovic, Lewis Ball, Tony Crawshaw, Harvey Cohen, Harvey Green, Carolyn Little, Adele Little, Renata Watkinson, the late Brian Cooper, Fred Blackman, Marjorie Thompson (*née* McKechnie), Bruce Slee, the late Don Yabsley, Paul Wood, Melanie Grogan, Kerrie Jarvis, Katherine Newton-McGee, Grace Noble, the late Marie Alewood, Bob and Christa Younger, Alex Colley, the late Dot Butler, Hastings and Liz Pawsey, Brian Bolton, the late Merle Watman, Margaret Giannesca, Bill Holland, Patrick James, Shirley Hokin, Shami Chatterjee, Lyn Frost, Renata Mancini, the late Arthur Gilroy, Letty Bolton, Renata Wakinson, Robert Makinson, Peter Davidson, Bruce Yabsley, Lindsay Baudinet, Marjorie Lobban, Eric Aarons, Doug Milne, Roy MacLeod, Margaret Holmes, Elaine Pacey, and John O'Byrne.

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I extend a special word of appreciation to my former advisor, colleague, and friend, Dr. Nan Dieter Conklin. Nan has been a steadfast supporter for 44 years; she is the first US woman radio astronomer.[11]

The extensive archive of material for this book will be deposited in the National Radio Astronomy Observatory Archive under the direction of Ellen Bouton; this will include interviews, archival material, and video material. The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

W.M. Goss

[11]See her autobiography, *Two Paths to Heaven's Gate*, published by the National Radio Astronomy Observatory, 2006 (available from NRAO).

Contents

Chapter 1
Introduction: The Life of Ruby Violet Payne-Scott – 28 May 1912 (Grafton NSW, Australia) to 25 May 1981 (Sydney, Australia)

In *Irresistible Forces: Australian Women in Science* (2004), Claire Hooker has written, "Yet if [Payne-Scott] was a feminine flare in radio astronomy, she was a bright one, both as a physicist and as a woman." In Fig. 1.1, a photograph of Payne-Scott as a young student in the 1930s is displayed.

The field of radio astronomy in Australia grew out of the radar research carried out during World War II at the Council for Scientific and Industrial Research (CSIR) Radiophysics Laboratory (RPL; see Appendix A). Payne-Scott joined the new institute in 1941 (Chap. 4), as one of the first scientific staff as well as one of the first woman scientists (Joan Freeman had joined a few months earlier). RPL played a key role in the War effort, producing numerous copies of the aircraft warning radars that were used so successfully in the Southwest Pacific Area by both US and Australian military personnel from 1942 to 1945 in the war against Japan. Payne-Scott made major contributions to this top secret radar research; she became the Australian expert on the theory of the detection of enemy aircraft using the display system that had been invented in the UK, named the PPI or Plan Position Indicator (Chap. 5). She was also an experienced radio engineer; her experience with B.Y. Mills in the development of an experimental high frequency (25 cm) aircraft warning radar contributed to her success as an experimental radio astronomer starting in mid-1945.

World War II provided an opportunity for women to join the work force in Australia. With many young men overseas in the armed forces, there was a personnel shortage and thus a need for any able-bodied workers, including the hitherto under-utilized female population. In the later stages of World War II, women in the civil service in the Federal government were paid wages equal to that of their male counterparts, which was in great contrast to the previous convention of paying women only two-thirds of the male wage. In 1949, Payne-Scott was involved in a public controversy when the CSIR began to withdraw wage parity. It was only in 1969 and 1972 that Australian women were given wage equality based on rulings of the Australian Conciliation and Arbitration Commission (Appendix H).

Payne-Scott became a radio astronomer by accident. Her first observation was made from the RPL building on the campus of Sydney University in March 1944,

W.M. Goss and R. McGee, *Under the Radar*, Astrophysics and Space Science Library 363, 1
DOI 10.1007/978-3-642-03141-0_1,

Fig. 1.1 Photograph of Ruby Payne-Scott as a student in the 1930s, possibly while she was studying at the University of Sydney 1929–1932, working on a B.Sc. degree in physics. Bill Hall family collection, used by permission of Peter Hall

during a test of radar equipment at 10 cm (Chap. 6). Thus Payne-Scott became one of the first radio astronomers, as well as the first woman radio astronomer. This observation also represented the first astronomical project with Joseph L. Pawsey, an association that became very profitable in the years 1945–1951.

