Australian Radio Astronomy 1945-1960

Slee Workshop
U. Sydney, August 9 2016

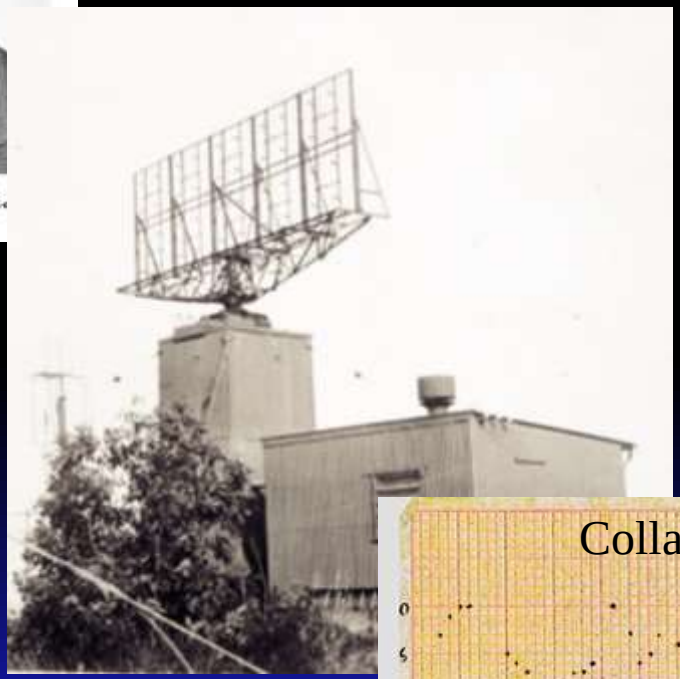
Ron Ekers
CSIRO, Australia

CSIR Division of Radiophysics background

- 1939
  - Radiophysics Laboratory – chief D.F.Martyn
    - Ionospheric propagation experiments
- 1939-1945
  - WW2 Radar
- 1946
  - Chief of Radiophysics Edward Bowen and Assistant Chief Joseph Pawsey decided on radioastronomy and rain-physics as the two main areas of research, with a third, radio propagation dropped in favour of the development of electronic computing.

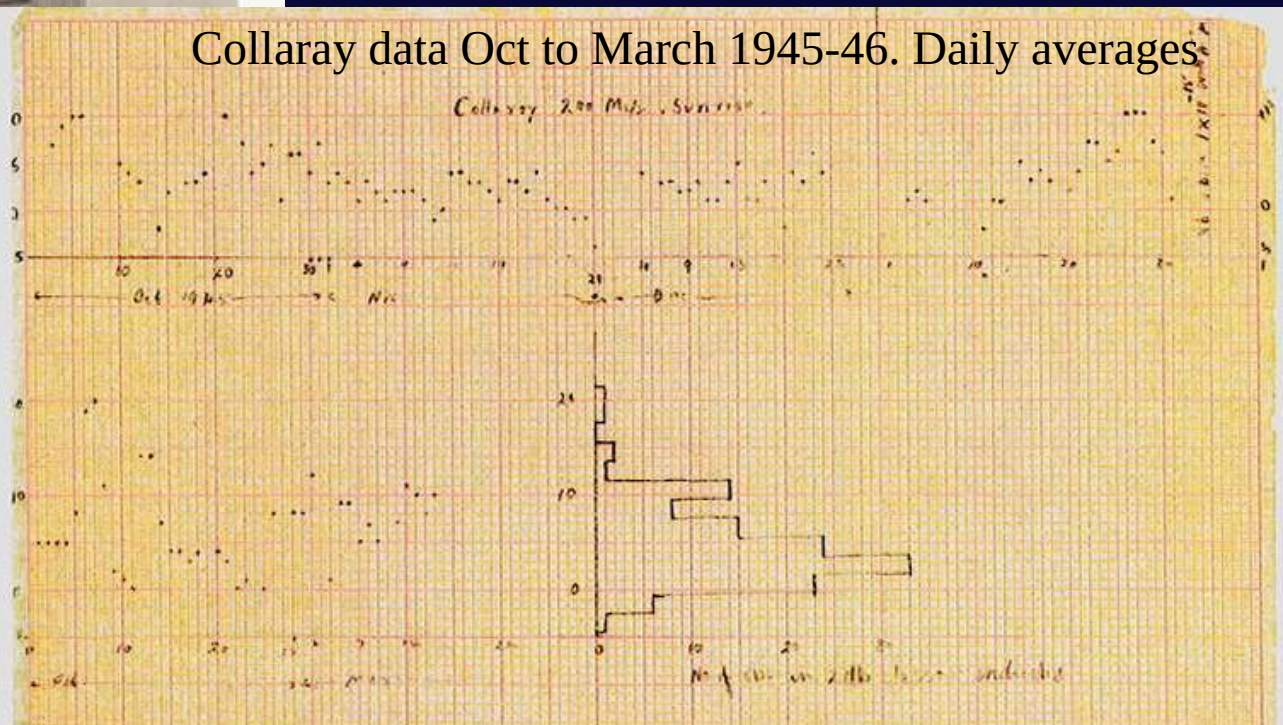
The Solar Group

First radio astronomy in Australia



- First Solar Noise Observations at Collaroy Sydney, October 1945
- Discovery of the Million Degree Solar Corona

Collaray data Oct to March 1945-46. Daily averages



Thanks to Miller Goss and Hastings Pawsey for providing this material.

CSIRO

Nature 2 November 1946

OBSERVATION OF MILLION DEGREE THERMAL RADIATION FROM THE SUN AT A WAVE-LENGTH OF 1·5 METRES

By Dr. J. L. PAWSEY

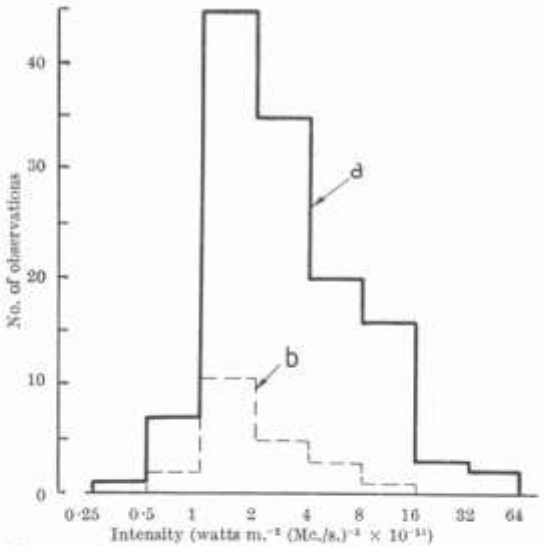
Radiophysics Laboratory, Chippendale, N.S.W.

IN the preceding communication, Martyn has shown that at wave-lengths of a few metres, thermal radiation corresponding to a temperature of about a million degrees should be radiated from the sun. The detection of this radiation is complicated by the presence of a further source, which is highly variable and is associated in some way with sunspots. This source can, on occasion, yield radiation up to 100 times the expected thermal intensity. If we confine ourselves to intensity measurements, it would in fact be detectable only if the intensity due to the variable source, not infrequently fell below that of the thermal one.

