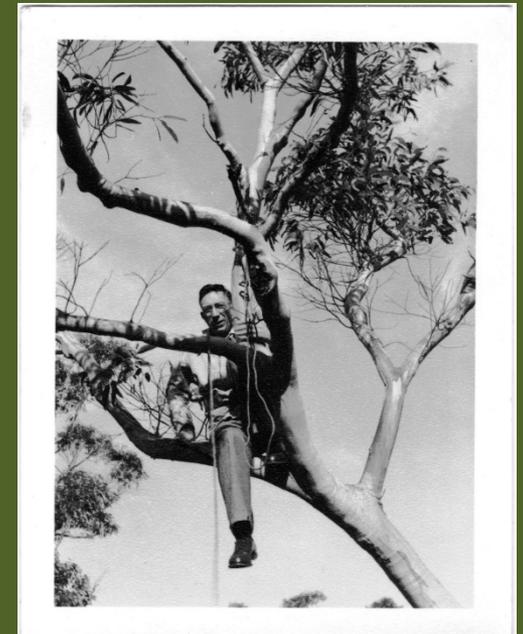




## Ruby- Payne-Scott



Joseph L  
Pawsey



Augusta 8 February 2019



Very Large  
Array Radio  
Telescope New  
Mexico

# Opening of the Second Window on the Universe in 1945: Radio Astronomy and the Role of Ruby Payne-Scott, First Woman Radio Astronomer



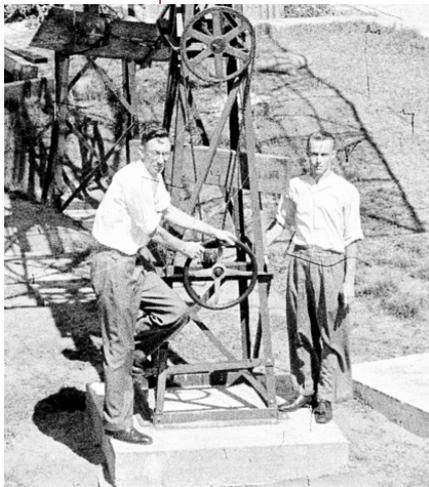
Miller Goss  
National Radio Astronomy Observatory  
Socorro, New Mexico



Physics and Chemistry  
University of Augusta  
8 February 2019

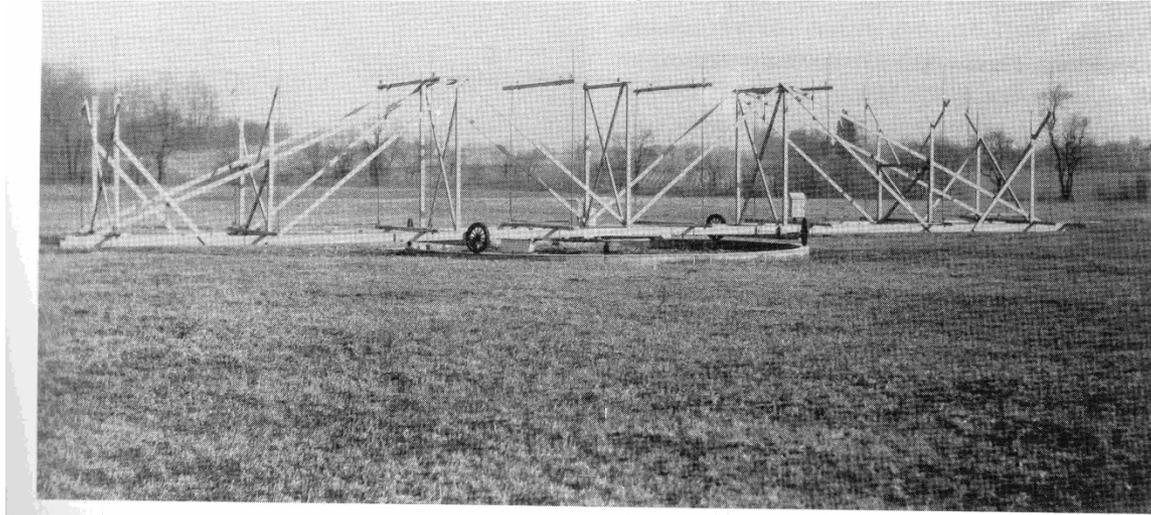
<http://www.nrao.edu/>

Jaeger, Pawsey  
and Payne-Scott



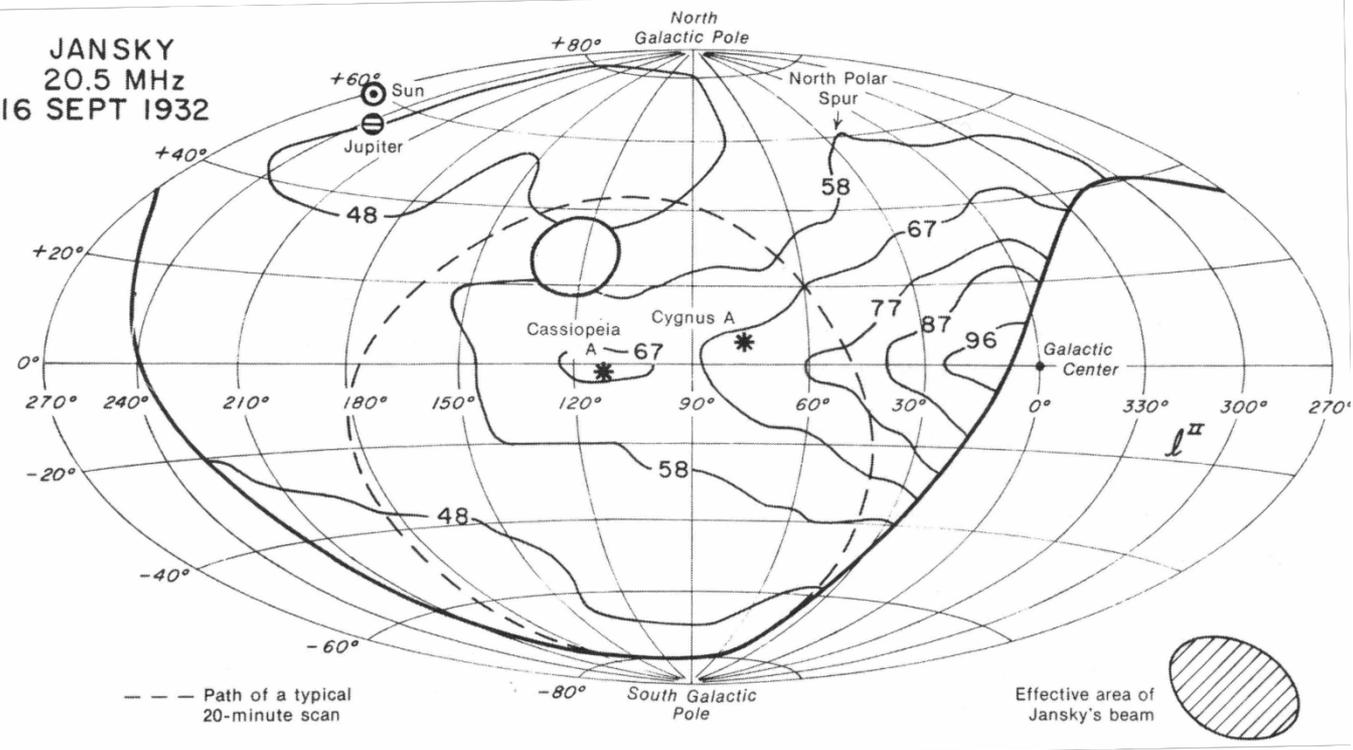
Pawsey and Yabsley

# Karl Jansky :1905-1950 Bells Labs in New Jersey - SERENDIPITY



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JANSKY  
20.5 MHz  
16 SEPT 1932

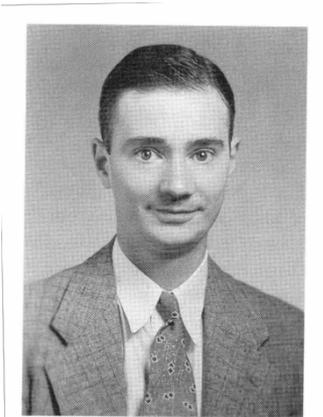


Beam 36 by 24 deg 20 MHz

# Grote Reber: 1911-2002--- W9GFZ



- 31 foot home made antenna in his backyard in Wheaton, Illinois 160 MHz Now at NRAO Green Bank West Virginia Virginia