An explosive growth of radio astronomy occurred in Australia starting in late 1945. RPL became one of the pre-eminent radio astronomy institutes in the world under the direction of Pawsey and Edward ("Taffy") G. Bowen. Within a few years, Australia established its international leadership in radio astronomy. Payne-Scott participated in the first publication of the budding Australian radio astronomers; she wrote one of the first radio astronomy summary papers in December 1945 (Chap. 6). From 1945 to 1952, the RPL radio astronomers published 62 papers in radio astronomy; Payne-Scott was a participating author in nine of these ground-breaking investigations.

In the short period from 1945 to her resignation in July 1951, she became a driving force in the early radio astronomy efforts in Australia; she was the first scientific leader in the solar radio group, directed by Pawsey (Chaps. 7–9). Her leadership role was diminished in the post World War II era as new recruits (J.P. Wild, J.G. Bolton, W.N. ("Chris") Christiansen, B.Y. Mills and F.J. Kerr) became prominent in the late 1940s to the early 1950s; she continued, however, to play a significant role. In 1946 she discovered Type III solar radio bursts (Chaps. 7 and 8) which originated at long radio wavelengths in the solar corona and played an important part in the discovery of Type I bursts (1946) and Type II solar radio outbursts (1947).[1] Payne-Scott, together with Alec Little (1925–1985), even detected Type IV solar radio outbursts with the Potts Hill swept-lobe interferometer in 1949–1951, several years before they were recognized as distinct physical entities by the French group of Boishot and Denisse in the mid-1950s (Chap. 9). In Fig. 1.2, we show the well-known photograph of Ruby Payne-Scott, Chris Christiansen and Alec G. Little, taken at Potts Hill sometime between 1949 and 1951. This is the only photo of Payne-Scot that has traditionally been displayed in a number of publications in Australia in the last 20 years.

Payne-Scott also made major contributions to the development of radio astronomical techniques. Two prominent examples were: (1) the mathematical development of "aperture synthesis" (Chap. 7), the technique utilized by many of the advanced radio astronomy instruments of the modern era (e.g. the Very Large Array, the Atacama Large Millimetre Array, the Multi Element Radio Linked Interferometer, the Australia Telescope Compact Array, etc.); and (2) the swept-lobe interferometer at Potts Hill, developed by her and Little. With this instrument the scientists could make a crude movie (25 frames a second), showing the motions of the solar radio bursts as the emitting gas moved outwards in the corona at high velocities. In addition, there is strong evidence that she was the first person in Australia to recognize the importance of confusion in radio astronomy (the necessity to achieve high angular resolution in addition to sensitivity in order to recognize distinct radio sources).

In these first years of growth in radio astronomy after World War II, Payne-Scott began to come into conflict with one prominent colleague and with the bureaucracy of CSIR.

Payne-Scott was subjected to discrimination against women, prevalent in all aspects of Australian society in the 1940s and 1950s.[2] These controversies have been mentioned in a number of popular articles in the Australian press and also in books providing summaries of Australian astronomy. The latter have been correct

[1]Curiously, Payne-Scott soon lost confidence in the reality of the important Type II outbursts, associated with large optical flare events on the sun and delayed (by about a day) aurora and magnetic storms on the earth.

[2]There is a temptation to evaluate these issues with the viewpoint of the more egalitarian society of the early twenty-first century; as a number of correspondents have pointed out to the authors, the draconian treatment of Payne-Scott in the mid-twentieth century was consistent with practices in many walks of life. The characteristic that distinguished Payne Scott was her resistance to these inequalities.

Fig. 1.2 The most commonly published photograph of Ruby Payne-Scott. This was taken at the Potts Hill Reservoir, likely in late 1948. "Chris" Christiansen is to the right with Alec Little in the middle. Payne-Scott and Little were working on observations of the sun at 97 MHz using the newly constructed swept-lobe interferometer (Chap. 9). (ATNF Historical Photographic Archive: B14315; permission granted by Jessica Chapman.)

in attributing her 1951 resignation to the birth of her first child in late 1951. The nature and the consequences of the discovery in 1950 of her "secret marriage" of 1944 have been described with considerable distortion in popular articles.[3]

[3]One source claims erroneously that "She was obligated to resign when her marriage was exposed". (See also the Preface.) Another source suggests that her resignation when pregnant in 1951 was a protest against the marriage bar; we have found no evidence for this. An ASIO report (Chap. 13) of 2 March 1959 "... identified a Ruby Payne-Scott, a Research Officer at Radio Physics [sic], NSW, whom [BLANK-redacted] had referred to as 'a Red' and who was dismissed from CSIRO for failing to give notification of her marriage". At a subsequent location in the file, the correct reason for her resignation "because of her child birth" was stated.