Daily measurements of intensity on a wave-length of 1·5 metres over a period of about six months indicate that this condition is satisfied in this part of the spectrum. The distribution of observed intensities is shown in the accompanying histograms. This distribution is markedly skew, having a sharp cut-off on the low side at the intensity range 0·5–1·0 × 10^{-13} watt $m.^{-2}$ $(Mc./s.)^{-1}$, corresponding to effective temperatures between 0·6 and 1·2 × 10^6 degrees Kelvin. This distribution is consistent with the co-existence of a steady source, of intensity equal to the cut-off value, and a symmetrically distributed highly variable source, which, on this wave-length, exceeds the steady value for about 60 per cent of the observations.

The agreement between the observed cut-off intensity, which corresponds to a temperature of about one million degrees Kelvin, and the effective temperature derived by Martyn, 0·8 × 10^6 degrees Kelvin, leaves little doubt that million degree thermal radiation is being observed at this wave-length.

I am indebted to Dr. D. F. Martyn for pointing out to me the probable existence of high-level thermal



HISTOGRAMS SHOWING DISTRIBUTION OF DAILY VALUES OF SOLAR RADIATION INTENSITY AT 1·5 METRES WAVE-LENGTH (INCREASES OF A FEW SECONDS ARE NEGLECTED). (a) DAILY; OCT. 5, 1945–DEC. 12, 1945; JAN. 1, 1946–MARCH 15, 1946 (R.A.A.F. OBSERVERS). (b) SUNDRY DAYS, MARCH TO MAY 1946 (LABORATORY OBSERVERS)

radiation, and to members of the Royal Australian Air Force and of the Radiophysics Laboratory who took the observations.

This work is part of the research programme of the Radiophysics Laboratory, Commonwealth Council for Scientific and Industrial Research.

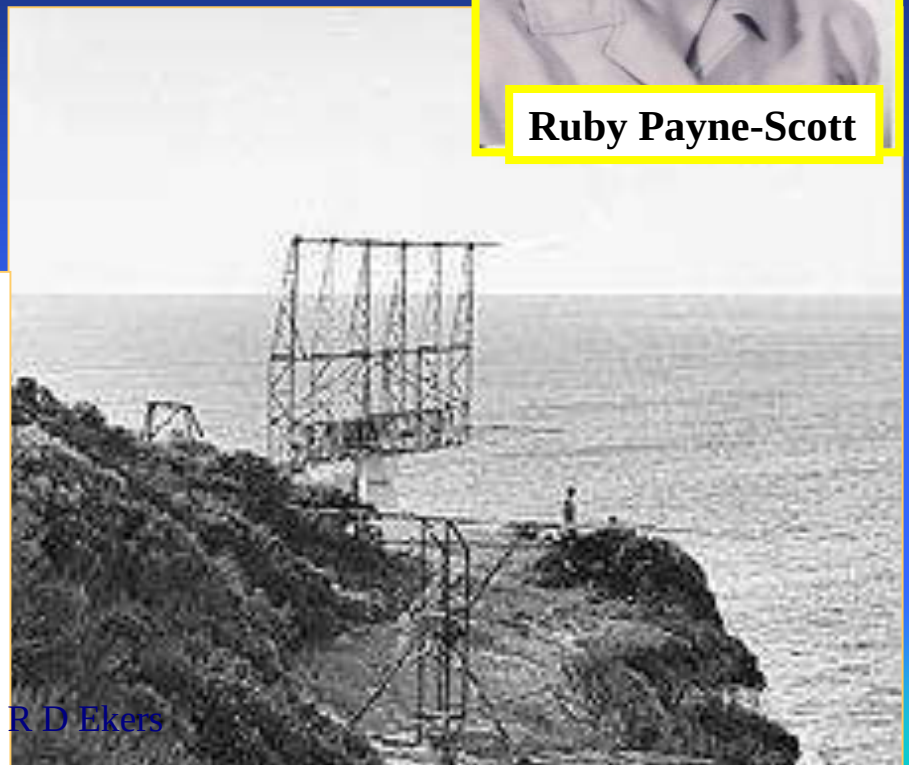
EDITOR'S NOTES AND AMENDMENTS

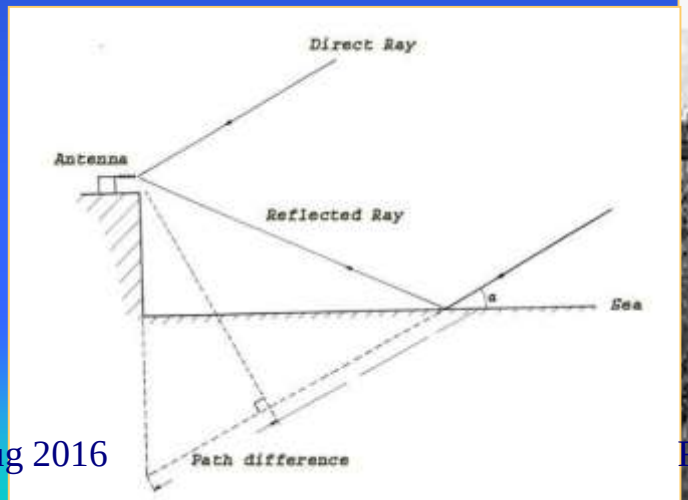
1. *Temperature radiation* is "thermal radiation".
2. Martyn (1948) later indicates that the definition of r_0 is rather nebulous and va with frequency; it is *not* the optical radius. Also, the ordinate of Figure 2 is in u of 10⁸ K.
3. In Figure 1 Martyn has used a value of 50 gauss (at least 20 times too large) for general magnetic field of the sun; modern observations do not show the predic effect.
4. Martyn (1948).
5. *Proc. Roy. Soc.* A190, 357 (1947).
6. Following p. 166.

Radio emission from sun spots Dover Heights 1946

- Fringe visibility to measure radio source size
- Fringe phase used to collocate radio burst with sunspot

Ruby Payne-Scott





Solar Radioastronomy

- Wild publishes hydrogen line theory 1949
- Ruby Payne-Scott uses a swept lobe Michelson interferometer at Pots Hill reservoir
- Wild Spectrograph Penrith 1948-49
- Wild and Roberts understand ionospheric scintillation
- Wild Spectrograph Dapto 1952-63
- Concept of multi-frequency synthesis
- Definitive work led to designation and properties of Solar Burst types I, II and III

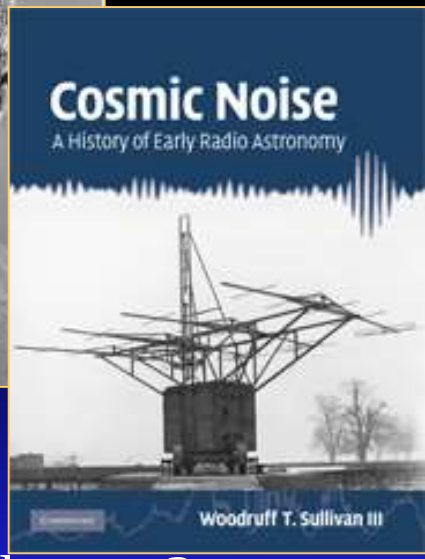
CSIRO

Culgoora Solar Heliograph 1968

- 2D dynamic images of solar bursts
  - 2sec/image
- Type II & III bursts
  - Evolution
- Type IV bursts
  - great loop structures
  - giant magnetic fields
  - circularly polarized
- Bruce Slee
  - radio galaxies and clusters
- Closed 1984
  - All important solar problems solved

