Reflections on the discovery of pulsars (pulsating radio stars)

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And

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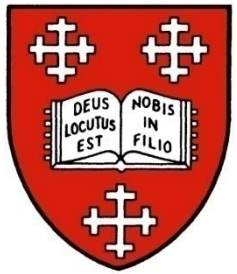
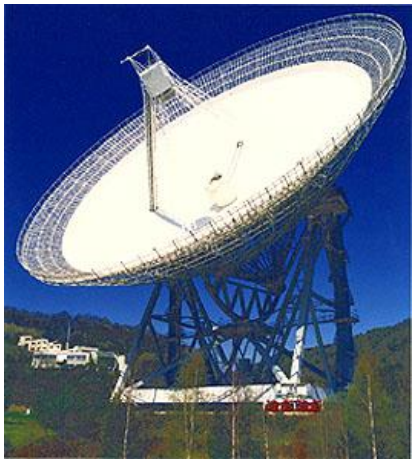


Topics

- A story from radio astronomy – the discovery of pulsating radio stars (pulsars)
- Pulsars today
- Pulsars *nearly* discovered: *s*ome ‘near miss’ stories
- Factors that led to the discovery



On arrival in Cambridge…..

Radio astronomy grad students presented with a set of tools

First build your radio telescope (through hail, rain and sunshine)

Typical working conditions for a PhD student

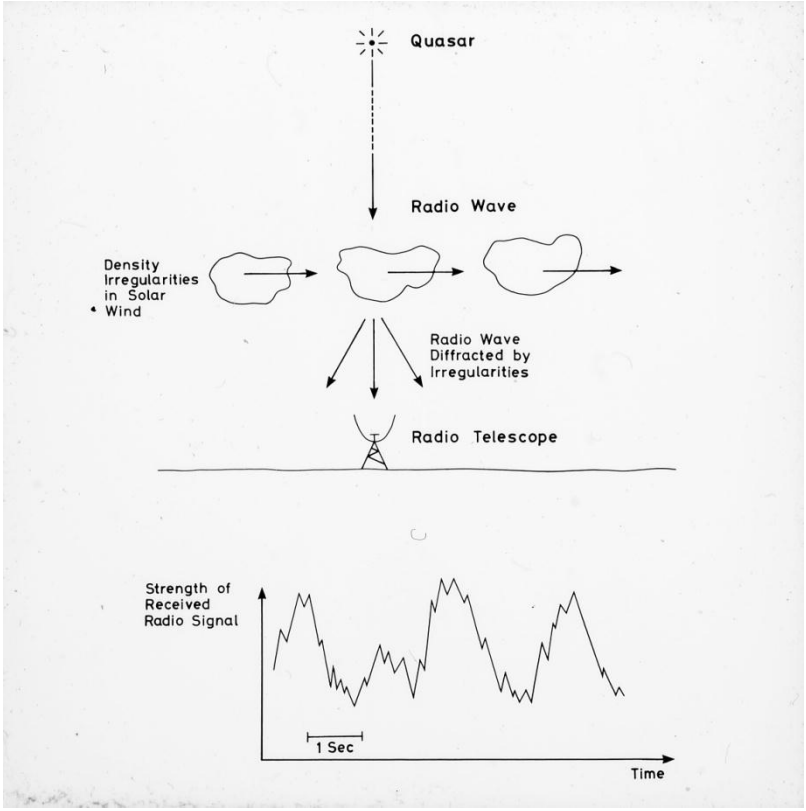
2048 81.5MHz λ/2 antennae (16 E-W rows of 64 + 64), 1000+ wooden posts, 120 miles/192 km wire and cable, area 57 tennis courts. Grant £12k. 6 people for 2 years.

The 4.5 acre* radio telescope (*1.8 hectares), looking W

- Phased interferometric array. Valve receiver!