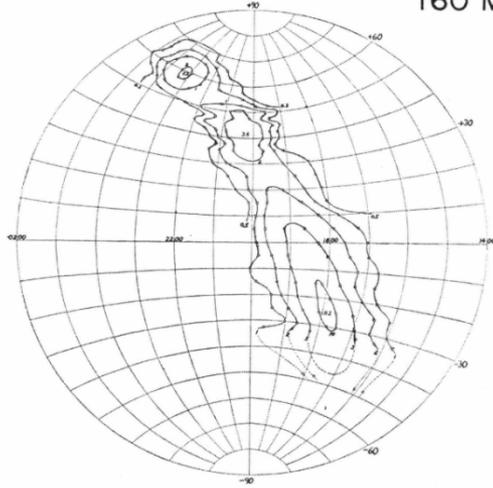


7.5 m Wurzburg German ex WWII radar in Washington DC in 1950 . Reber

# 160 MHz 12 deg beam, 480 MHz is 4 deg

REBER

160 MHz (1943)



# Pawsey: The FOUNDER of Australian Radio Astronomy- his life

- Born Ararat Victoria Australia May 14, 1908
- His mother - maternal ambition
- Died Sydney , 30 November 1962
- University of Melbourne 1926-1929 BSc
- Master of Science 1931
- Given a 1851 Exhibition Scholarship to University of  
feetsteps of E Rutherford- 1934 PhD working on mo  
layer of the ionosphere with J.A. Ratcliffe and E Ruth
- Moved back to Australia at the end of 1939. one of t  
leaders of the radar research in Australia 1940-1945  
successful weapon the Australians developed in WWII was the  
LIGHT WEIGHT AIRCRAFT WARNING – 200 MHz radar



Joe Pawsey

Ratcliffe, Kapitsa,  
Chadwick

Anne Davies, Marie Sparshott



Ted Nicoll

Cavendish  
Lab 1932.  
9 current and  
future Nobel  
prizes



Massie

Oliphant

JJ Thomson

Rutherford

Blackett,  
Cockcroft

# 1957 University of Illinois



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# Ruby's early Life



- Born: 28 May 1912 . Grafton , New South Wales, 600 km north of Sydney Australia
- Moved to Sydney when a young child and attended Cleveland Street School
- At Sydney Girls High . Leaving Certificate in 1928 . Started in Feb 1926
- Sydney University .
- 1933: B Sc 1st Class Honors in Math/Physics

# Ruby and her students –South Australia in 1939 : Woodlands School - Glenelg

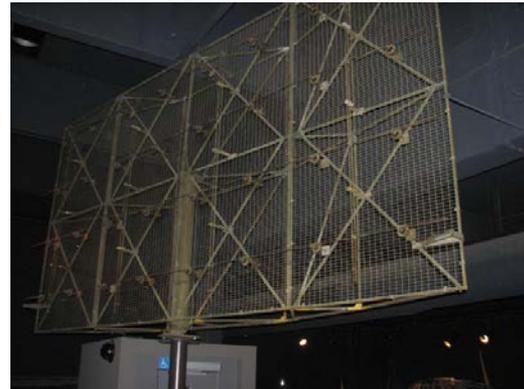
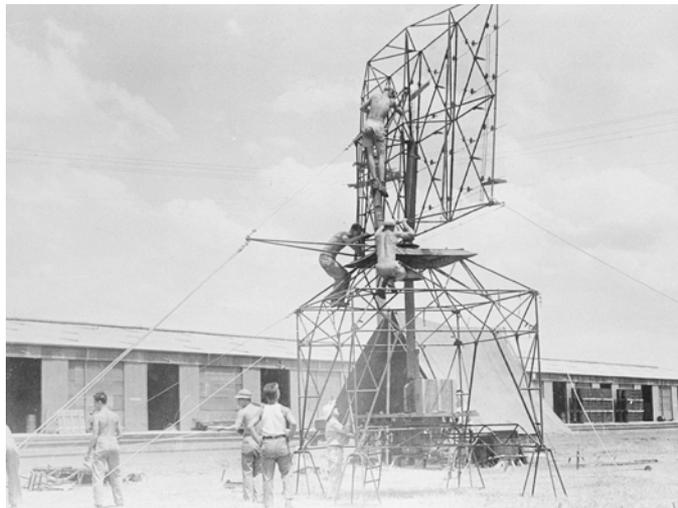
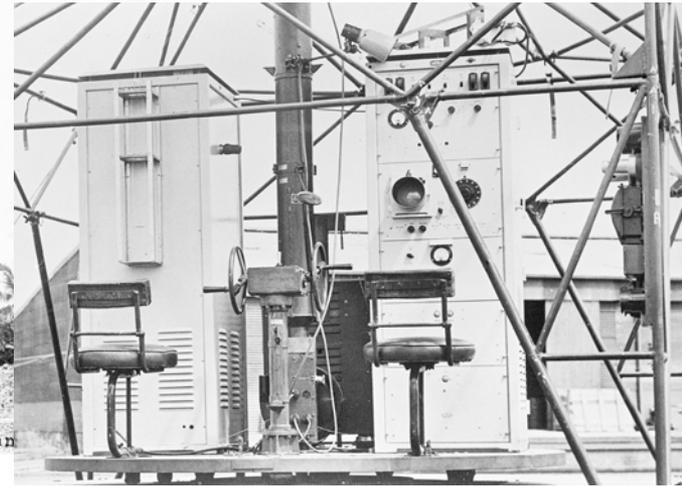
1939 Physics Lesson in the old Science laboratory.  
Miss Payne Scott, Elizabeth Brookman, Nancy Robertson, Mary Rainsford, Helen Eyles  
(last three students now have B.Sc.)



# World War II – an opportunity for women in the workplace

- 1939-1941: Radio Engineer , Amalgamated Wireless Australasia ( AWA )
- Hired as the librarian and later on became an engineer
- War in Australia began in 1939 with the UK
- As the Pacific war looked likely, Australia realised they would be attacked by Japan- air defense was necessary. Radar research started at the Division of Radiophysics at the University of Sydney campus. June 1941
- Extensive bombing after Feb 1942 in Northern Territory (Darwin), Queensland and Western Australia. Example of women in the armed forces: the Royal Australian Air Force about 15 per cent personnel were women, often radar operators- WAAAF

# Dover Heights WWII Shore Defense and Light Weight Aircraft Warning 200 MHz



Australian War Memorial  
Restored Radar



# Radars and WWII

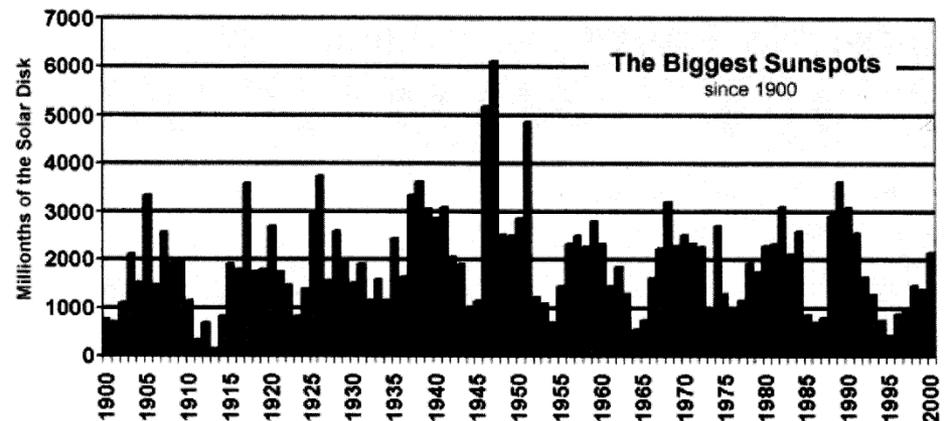
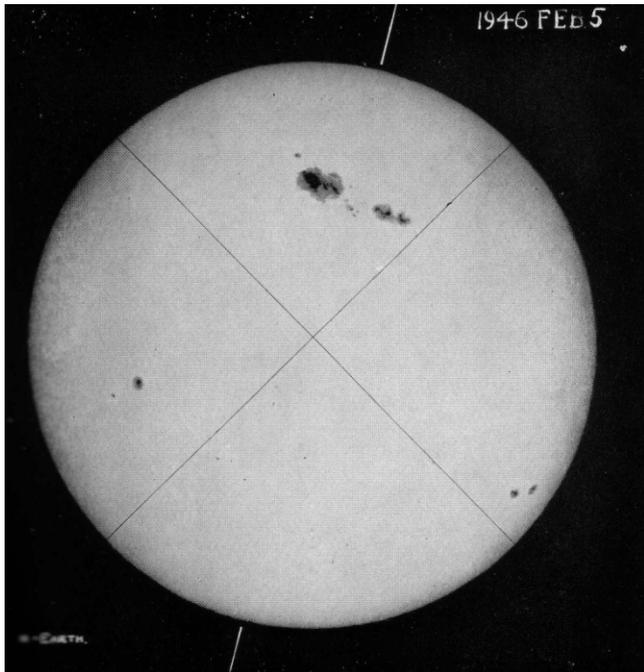