The Cosmic Group

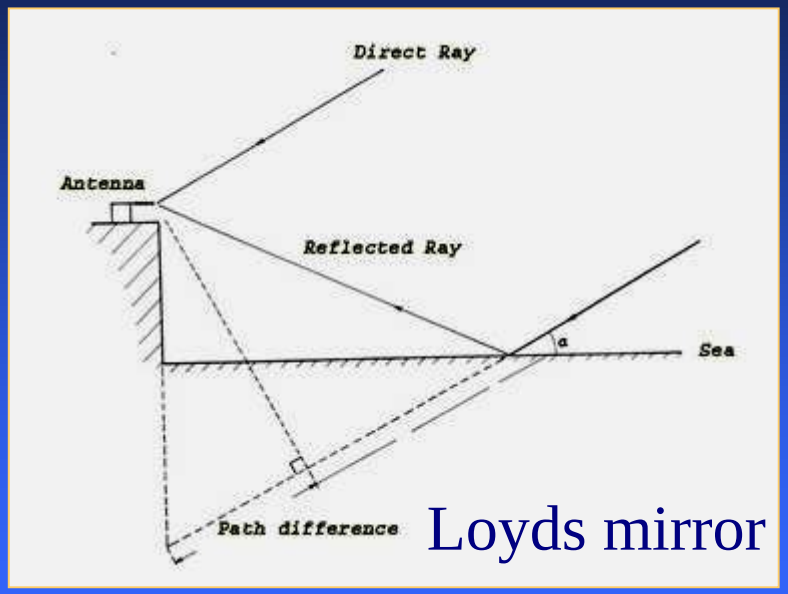
Cygnus A
strongest radio source in sky



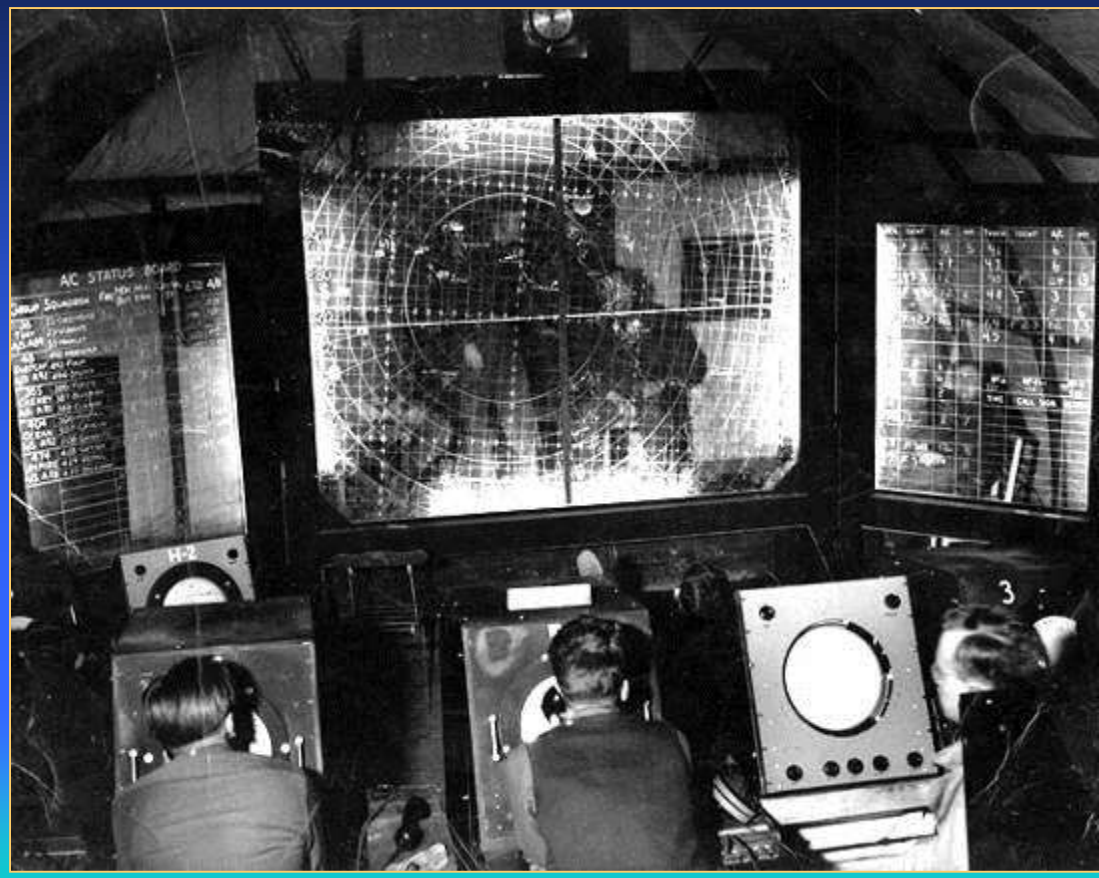
- Hey 1946
  - source with variable intensity
  - time scale of seconds to minutes
  - must be small diameter
  - the first “radio star”
- What was it?
  - no optical counterpart
  - was the whole galactic plane was made of such stars?
  - no theory linking diffuse galactic emission to cosmic rays