The major conflict that Payne-Scott experienced in her career at CSIR and CSIRO[4] occurred in the period February–May 1950, probably starting when she met in person with Sir Ian Clunies Ross, the Chairman of the new CSIRO. Ruby Payne-Scott and William "Bill" H. Hall married in September 1944; this was known by most of her colleagues at RPL. The rule against married women at CSIRO maintaining their permanent employment status was challenged head on by Payne-Scott; Clunies Ross wrote her a series of forceful letters with equally strong replies from her side (see Appendix I for Clunies Ross's scathing reply of 3 March 1950). As expected, Payne-Scott lost this battle and became a temporary employee of the CSIRO. The major losses were her superannuation (pension) rights, the non-return of the CSIR/CSIRO contributions (1946–1950), and the loss of accrued interest when her own contributions were returned. Details of this conflict are presented in Chap. 4.

A chronic conflict with John G. Bolton was a part of Payne-Scott's life at the RPL after he joined the CSIR in September 1946; Bolton was demobilized from the British Navy in late 1945, having served as a radar officer on the Royal Navy *Unicorn* (aircraft carrier) for about a year in the East Indies and the Pacific.[5] By the time of Pawsey's overseas trip in September 1947 to October of the following year, the conflict reached a boiling point. The sharing of the Dover Heights site produced continual conflict and Payne-Scott was "exiled" to the Hornsby field station (Chaps. 7 and 8).

During World War II there was an environment of complete secrecy at the RPL, due to the military nature of the research on radar. Each of the scientists had signed an oath of secrecy. Most documents were classified with different levels of secrecy. Thus the 1944 report on the first radio astronomy experiments at 10 cm (Chap. 6) carried the designation "confidential"; in 1945 or 1946 this was changed to "unclassified". This aspect of Payne-Scott's employment as a scientist and government employee is discussed further in Chap. 4.

After World War II Payne-Scott was concerned that CSIR would continue carrying out secret research, even though Australia was not then at war. In 1948, Payne-Scott took a strong stand against continued secret research within the CSIR. She wrote an un-equivocal letter to *The Sydney Morning Herald* on 29 July 1948 (Chap. 13), signed by many colleagues, pointing out that classified research in the

[4]The transition from the CSIR to the CSIRO (Commonwealth Scientific and Industrial Research Organisation) occurred in the period March–May 1949 with the passing of the Science and Industry Research Act 1949 by the Australian Parliament. The change from "Council" to "Commonwealth" was chosen to emphasise the national character of the new organisation and the word "Organisation" was used to highlight the changed character of the administration by the new CSIRO Executive of five members (including three scientists) (Schedvin 1987).

[5]D.B. Melrose and H.C. Minnett (1917–2003) have written a *Bibliographical Memoir* (1998) of Jack H. Piddington (1910–1997), who worked at RPL and then the Division of Physics for much of his career. He had played an important role in the Darwin anti-aircraft radar events of February 1942. Melrose and Minnett have quoted a colleague at RPL as mentioning that there was "a triangle of antagonism between John Bolton, Ruby Payne-Scott and Jack Piddington" at RPL in the late 1940s. Minnett also acknowledged these antipathies and described them as "creative tensions between very different personalities". RPL was blessed with some strong personalities!

CSIR would inhibit creativity. This issue would play a role in the transition to the CSIRO in May 1949; a major issue of contention was whether the CSIR would continue secret military research in the peace time environment.[6] Most classified research was moved out of the new CSIRO.

Payne-Scott had been known as a "left winger" at the RPL in the 1940s (Chap. 13). The Australian Security Intelligence Organisation (ASIO) maintained a large dossier concerning her and suspected that she was, in fact, a member of the Communist Party of Australia (CPA). ASIO had no proof of this affiliation at the time of a 1950 report. In 1999, however, the authors discovered that she had been a member of the CPA, possibly breaking with the Party later in the 1950s.[7] Behind her back, she was often referred to as "Red Ruby", even by her closest friends.[8] ASIO was aware of Payne-Scott's participation in the letter to *The Sydney Morning Herald*, along with numerous other colleagues not considered left-wing, including J. Paul Wild, future Chairman of CSIRO from 1978 to 1985.