# Post war August 1945

- Transition from war time research to something else- radio astronomy. In Australia no academic university groups for their future careers. The name was initially **solar noise** and **cosmic noise**. Pawsey invented the word '**radio astronomy**' in January 1948
- Evolution of the radar lab to peace time work
- They had heard of results of Jansky and Reber – took more than 12 months before the Reber paper of November 1944 arrived in Australia
- The war time detections of the sun- published in 1945-1946- the Norfolk Island effect from NZ colleges and reports of war time secret detections of the sun in the UK and in the US
- Pawsey appointed Payne-Scott to lead the science efforts as solar noise research began October 1945
- Not a single astronomer in the group until the mid 1950s

# Incredible good fortune

- One of the larger sunspots of recorded history in first days of Feb. 1946- second largest sunspot in recorded history



Good fortune that radio astronomy restarted in 1945- just in time for the huge sunspot cycle of 1947

EW size was 300,000 km! 0.4 of the solar radius

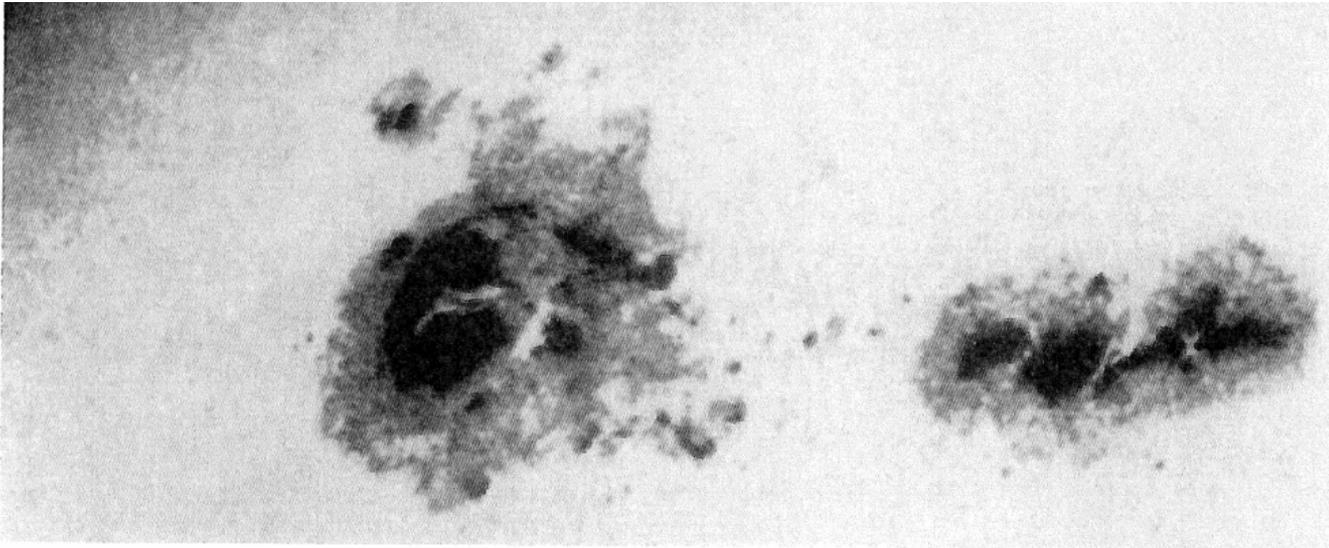
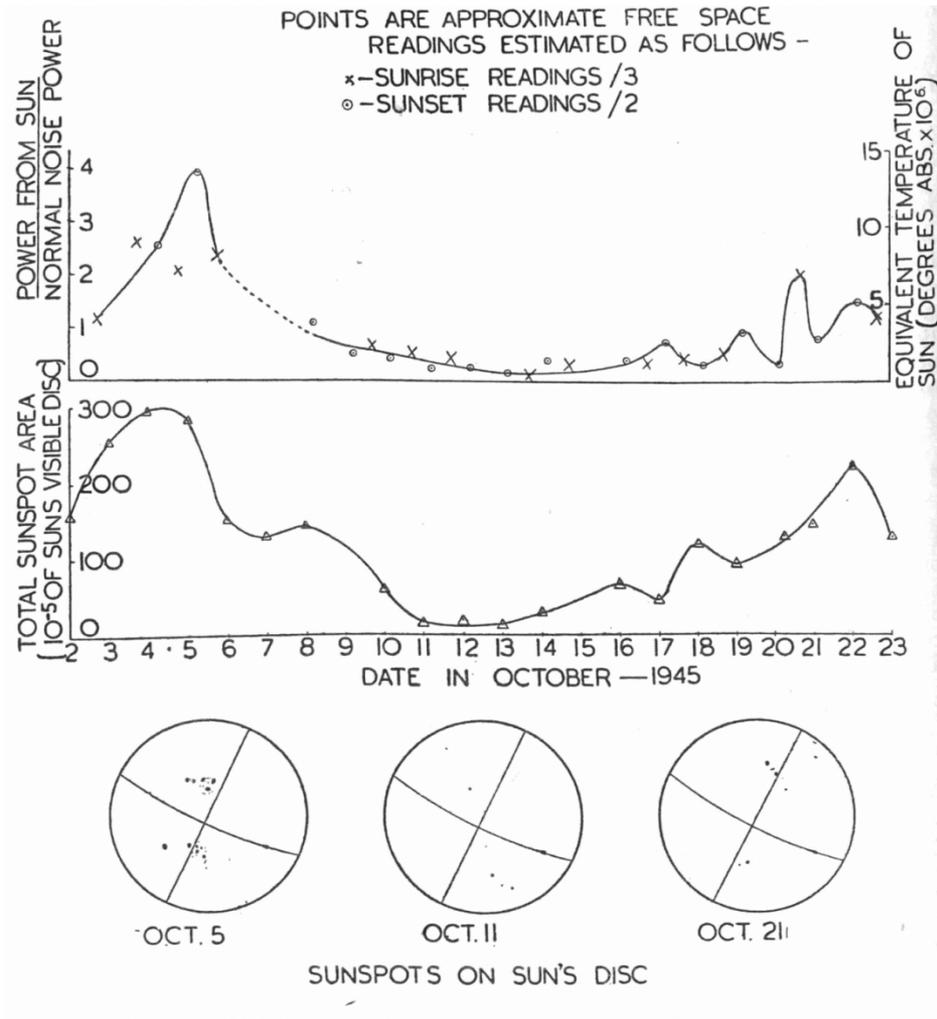
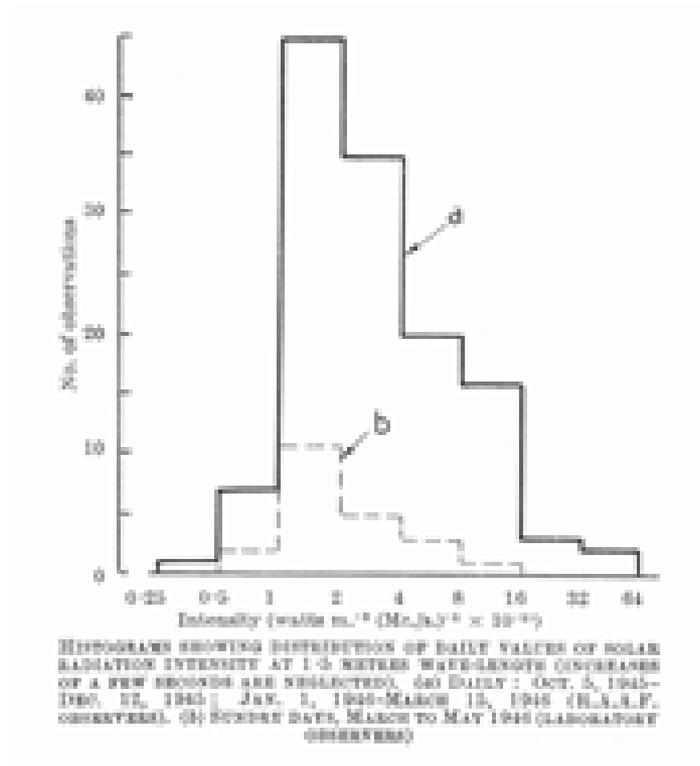


Figure 7.8 The sunspot group of February 1946, the largest ever recorded up to that time. Its associated radio bursts were seen by Pawsey's group with a sea-cliff interferometer and by Hey's group at AORG (Section 6.4).