What are the Radio Stars? Cliff Interferometer - 1948

- Bolton, Stanley and Slee (CSIRO, Australia)
  - 100MHz Yagi

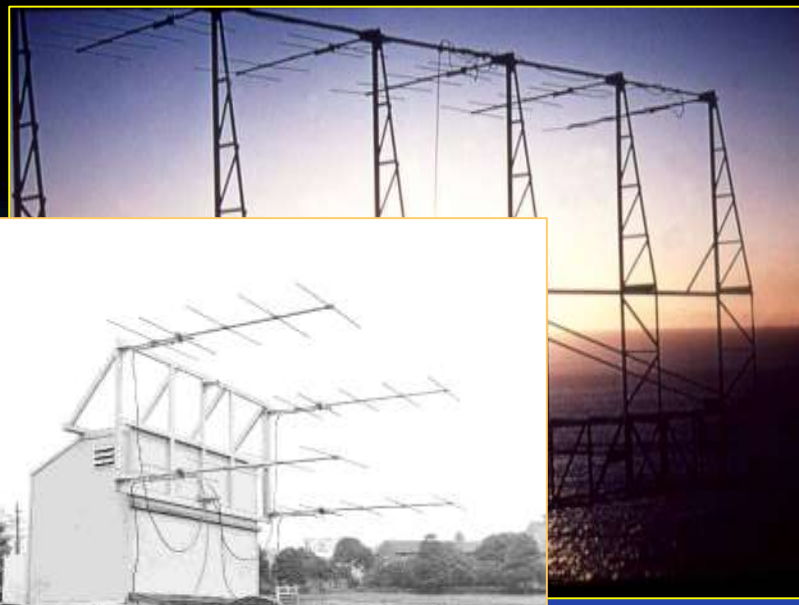


Loyds mirror

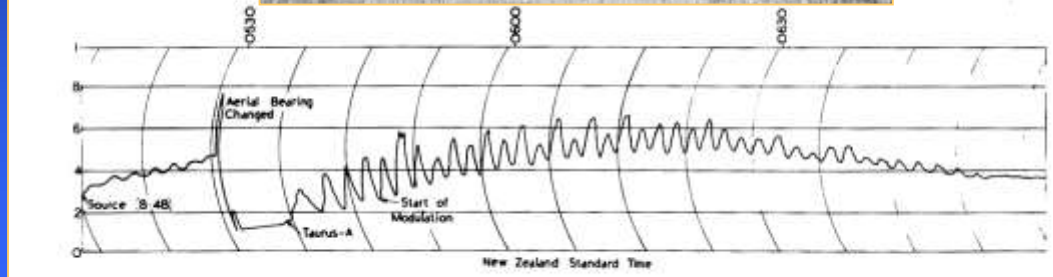


CSIRO

Australia - New Zealand 1948

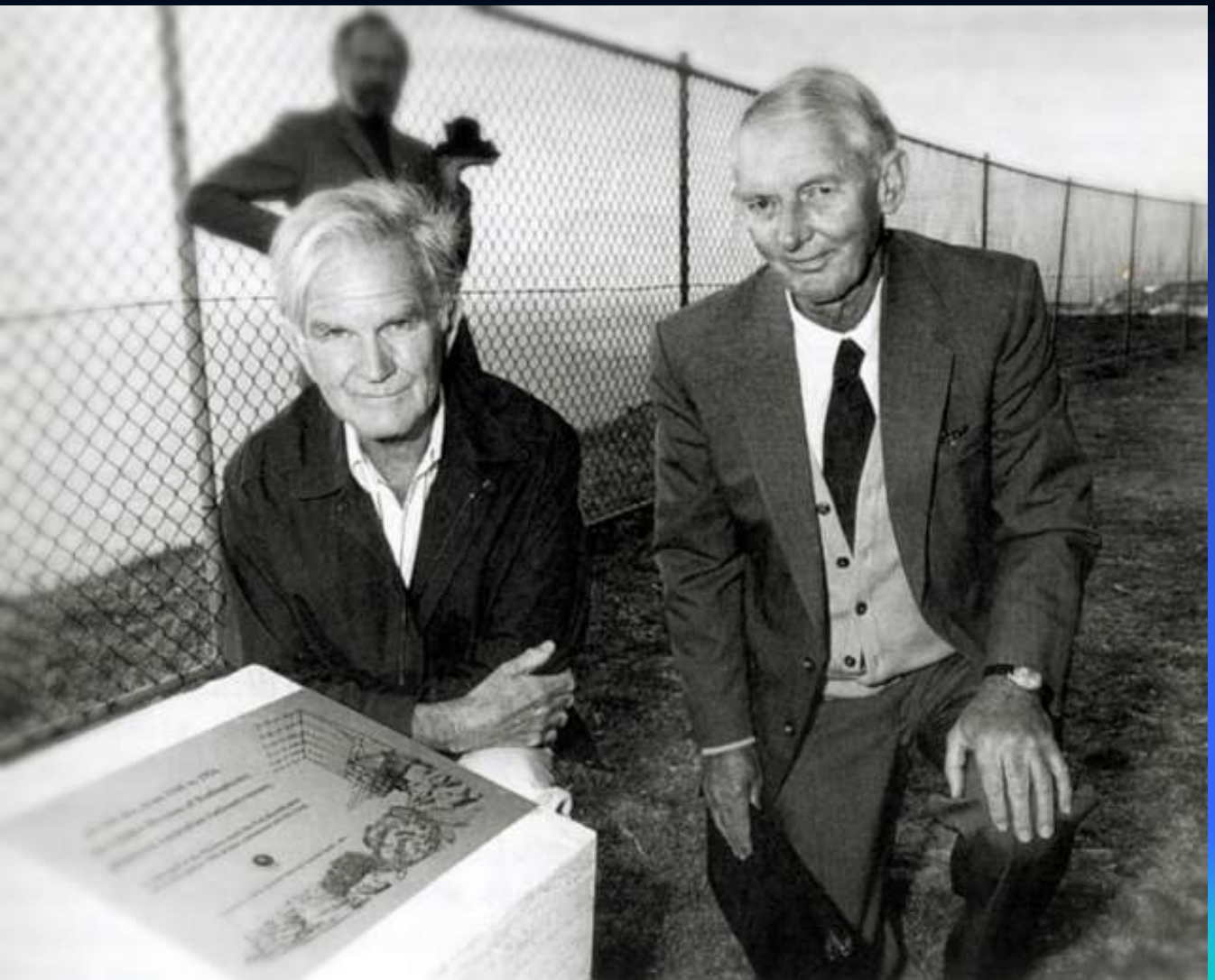


- Bolton & Stanley, CSIRO
  - 100MHz Yagi
- Dover Heights, Sydney
- Pakiri Hill near Leigh