Interplanetary scintillation

- Compact radio source scintillates, extended does not.
- Quasars (quasi-stellar radio sources) are compact; other radio sources are not



Discovery of pulsars

- Repeated mapping of the sky to identify quasars (and measure their angular diameter)
- Short time constant (short integration time) to study rapidly varying phenomenon (interplanetary scintillation). $\tau = 0.1$ s.
- 6 months' observing, starting July 1967

Data analysis

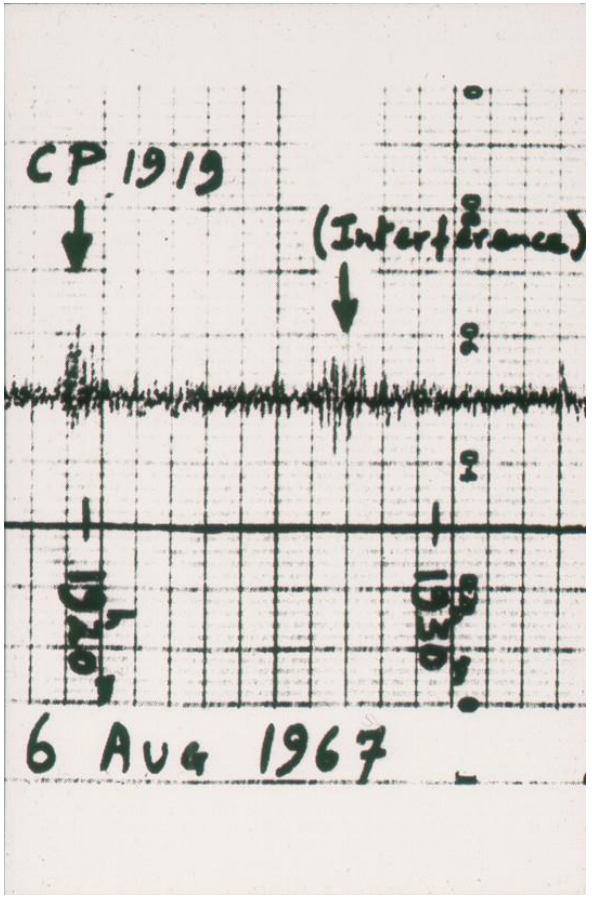
No computer!

3-pen chart paper

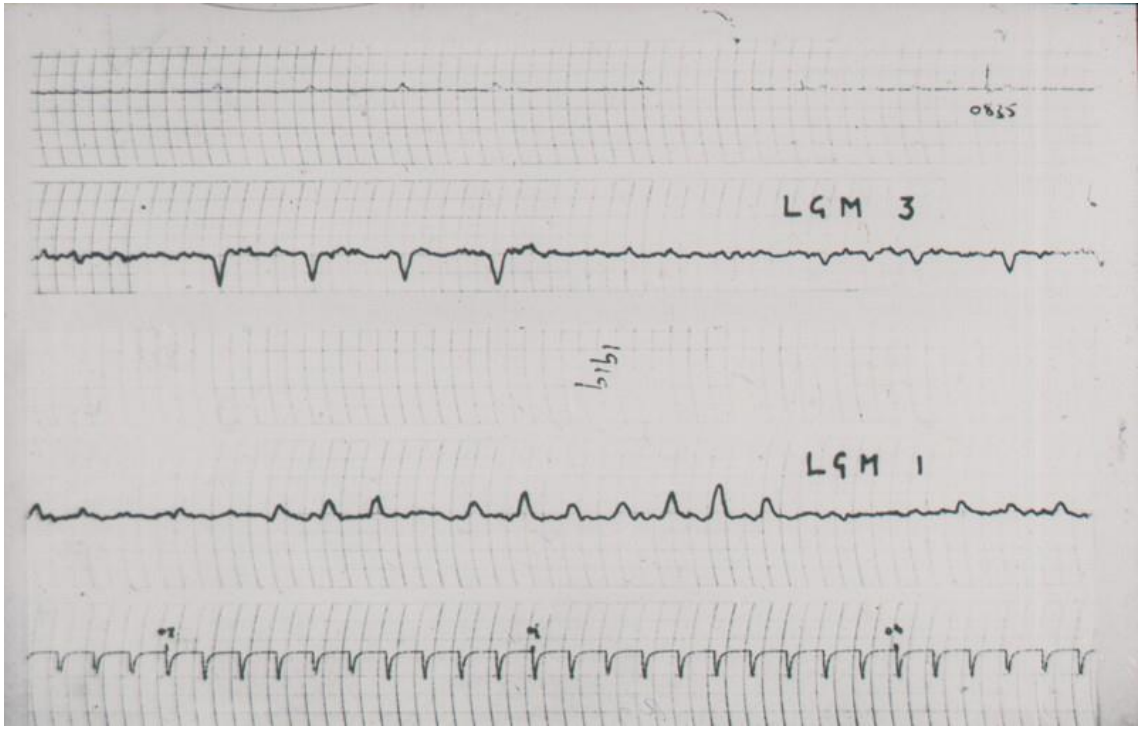
- 100’ (30m) / day
- 400’ (120m)/sky scan
- 3.3 miles (5.3km) total