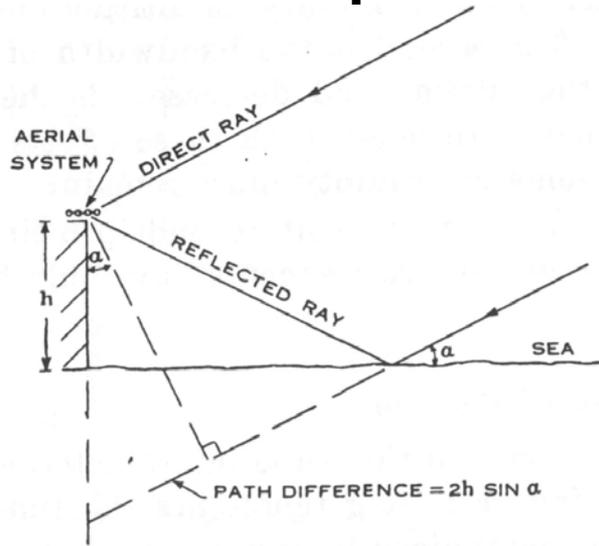
# Type I bursts associated with sunspots- published Feb 1946



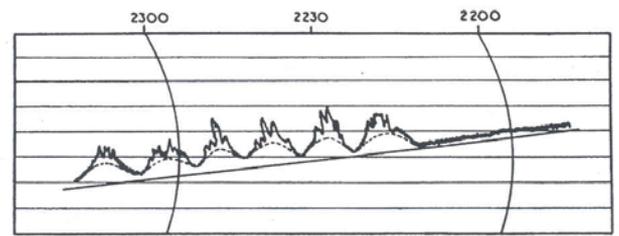
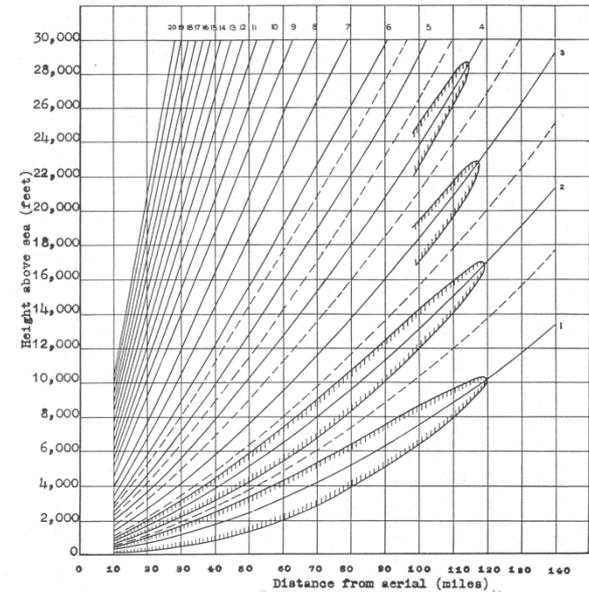
# Published 2 Nov 1946, Nature, the existence of the radio hot corona established by Pawsey



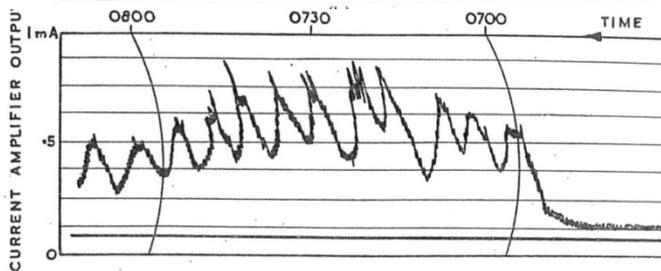
# The Sea-cliff interferometer and lobe pattern for the radar



(a)



Cygnus A – 100 MHz 10000 Jy  
With noise of 300 Jy

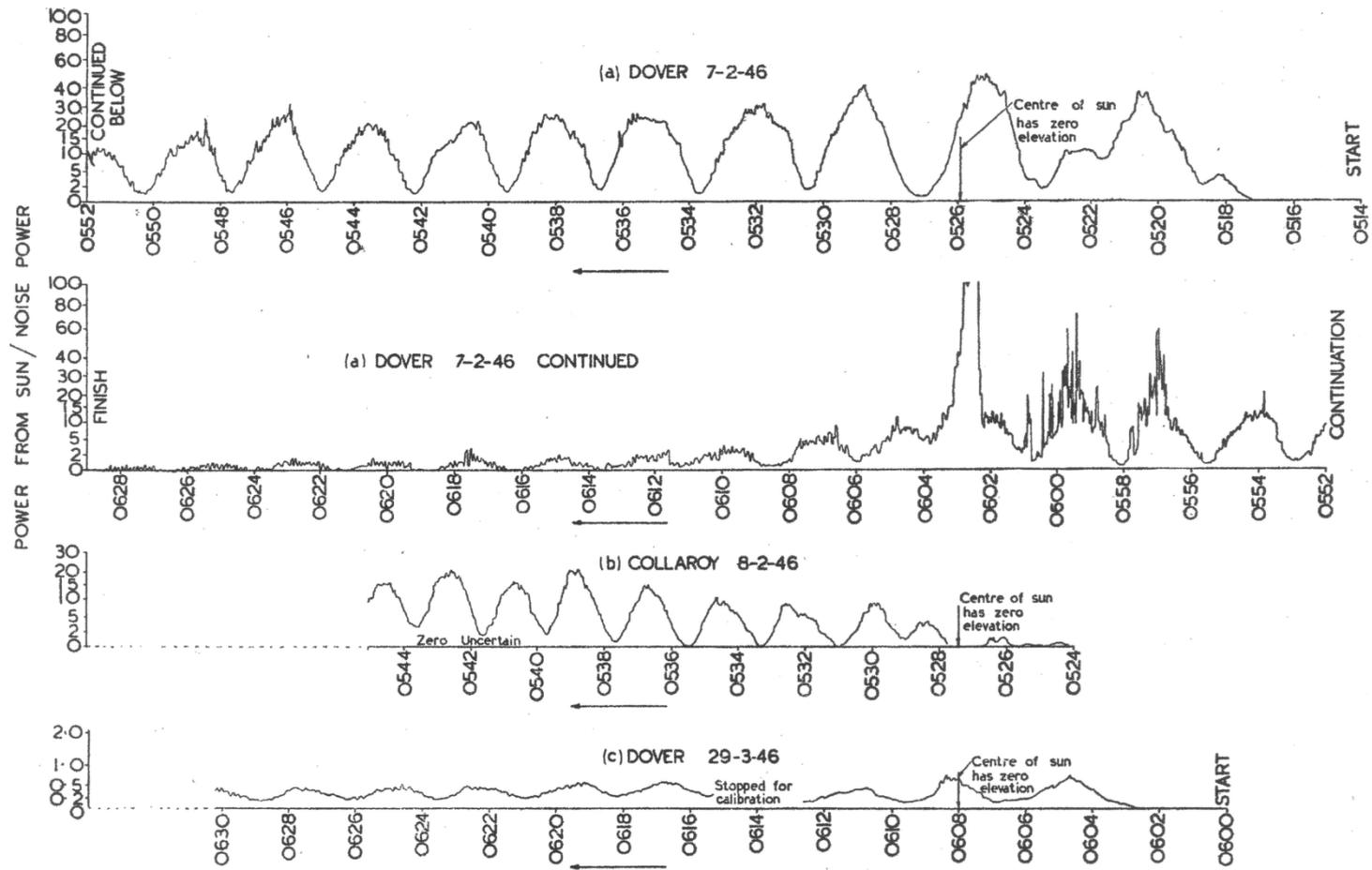


Quiet Sun June 1947

The Sea Cliff Interferometer- first use of radio astronomical interferometry 26 Jan. 1946- Australia Day- by Ruby Payne-Scott , Pawsey and McCready