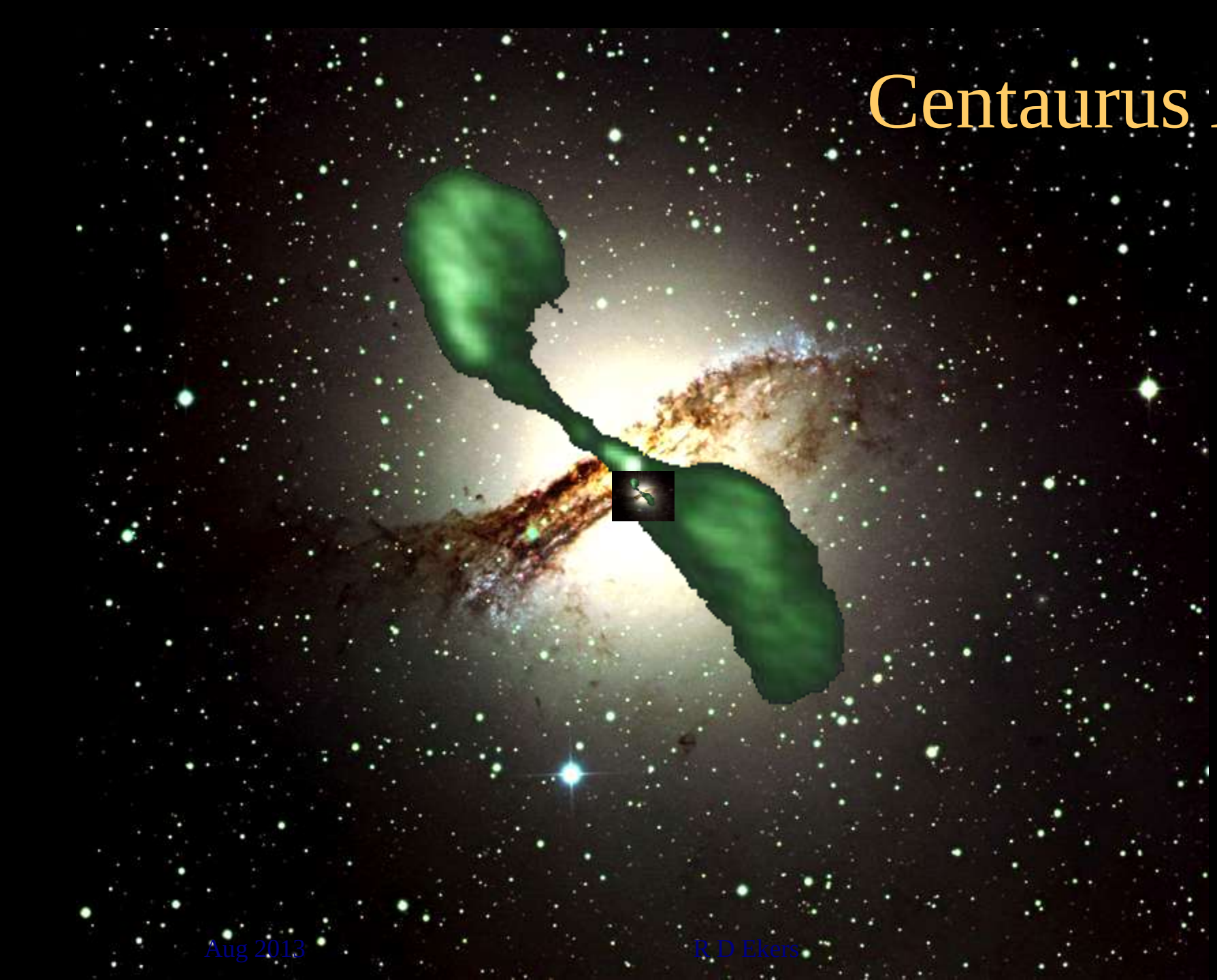


- Positions for Cygnus, Taurus, Virgo, Centaurus

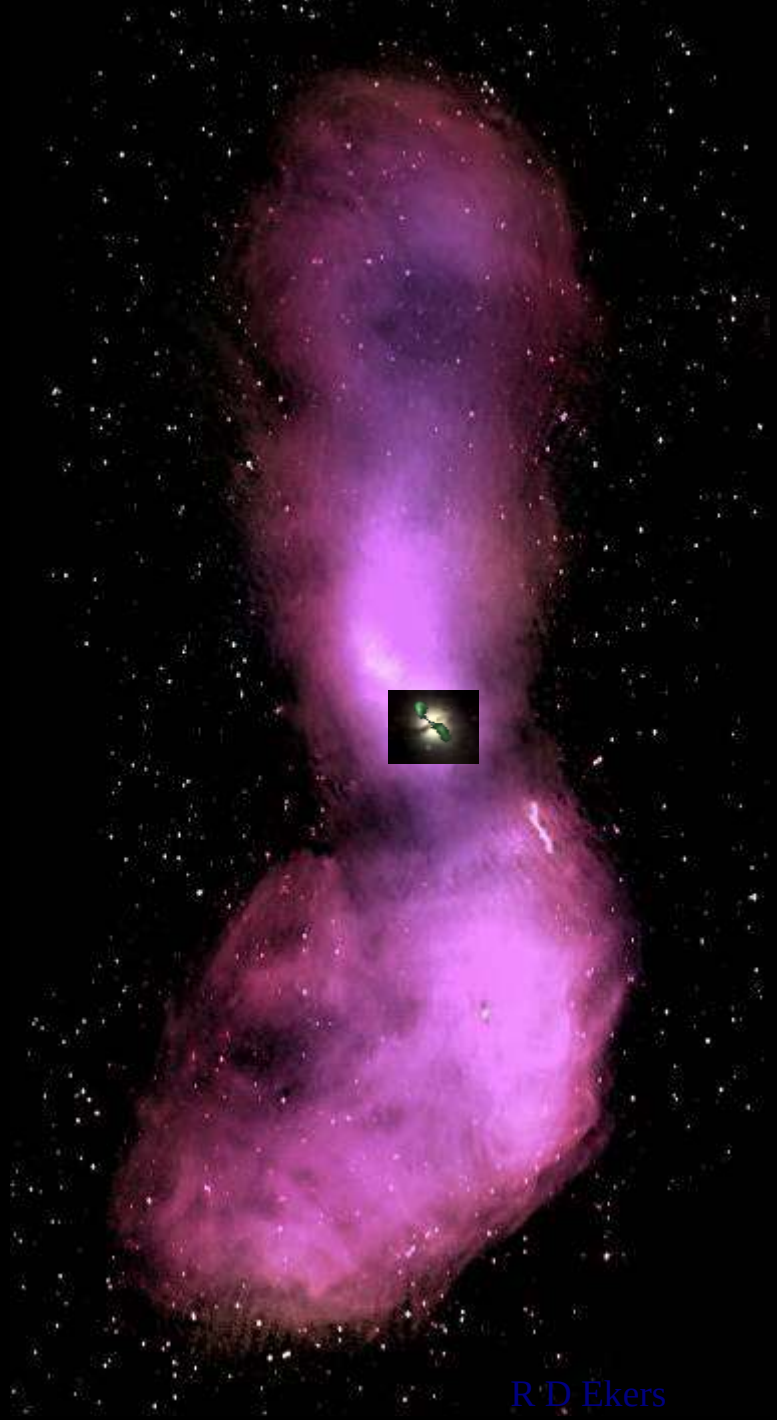
Dover Heights plaque Bruce and John 1989



Centaurus A

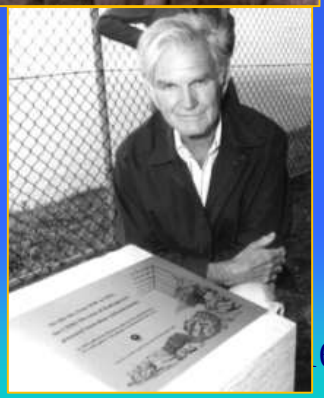


Centaurus A
ATCA Mosaic



1949: The First Radio Galaxies

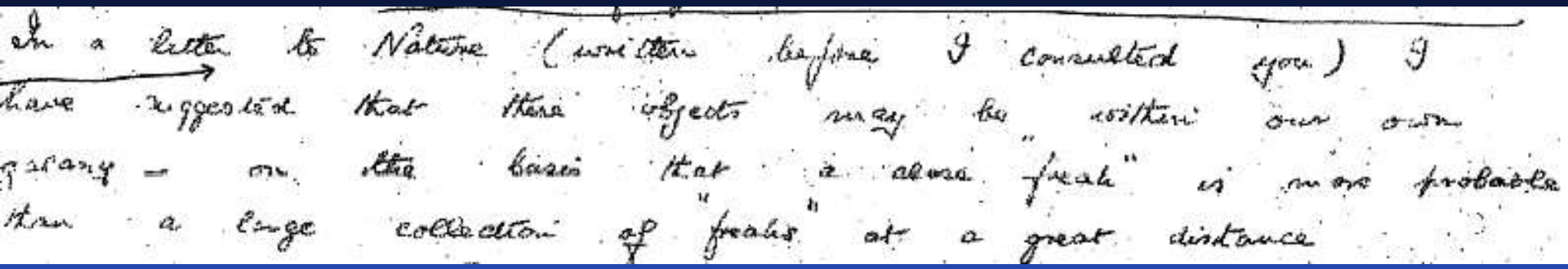
- Positions of Three Discrete Sources of Galactic Radio-Frequency Radiation
  - *"NGC 5128 and NGC 4486 (M87) have not been resolved into stars, so there is little direct evidence that they are true galaxies. If the identification of the radio sources are accepted, it would indicate that they are within our own Galaxy."*



- *Bolton, Stanley, and Slee, Nature 164, 101*

Why was it so difficult to accept extra-galactic?