In July 1951, Payne-Scott resigned from the RPL, with an advance notice of only 2 days. She was pregnant; her son Peter G. Hall – future Professor of Mathematics at the University of Melbourne and Fellow of the Royal Society of London – was born on 20 November 1951. A daughter, the famous Australian artist Fiona Hall, was born 2 years later (Chap. 12).[9]

After the birth of her children, Payne-Scott remained at home in Oatley (a suburb of Sydney), while she and Bill Hall raised the two young children (Chap. 12). After the children were about 10 and 12 years old, Payne-Scott became a mathematics and science teacher at Danebank Anglican School for Girls in nearby Hurstville; she was in this position from 1963 to 1974 (Chap. 14). It is likely that she developed Alzheimer's disease at an early age; she died in Sydney a few days before her 69th birthday (25 May 1981). Bill Hall died 21 July 1999.

An important aspect of Payne-Scott's career at RPL was the interaction and support of other prominent women colleagues during World War II. These colleagues were Joan Freeman Jelly and K. Rachel Makinson (Chap. 11). Joan Freeman's autobiography (*A Passion for Physics*, 1991) preserves a number of famous anecdotes about Payne-Scott. Rachel Makinson has also described a number of

[6]Collis, in a history of CSIRO, *Fields of Discovery: Australia's CSIRO* (2002), has described this controversy. As an example, the CSIR Division of Aeronautics was moved in 1949 from the CSIR to the Department of Supply and Development of the Australian Government (then Aeronautical Research Laboratories). The Chairman of the CSIR, Sir David Rivett, resigned on 18 May 1949; Rivett had been the founding CEO of CSIR (from 1927 to the end of 1945, then Chairman until May 1949)

[7]Peter Murphy, the Sydney Secretary of the Social Education and Research Concerning Humanity (SEARCH) Foundation, has been of considerable assistance (Chap. 13) in sorting out Payne-Scott's connections with the CPA. Her redacted ASIO file is in NAA: A6119/83, 1679, with the title "Payne Scott, Ruby Violet a.k.a. Hall".

[8]Rachel Makinson, February 2007.

[9]Payne-Scott experienced a miscarriage earlier. The date is uncertain; based on attendance at meetings of the radio astronomy group we surmise that this event may have occurred in late 1946 (see Chap. 7).

relevant events in the life of Payne-Scott in interviews with Goss in 2003 and 2007.[10]

Payne-Scott's legacy consists of two major components. First, she was an unconscious crusader for the rights of women in the scientific work place in Australia. Other women had experienced discrimination; Payne-Scott complained loudly about the treatment. She helped pave the way for future generations of women. Secondly, Payne-Scott was one of the first three pioneers in the new field of radio astronomy, which burst into prominence at RPL in Sydney in 1944–1945. Within a few years, Australia and the United Kingdom became the leaders in this new astronomy. Pawsey and Payne-Scott initially provided the key leadership for the rapid growth in solar physics that solar radio astronomy created in the first decades after World War II. When she retired in mid-1951, the leadership roles in solar physics were maintained by Pawsey and Paul Wild.

In 2008, the CSIRO recognized Payne-Scott with the establishment in June 2008 of the "Payne-Scott Award". This award is "for researchers returning from family related career breaks". The description states:

> The grant [$A35,000 for 1 year] will provide support to researchers to re-establish themselves and re-connect with the research underway in their field and related fields of research.

The grant targets women in research taking extended leave for family care; men involved in primary family care are also eligible. In the first year of the new grant program, ten individuals applied and six awards were granted. Given the level of conflict that Payne-Scott had over her marriage in 1950 (Chap. 4) and the career-ending nature of her pregnancy in 1951, this grant in her name is appropriate. (The "Payne-Scott" Award was announced at the same time as the "Newton Turner" Award for senior scientists at CSIRO, named after the prominent agricultural statistician at the Division of Animal Genetics from 1946 to 1976. In Appendix H a possible connection between Payne-Scott and Newton Turner is described.)