# Type I Noise Storm associated with the huge Sunspot of Feb. 1946



# Limits on $T_b$

- Size is less than 6.5 arc min- fringe spacing is about 28 arc min. Thus much smaller than the diameter of the sun of 30 arc min. Peak flux density is  $10^7$  Jy or  $T_b > 3 \times 10^9$  K. Type I bursts are now known to be the fundamental frequency plasma emission, explaining the high brightness temperature

## Key Results of Sydney group in the paper of 1947 in the Proceedings of the Royal Society

- Bursts associated with sunspots, size limits and position determination. Non-thermal emission, Payne-Scott proposed the calibration scheme used by radio astronomers, then and now
- At Cambridge University in the UK after the war the radio astronomers had as colleagues **crystallographers** – Sir Lawrence Bragg was proud of the fact that the same math and techniques worked over a wavelength range of  $10^{10}$  and scales sizes with ratio  $10^{31}$  from angstroms to megaparsecs

# March 8 1947 Giant Outburst – first Type II – Payne-Scott, Yabsley and Bolton

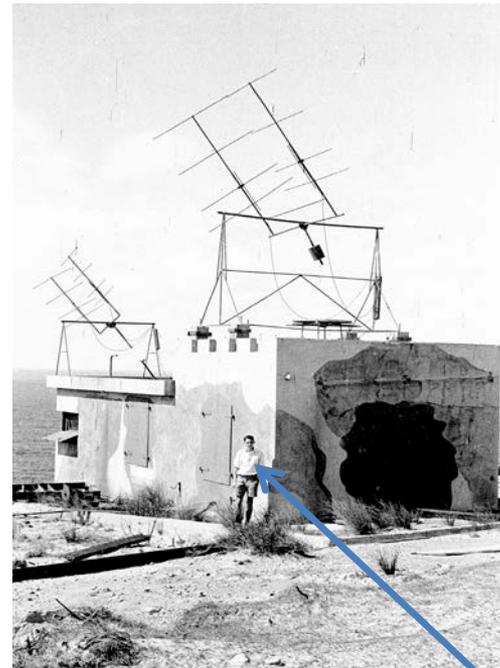
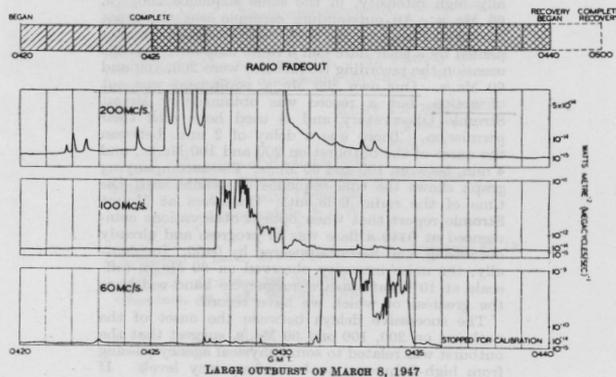
(Reprinted from NATURE, Vol. 160, page 256, August 23, 1947.)

## Relative Times of Arrival of Bursts of Solar Noise on Different Radio Frequencies

It is becoming recognized that on metre wavelengths solar noise from the disturbed sun is characterized by the occurrence of sudden large increases in intensity of a duration of several seconds or minutes. Bowen<sup>1</sup>, of this Laboratory, has reported that these increases of intensity are not necessarily coincident in time or shape when observed on different radio frequencies. The present communication describes observations, chiefly during July and August 1946, of the relative times of arrival of such bursts on 200, 75 and 60 Mc./s., with a few observations on 30 Mc./s. For each frequency a separate receiving system, actuating its own recording meter, was used. Loud-speakers were also connected giving aural confirmation of the recorded data.

Three main conclusions can be drawn from these observations:

1. *Lack of correlation between most bursts.* First and most important, the majority of the intensity variations, particularly the smaller ones, show no correlation with those on other frequencies. This supports a hypothesis that the noise on different frequencies normally originates in widely separated levels in the sun's atmosphere, and that the disturb-

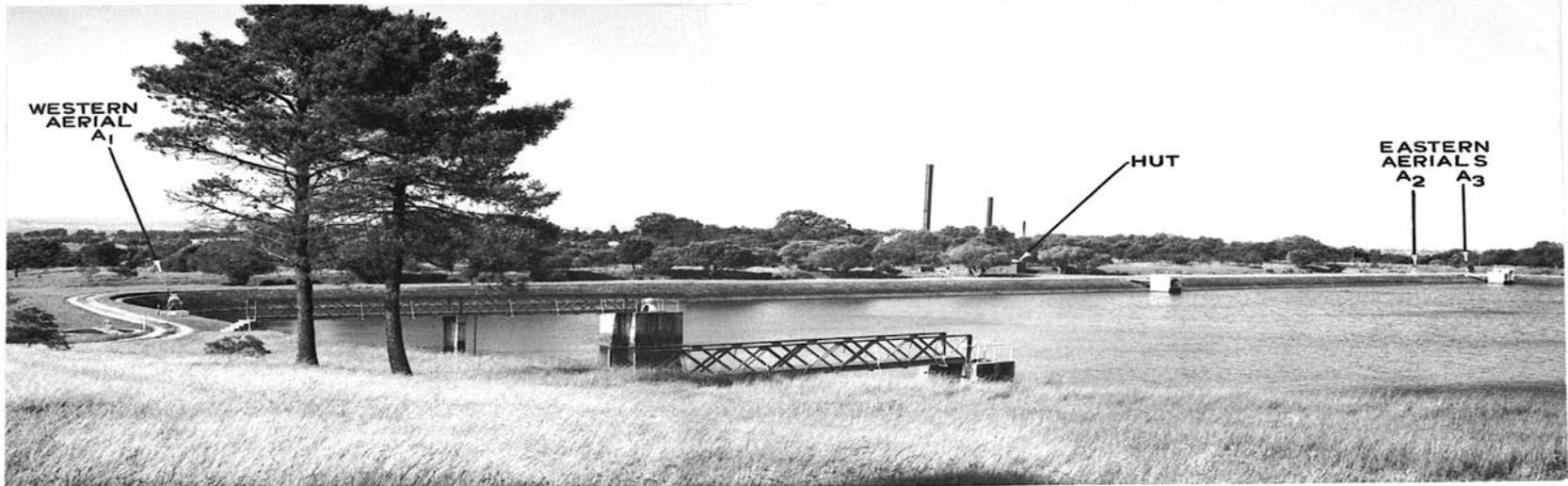


John Bolton

# Details

- This was another giant sunspot- few days after the Type II- aurora observed in Sydney !  
Inferred velocity of 500 to 1000 km/s
- Claim is that the flux density at 60 MHz is  $10^{11}$  Jy- likely the largest signal ever detected in radio astronomy. But is very uncertain