- Letter from Bolton to Minkowski 20 May 1949


In a letter to Nature (written before I consulted you) I have suggested that these objects may be within our own galaxy – on the basis that a "freak" is more probable than a large collection of "freaks" at a great distance

- There were no galaxy experts at CSIR and very few in Australia
- It was easier to assume that the strange galaxies were unusual galactic objects
- There were no known mechanisms to explain the powerful radio emission if extragalactic

Theory

- Pawsey knew that progress could not be made without understanding the emission theory
- Thermal was not possible
- In Australia Mills came closest to recognising that it was synchrotron emission
- The Australian theorists failed to make any progress
- Again isolation was a factor

What is the Non-thermal Radio Emission?

- A very confusing story
- Misinterpretation of radio data added to the confusion
  - some radio sources had small diameter (Hey).
    - Hey was correct but it was incorrectly assumed that all radio emission was the sum of these radio stars
  - It was assumed that the radio stars were like the sun
    - this was also incorrect.
    - they were galactic nebula (SNR) and extra galactic (AGN)

Synchrotron Model for Radio Emission

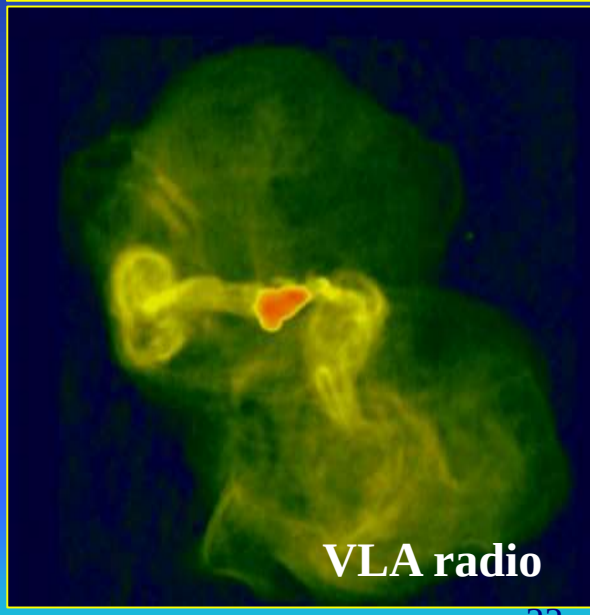
- 1949 Unsold: sunspots *anomalous radiation*
  - non-thermal
  - plasma oscillations
- 1950 Alven: synchrotron from sunspots
- 1950 Kiepenheuer; proposed the ISM rather than stars
  - needed magnetic field and high energy charged particles
- Mostly ignored in the West but enthusiastically embraced in Russia by Ginzburg and Shklovski

Linking non-thermal radio emission and cosmic rays

- 1951 Ginzburg
  - *Synchrotron radiation by relativistic electrons in Galactic Magnetic fields "is very natural and attractive as an explanation for the general radio emissions of the Galaxy“*
- 1953 Shklovski: Crab nebula has radio and optical synchrotron
  - polarization
  - No reference to Ginzburg!
- 1957 Burbidge: M87 jet synchrotron in radio and optical

M87 – NGC4486

- 1918 Curtis: Unique peculiarity
  - *"curious straight ray ... apparently connected with the nucleus by a thin line of matter"*
  - *Pub Lick Obs., 13, 1918*
- 1949 Bolton: Identification of Virgo A
  - *Bolton, Stanley, and Slee, Nature 164, 101*
- 1955 Oort: Synchrotron emission from wisp
- 1955 Shklovski: Synchrotron with energy from nucleus
- 1956 Baade: optical jet is polarized
- 1957 Burbidge:
  - Assume M87 jet has radio and optical synchrotron
  - Calculates minimum total energy
  - Energy source not understood – not colliding!
  - *Astrophysical Journal, vol. 124, p. 416*



CSIRO

1950
21cm Hydrogen Line Detected

- Predicted by van de Hulst
  - Leiden 1944
- Transition probability calculated by Wild
- Detected by Ewen & Purcell,
  - Harvard 1950
- International collaboration
  - First detected in the US
  - Confirmed by Dutch & Australian groups