Most of the 16 chapters of this book have been summarised throughout this introduction. In Chap. 2 the ancestors of Payne-Scott, her early childhood, her move to Sydney to attend high school and her university years at the University of Sydney, are described. In Chap. 3 we describe her period as a science teacher at Woodlands School in Glenelg (Adelaide), as well as her short period working at

[10]The most famous colleague of the RPL during the War was certainly Dame Joan Sutherland, the famous opera singer. Although she may have heard of Payne-Scott while she was a clerical assistant at the RPL from April 1944 to January 1945, she never met Payne-Scott (Letter from Sutherland to Goss, 23 April 2007). In 1944, Sutherland was the typist of a report written by E.G. Bowen concerning the meteorological effects on radar reception. The most famous story about Joan Sutherland concerns the Musical Revue, *Hush-Hush*, in late 1944, staged by Robert Coulson. This was a spoof of the *Mikado* with a skit involving the "Lord High Clerical Officer" draped in red tape. Joan Freeman was in the chorus together with Sally Atkinson. The 18 year old Sutherland auditioned for a part and was rejected (confirmed by a letter from Dame Joan to Goss, April 2007). It appears that this rejection had no adverse effect on her career; already in 1947 she had made her concert debut in Sydney as Dido in Purcell's *Dido and Aeneas*.

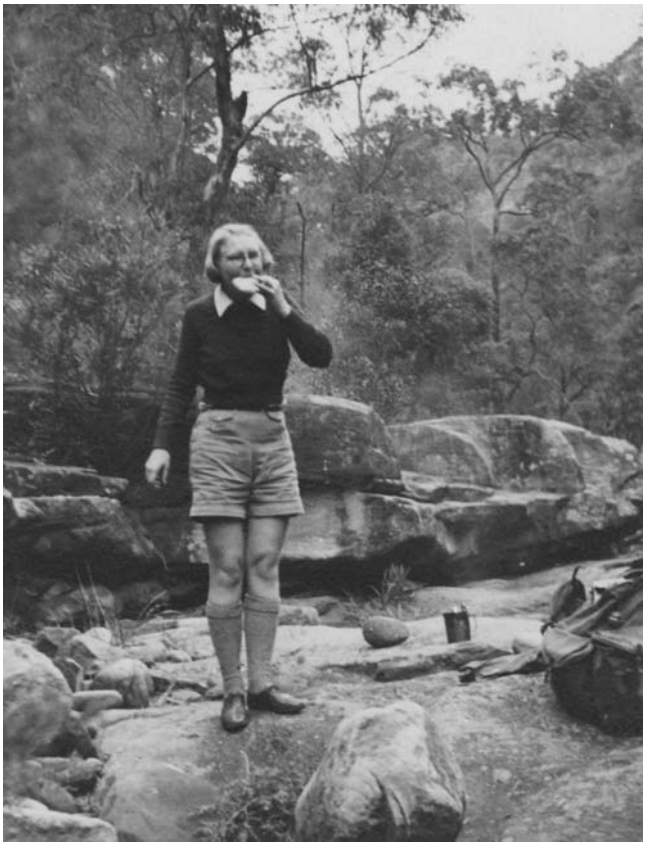

Fig. 1.3 Bushwalking, a passion of Ruby Payne-Scott. Here she is probably in the Blue Mountains in the 1940s. Many photos of Payne-Scott show her eating or drinking at the time of the photographic session. Her daughter Fiona suggested that her mother likely thought that posing for photos was a waste of time; thus she could be more efficient when combining posing with eating or drinking! A companion photograph is shown in Appendix J. (Fig. J.3a). Bill Hall family collection, used by permission of Peter Hall

Amalgamated Wireless, Australasia (AWA)[11] in Sydney. Chapter 4 contains the details of Payne-Scott's personnel interactions with CSIR and CSIRO from 1941 to 1951; the details of the marriage controversy of 1950 and the equal pay conflicts of the post War era are summarised. Chapter 5 provides a detailed summary of her research in the area of War time radar. Chapter 6 contains the description of the first radio astronomy observations of 1944 and the transition to peace time in 1945. Chapter 7 contains the formative period of the first sea-cliff interferometer at Dover

[11]Amalgamated Wireless (Australasia) Ltd., formed in 1913 from the merger of Marconi's Wireless Telegraph Co. Ltd. and the Australian Wireless Company.