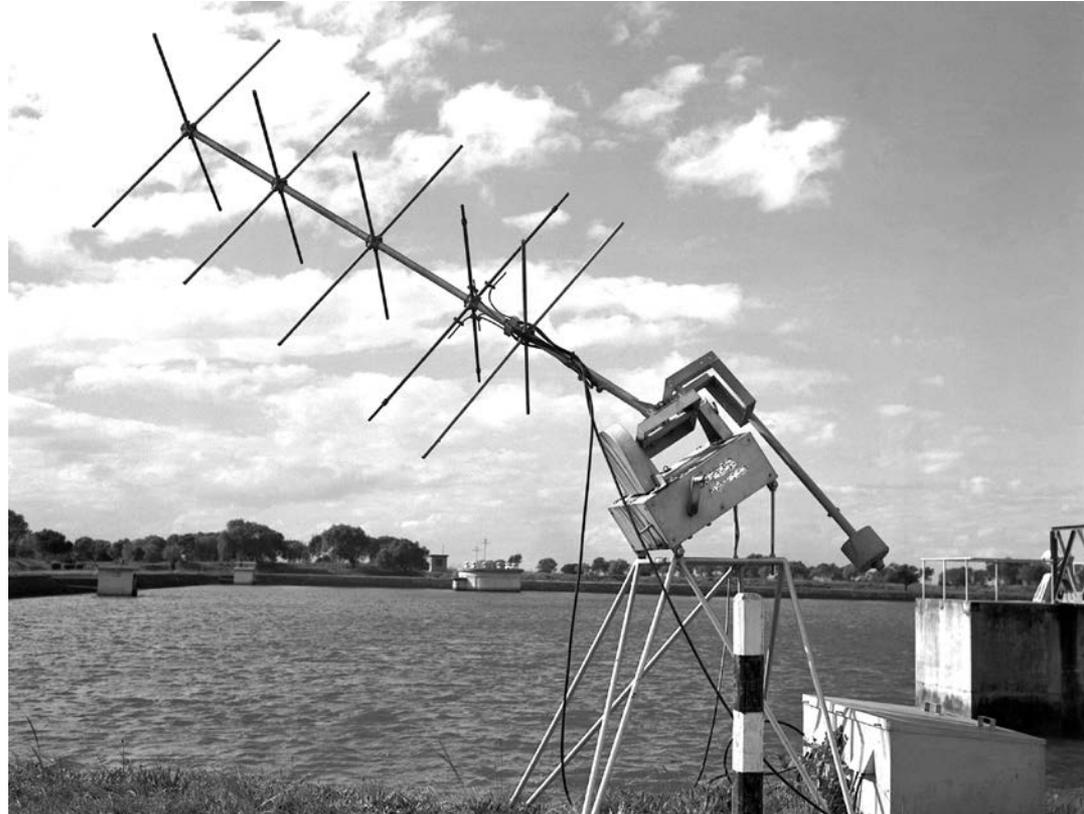
# Potts Hill Reservoir Sydney



POTT'S HILL INTERFEROMETER SITE LOOKING NORTH-EAST  
PLATE I

The rotating fringe interferometer to locate positions of solar bursts in the solar corona at 25 times per second- the first Michelson radio interferometer in Australia- 1948

Movies of Type IV bursts- established the velocity of these at roughly 1000 km/s



# Payne-Scott's achievements

- First person to recognize Type I bursts
- And Type III bursts – using adjacent radio telescope with several different frequencies, before the day of dynamic spectra – the swept frequency radio telescopes. Inferred velocities was 0.1 to 0.5c !
- Her claims were not generally accepted at the time but her results are now confirmed
- Then DIRECT (not inferred ) velocities of the Type IV bursts with the swept lobe interferometer She made movies of their motions at 1000 km/s

# URSI 1952 Sydney University- show case for Australian radio science Bolton

*To Miller Goss with the compliments  
of the Organizing Secretary,  
Ron Bracewell*

**UNION RADIO-SCIENTIFIQUE  
INTERNATIONALE**  
2006 Sep 28

**TENTH GENERAL ASSEMBLY**

**Graham-Smith**

**List of Participants**

**SYDNEY  
AUGUST, 1952**



Wild

Doc Ewen

Slee

Chris

Mills

Hanbury Brown

Ruby

# Three Conflicts

- Her “secret marriage”
- Equal wages during the war (before war women were paid a  $3/4$  men’s wage) and the cessation of this policy in the postwar era
- Her concerns about possible secret research in the new CSIRO (1948-49)

# The most important controversy of her career- her marriage

- In Australia at this time in most jobs if a woman married she became a temporary employee- she lost her superannuation or pension contributions etc.
- Ruby married in 1944 and her colleagues knew this; they helped keep it secret. The CSIRO administration learned of this after the war and was upset – Sir Ian Clunies Ross wrote her in 1950:

# Sir Ian Clunies Ross- chair of CSIRO wrote to Payne-Scott 3 March 1950

In conclusion, I think the simplest way of regularizing the whole affair would be for you to tell us the date of your marriage. We will then look into the matter and tell you what should be done in your own and our best interests.

Yours sincerely,

CHAIRMAN.

# Wage equality for women

- During the later part of the war the WEB-Women's Employment Board said that women technical officers were to be paid the full male rate instead of the reduced rate. She complained in public with letters to the editor etc

# Her prominent children

- Peter Hall – born 20 November 1951-  
deceased 9 January 2016. mathematician ,  
Professor, University of Melbourne, Fellow of  
the Royal Society, AO 2013 .
- Fiona Hall – born 14 November 1953.  
Prominent artist in Australia and overseas,



any capital cities



d



# After her daughter was 10 years old

- She returned to school teaching in Sydney from 1963-1974
- She suffered from Alzheimer's disease from 1975 to her death in 1981

# Summary

- Amazing good fortune that the sunspot maximum close to the end of WWII
- Solar noise research gave : interferometry, dynamic spectra, enhanced understanding of free-free emission (eg solar corona), new insights into physics (plasma emission, synchrotron emission etc), aperture synthesis



# Conclusion 1 of 2

- My friend Claire Hooker in Sydney – historian of science, expert on Australian women in science- has described Payne-Scott as
- **Brief Feminine Flare in Radio Astronomy**
- Ruby Payne-Scott was the first woman radio astronomer and one of the first radio astronomers. She was mentored by J.L. Pawsey, one of the top three radio astronomers of the mid 20<sup>th</sup> century and the father of Australian radio astronomy. And the second director of National Radio Astronomy Observatory who died a few months after coming to the US at age 54 in 1962
- Ruby Payne-Scott made a number of substantial contributions to radio astronomy- science and techniques- from 1944 to 1951, with a major impact on the future of radio astronomy after 1951. She is a co discoverer of aperture synthesis in radio astronomy



# Conclusion- 2-continued

- What would have been the impact on solar radio astronomy if she had not left the field after only 6 plus years
- Why did she succeed? Factors are her abilities and experience in math and physics

She benefited from World War II and the realization that women were to play an important role in the defense of Australia. She was almost 10 years older than most of her colleagues in 1941; her male colleagues supported her. There was a small cohort of three women scientists at the lab that supported each other



# Recognition for Payne-Scott

- Since about 1999, several national Australian radio and television programs . 2020 a feature film ????
- The Payne-Scott Award of CSIRO since 2008
- ---‘ For researchers returning form family related career breaks’
- ----Targets women in research taking extended leave for family care; men involved in primary family care are also eligible
- ----To help re-establish the scientist after a leave and to re-connect with the research underway in their field

# Google Doodle, Ruby Payne-Scott's 100<sup>th</sup> Birthday . 28 May 2012



# OVERLOOKED , New York Times

- Since 1851, obituaries in The New York Times have been dominated by white men. Now, we're adding the stories of other remarkable people.

# Overlooked No More: Ruby Payne-Scott, Who Explored Space With Radio Waves

29 August 2018 – NY Times text

- 28 May 1921 to 25 May 1981
- Payne-Scott helped establish the field of radio astronomy by using radio waves to detect solar bursts, but she was forgotten after she got married.



# NY Times 29 August 2018

- By Rebecca Halleck
- Every so often our sun emits an invisible burst of energy.
- This energy ripples through space as electromagnetic waves and then crashes into planets and meteors and space debris and one another, causing a great cacophony above and around us.
- A cacophony that was inaudible, until Ruby Payne-Scott entered a laboratory.
- In the 1940s, Payne-Scott helped lay the foundation for a new field of science called radio astronomy. Her work led to the discovery of deep-space phenomena like black holes and pulsars and later helped astronauts understand how solar storms disrupt weather in space and electrical grids on Earth.
- Beatrice Tinsley New Zealand astronomer (1941-1981) published 18 July 2018

A

ustralian Children's B



### RUBY PAYNE-SCOTT

SCIENTIST (1912-1981)

Ruby Payne-Scott was the first woman to 'listen to the stars'.

After undertaking top-secret radar work during World War II, Ruby became one of the first radio astronomers in the world.