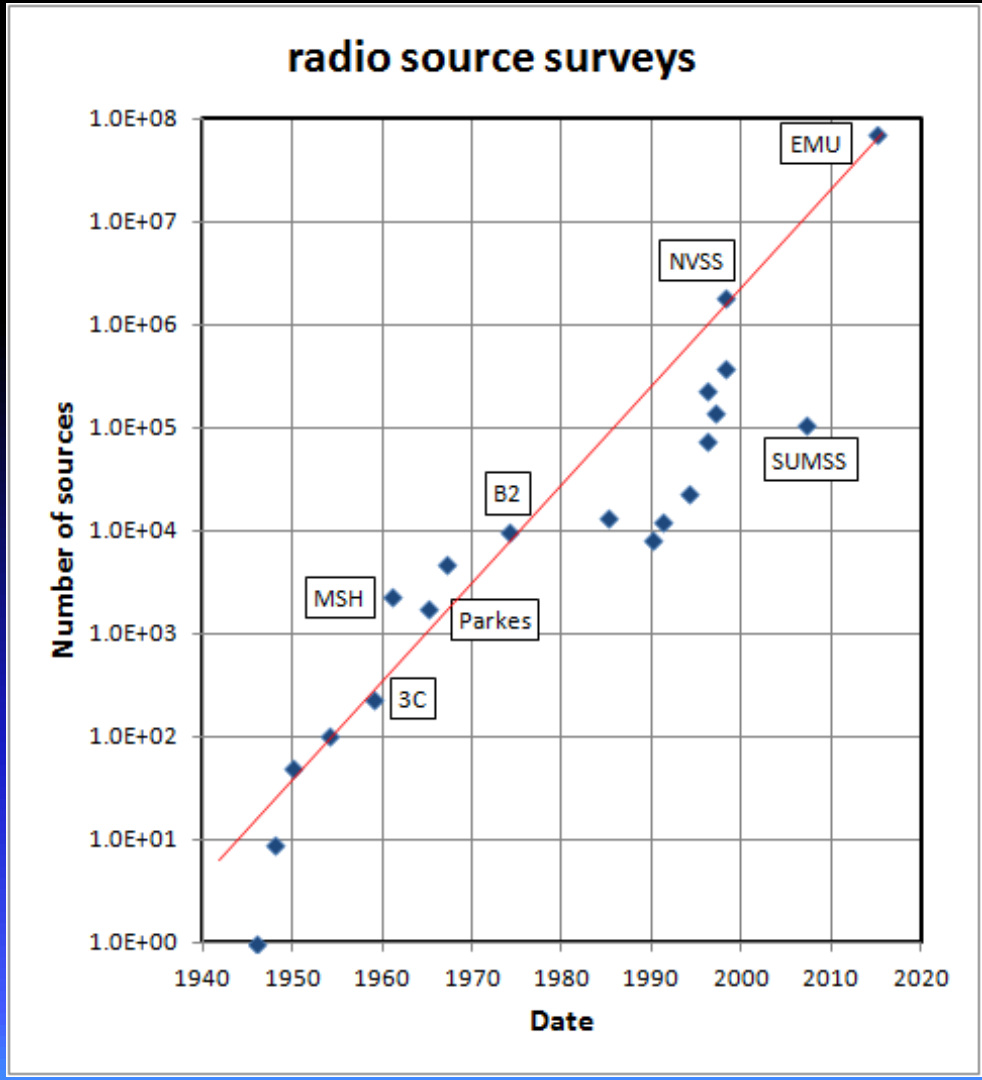
H - Line Astronomy Foundations

- Potts Hill 1951
  - Ex Georges Heights Radar antenna
    - Christiansen Hindman confirmed Ewen & Purcell's work
  - 11 metre antenna
    - Hindman, Kerr, Robinson Magellanic Clouds work
    - Kerr, Hindman, Carpenter found spiral arms in galaxy
- Murraybank
  - 6.4 metre telescope with 48 channel receiver
    - Murray, McGee neutral hydrogen survey
    - Magellanic Clouds survey
- Parkes 64m "The Dish"
  - Inherited the 48 channel receiver from Murraybank

CSIRO

Radio surveys and cosmology

- Ryle 2C survey measures $S^{-2.5}$
  - The universe is evolving
  - Initially $S^{-2.5}$ later revised to $S^{-1.8}$
- Mills Slee & Hill measure $S^{-1.5}$
  - Measured $S^{-1.8}$ and corrected it to $S^{-1.5}$ (resolution bias)
  - Concludes that the universe is consistent with static Euclidean or steady state.
- MSH was the better survey
  - But Cambridge got credit for evolution
  - Source counting gets a bad reputation



The Telescopes

McCready, Pawsey & Payne-Scott 1947

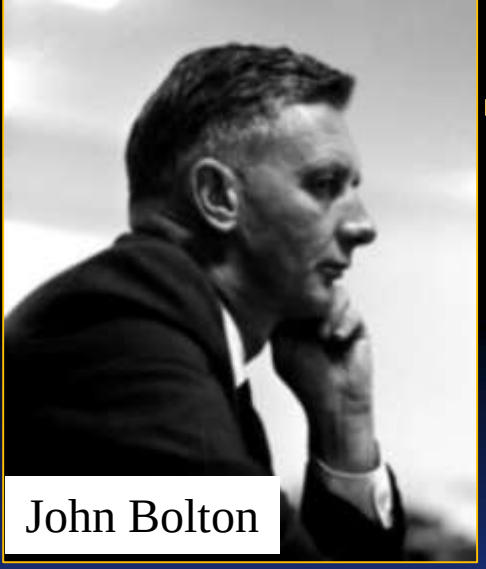
- Proc Roy Soc, Aug 1947 - received July 1946!
- Used the phase of the sea interferometer fringes (lobes) to co-locate solar emission with sunspots
- They note that its possible in principal to determine
  istribution by Fourie
  amplitude at a range
  .
  der using wavelengt
  unwise since the sol
  ency dependent struc
  hat getting a range o
  suggest a different i
  ore practical.

Joe Pawsey

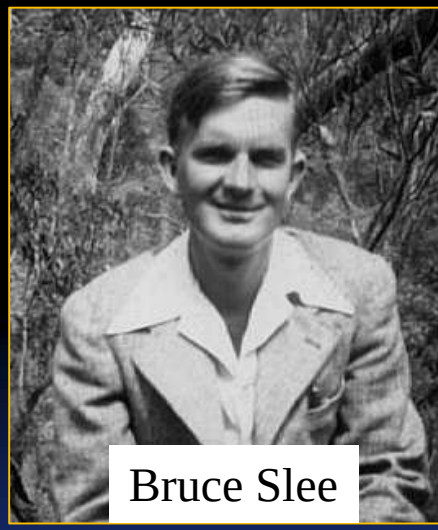
Ruby Payne-Scott

Radio astronomers need more resolution

- The Australian arrays
- 1951
  - Christiansen build the Potts Hill grating array
    - 32 steerable paraboloids
- 1953
  - Mills Cross (no computer)
  - Chris Cross (Fleurs)
- 1955
  - First synthesis image
  - FT computed by hand
  - Cambridge used EDSAC
  - Australia lost advantage


John Bolton

The hole in the ground antenna and the Galactic Centre


Bruce Slee

- Bolton and Slee built their own "hole in the ~~ground~~ sand" antenna (without approval)
- McGee and Slee survey
- Radio emission from the nucleus of our galaxy
  - Published in Nature
- Initial discovery by Piddington
  - Published in Aust J Phys but not cited

Appleton to Minister Casey:

Jan 1953

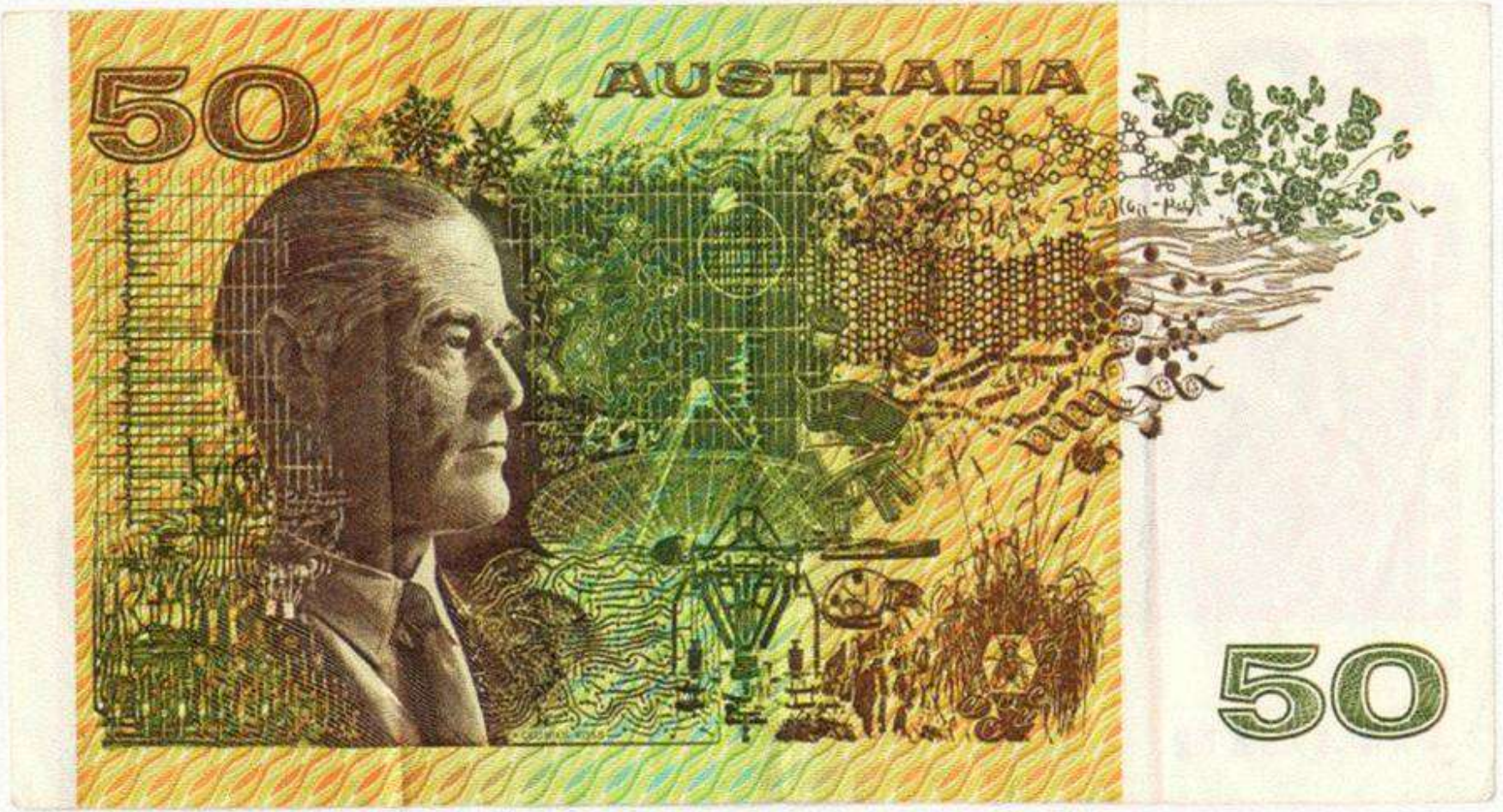
I believe that Australia has grown up and therefore should take her share of he world's fundamental research in pure science. You cannot go for ever relying on the older countries for this. You must endeavour to take your share when you can, and that depends on the incidence of special ability and interest. You have marked out for yourselves a very special place in this subject and I think that, in the interests of the world;s progress in pure science , you ought to go on pursuing it...

The Parkes 64m dish

Why did Australia have so much impact in post war Radio Astronomy?

- The transformation from war to peace
  - CSIR kept the Radiophysics radar group together
- Visionary leadership in CSIR
  - David Rivett (chairman of CSIR board)
  - Taffy Bowen (raised funds, built the group)
  - Joe Pawsey (scientific leadership)
  - *Get the best people, give them resources, let them run free*
- No existing strong astronomy groups
- Isolation generated independence
- NOT the Southern Sky

$50 note



“Radio Astronomy”

- Pawsey first uses the term “Radio Astronomy” in Jan 1948
- Aug 1948 IAU commission 40 “Radio astronomy”
  - Woolley Mt Stromlo - first president Com 40

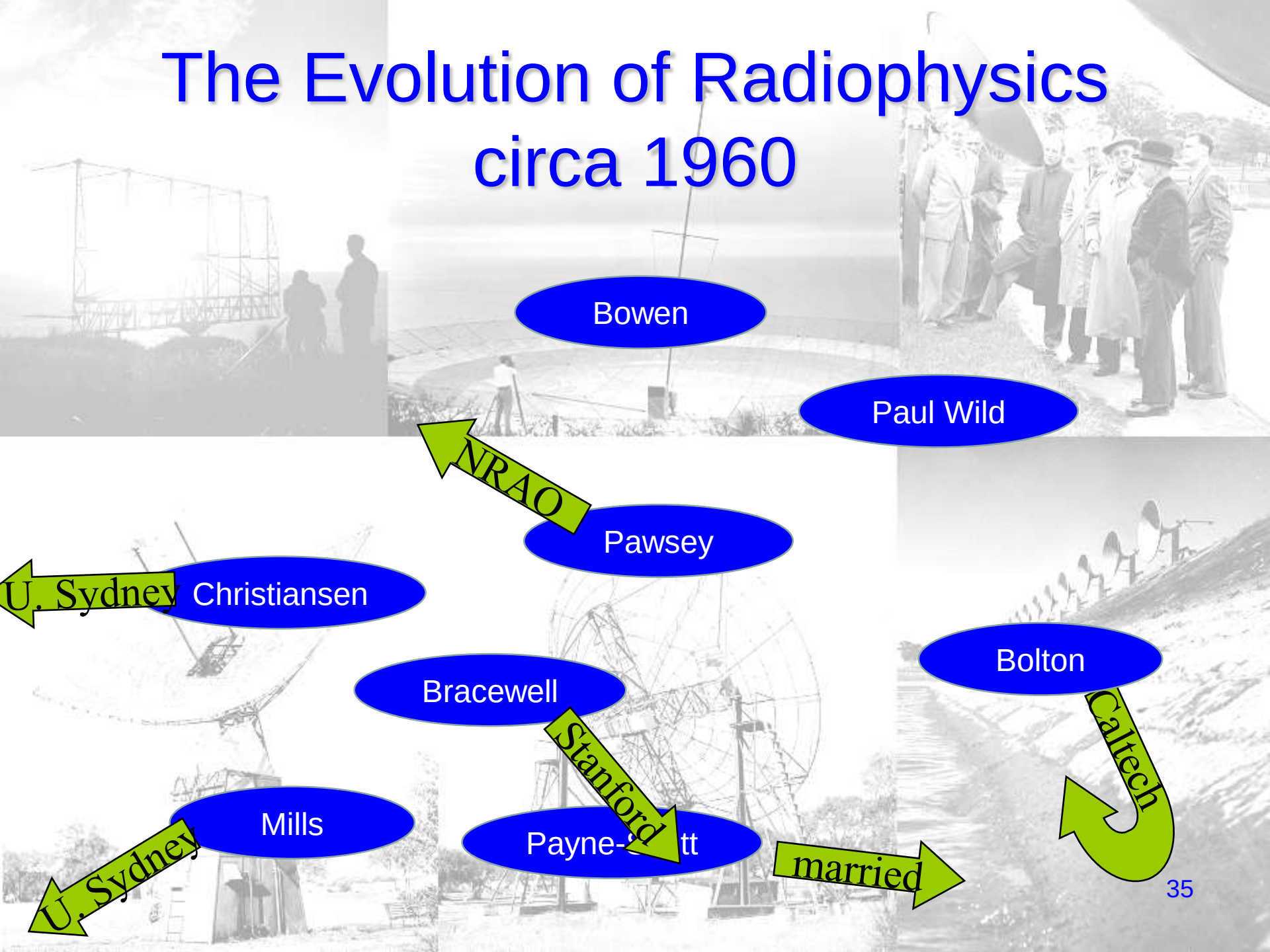
A word has to be said about Woolley's attitude towards radio astronomy, in which Australia, along with Britain, led the world for more than a decade after the war. Unkind things have been said about his 'conservatism'. Looked at as dispassionately as possible, however, Woolley took the reasonable view, and the radio people were just unreasonably lucky.

Bill McCrea

URSI GA Sydney 1952

First International meeting in Australia

The Evolution of Radiophysics circa 1960



Pawsey NRAO Director 1962 "Promising Fields of Radio Astronomy"

- HII regions in absorption at low frequencies
  - 20MHz observations
- Magnetic fields in inter-stellar space
  - linear polarization ☑
  - Zeeman splitting ☑
    - Weinreb digital correlator
- Counting sources
  - resolve the violent disagreements ☑
- High angular resolution of solar flares ☑
- But what was missed in just the next 10 years!
  - Quasars, CMB, Masers, Pulsars, ….