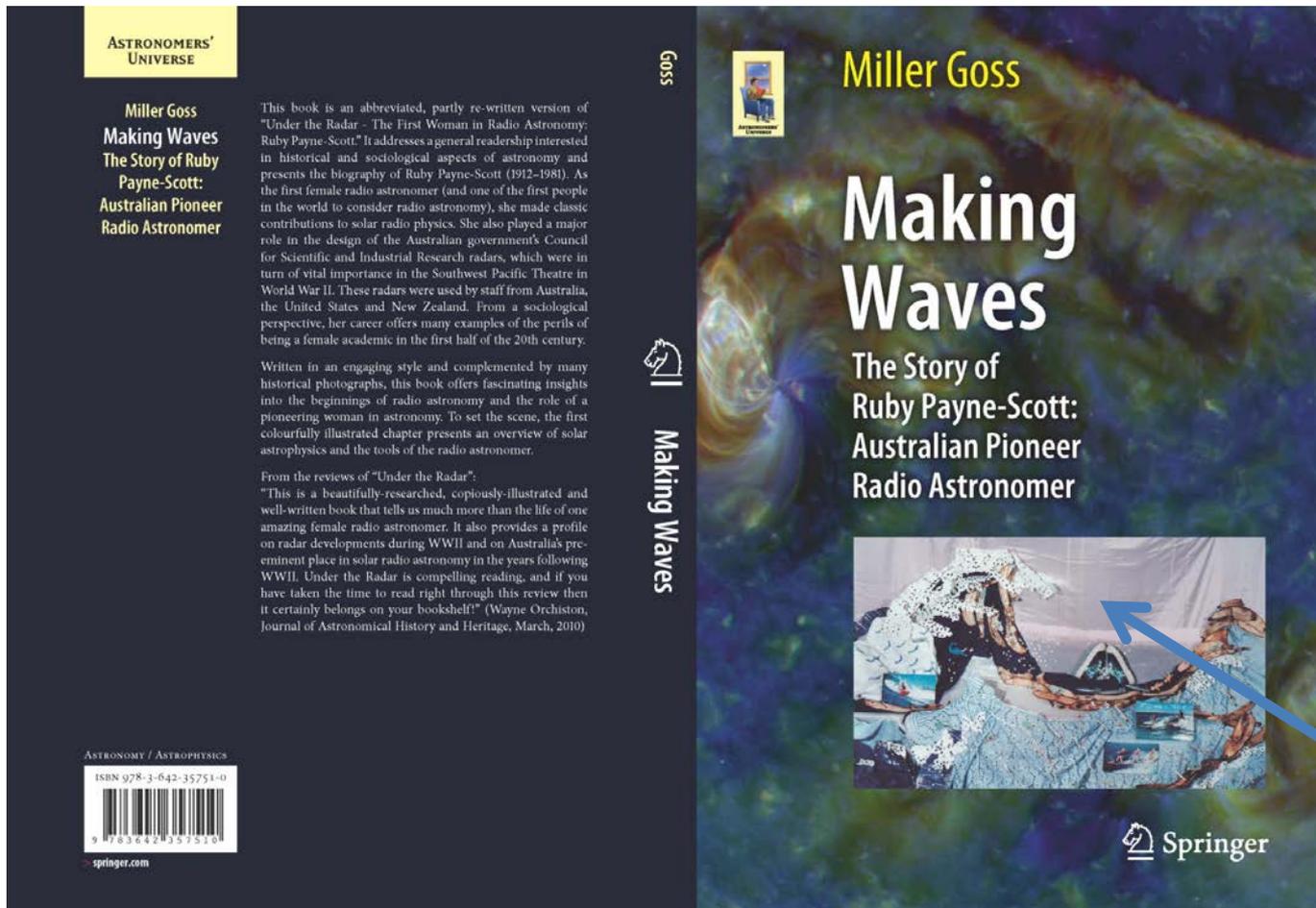
At the CSIRO (the Commonwealth Scientific and Industrial Research Organisation), Ruby and her colleagues set up some of the earliest radio telescopes, and she led the work to define sunspots and their effect on the Earth. Among many other things, she discovered that the electromagnetic radiation given off by the sun's corona travelled through the solar system – and when it hit the Earth's magnetic field, it made the Northern and Southern Lights – the auroras. She and her team also discovered that the temperature of solar flares was over ten million degrees! Before that, people had thought the sun was only about six thousand degrees.

In Ruby's day, any woman who worked for the Public Service in Australia had to leave their job when they got married; so, Ruby kept her marriage secret for six years, until she was going to have a baby. She fought for equal pay for female scientists, and for equal work conditions, such as being allowed to wear the same type of clothes as the men. Confident, brilliant and supportive of social justice, environmental issues and women's rights,

Ruby forged a path for other female scientists to follow.



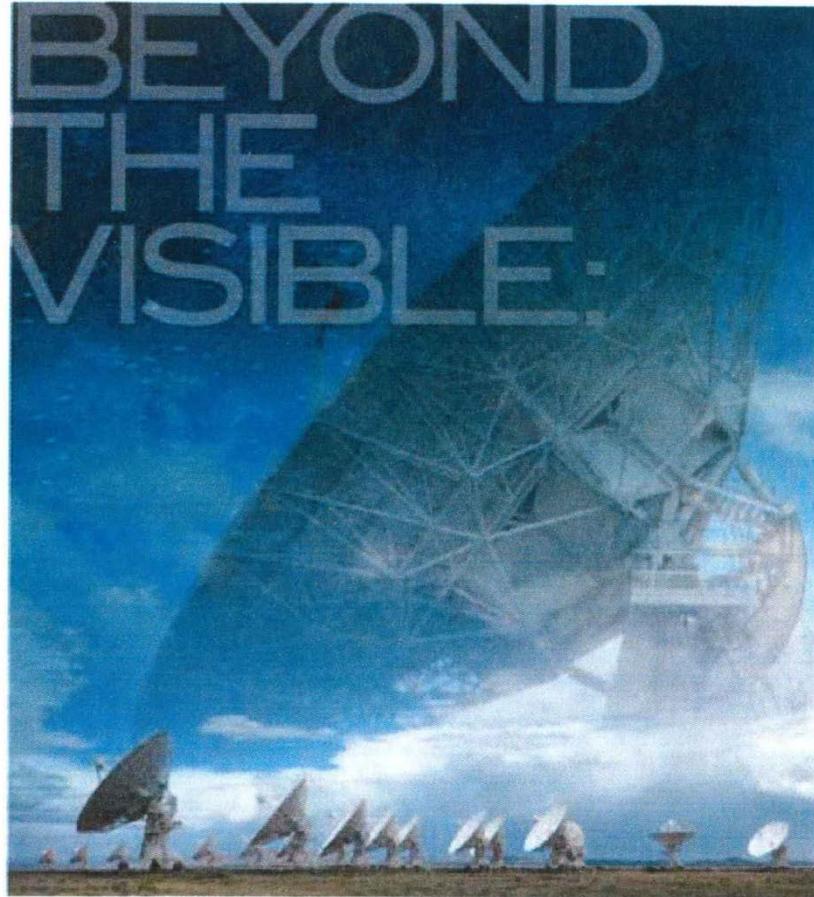
# August 2013- Amazon \$36-



# VLA 2018 Sgr A



Jodie Foster narrates the VLA film –see  
NRAO web site “VLA visitor film”



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# THE GLASS UNIVERSE

HOW THE LADIES *of the*  
HARVARD OBSERVATORY TOOK  
*the* MEASURE *of the* STARS

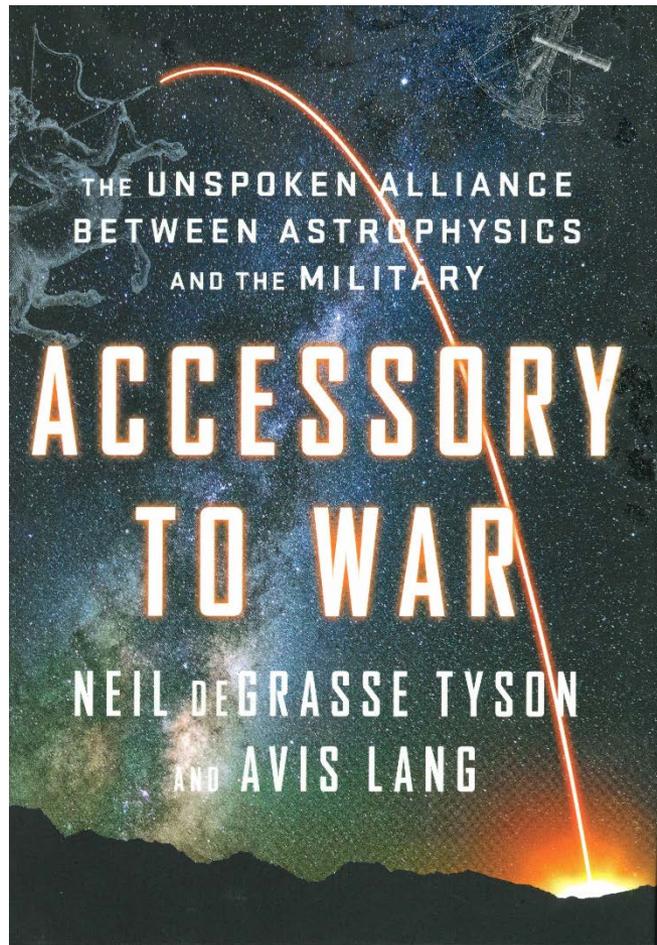


DAVA SOBEL

#1 NEW YORK TIMES BESTSELLING AUTHOR OF  
*Longitude* AND *Galileo's Daughter*

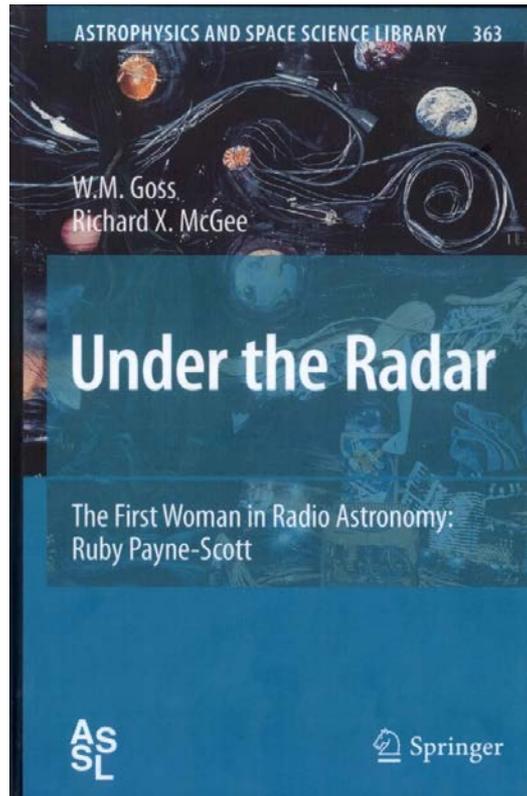
Augusta 8 February 2019

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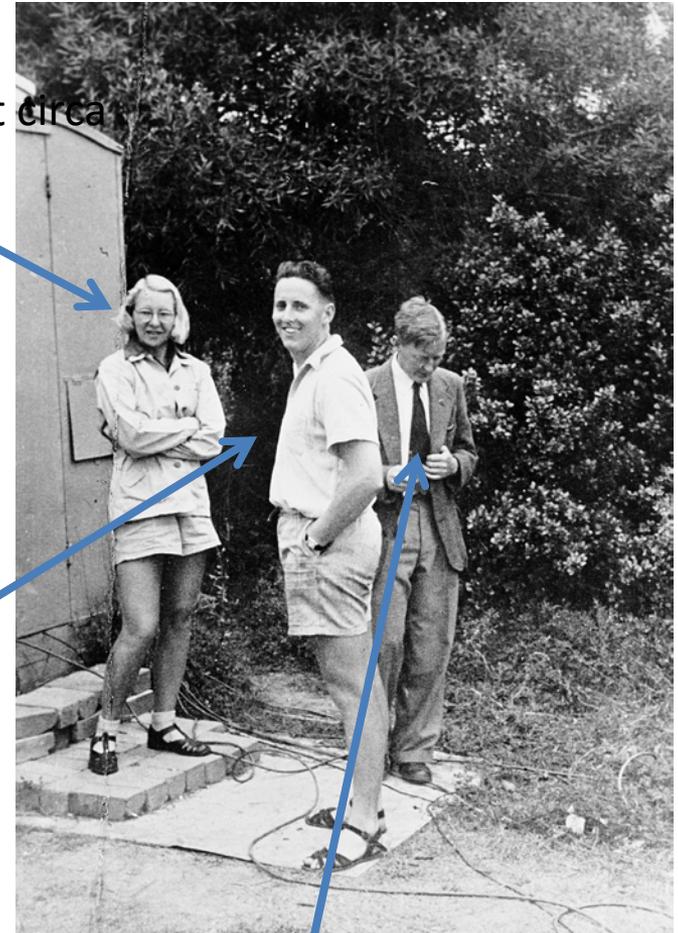
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November 2009 “The First Woman in Radio Astronomy- Ruby Payne-Scott ” published by Springer or from SpringerLink.  
Excellent source is the “Science Show” ABC – Robyn Williams 14 Feb 2004 - full transcript on line



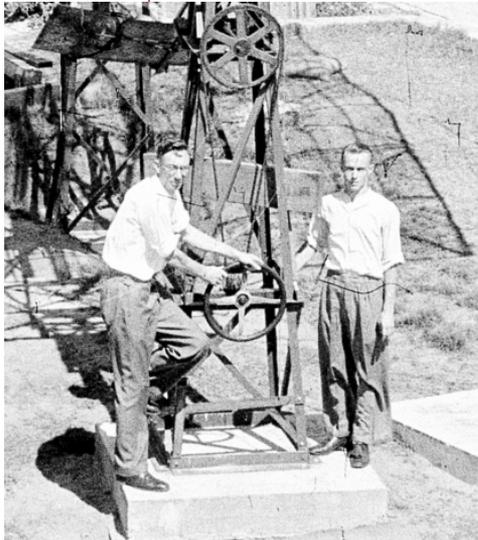
Ruby Payne-Scott circa 1950. Potts Hill

Alec Little



Chris Christiansen

# *Under the Radar: The First Woman in Radio Astronomy, Ruby Payne-Scott*



Miller Goss

National Radio Astronomy Observatory  
Socorro, New Mexico

Department of Astronomy-DAS  
Universidad de Chile  
15 November 2018

<http://www.nrao.edu/>

# Sunspot Numbers

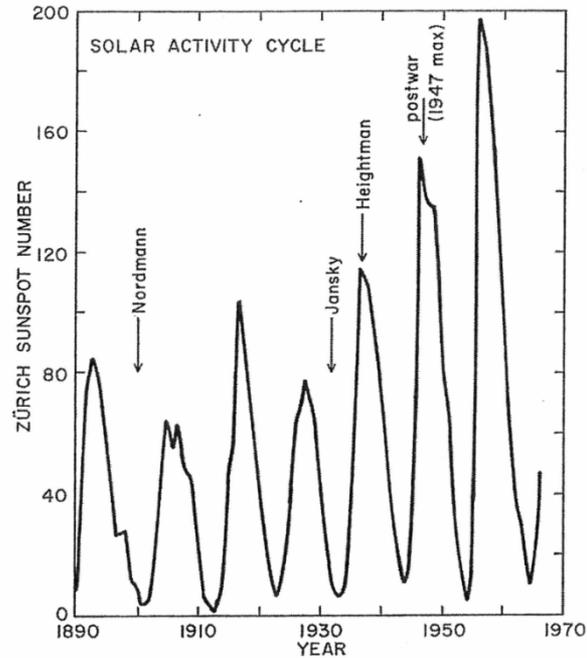


Figure 13.11 The solar activity cycle. Events in the history of radio astronomy affected by the solar cycle are indicated – solar minimum was unfortunate for Nordmann (Section 2.5), but greatly aided Jansky (Chapter 3). Maximum phase was important for Heightman in the 1930s (Section 5.4.2) and for all of the postwar solar work.

PPI- Plan Position Indicator- Ruby was the expert – probably why she was likely the first person in Australia to appreciate confusion- ability to recognize unique objects in a crowded image

- Angle is azimuth
- Radius is range

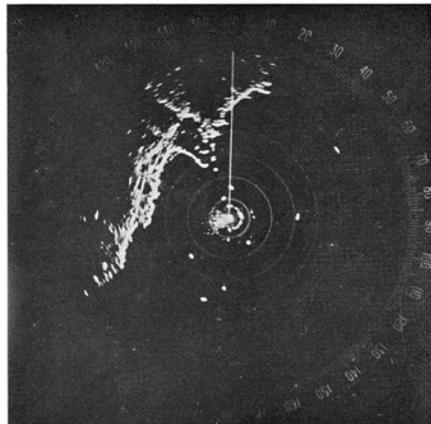


Fig. 63. A typical PPI picture. Normal, indirect, multiple and side echoes are showing.

Sullivan and why optical astronomers might have not paid any attention to the two radio astronomers in the 1930s

**Astronomy in the 1930s was only just exploiting the full power of the reflector over the traditional refractor telescope, of photographic techniques over traditional visual observations.**

**...Electronics were not part of the observatory and no observatory director would think of hiring a radio engineer instead of a conventional astronomer.**

**The world of decibels and superheterodyne receivers was simply too far removed from that of binary star orbits and Hertzsprung-Russell diagrams. The supreme night-time quiet of the observatory dome was the antithesis of the rumbles, click..... *hiss* of radio communications.**