Discovery of pulsars II

- Occasionally ¼” (0.5 cm) in the 400’ (120 m) showed an unusual signal.



High-speed recording



Centre trace shows pulsed nature of emission

What is it?

- Local radio interference? *No – keeps sidereal time.*
- Faulty equipment? *No – seen by a separate telescope and receiver.*
- Small (short pulses) and big (maintains pulse period accurately). *???????*

What is it (contd)?

- Dispersion measurement showed it was 200 light years away (i.e. beyond the Solar System, but nearby in the Milky Way)
- Little Green Men? They'd be on a planet orbiting their Sun; *no Doppler effect*
- Finding second, third and fourth

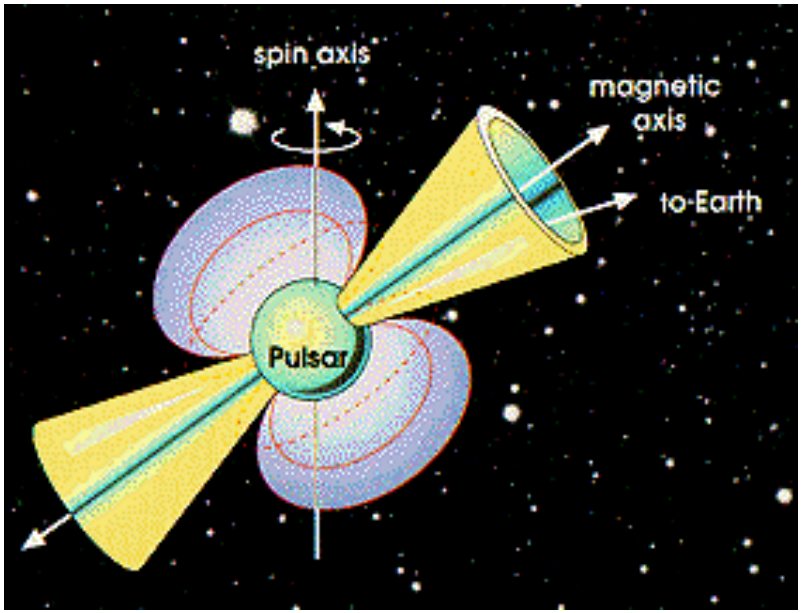
The naming of pulsars

- Interviewed by Science Correspondent of The Daily Telegraph – Anthony Michaelis – shortly after the discovery
- What were we going to call them?
- He suggested *pulsar* – cf quasar

The Daily Telegraph

Pulsars today

How we picture pulsars today



Sound of a typical pulsar
11 revs per sec

Sound of a fast pulsar
700 revs per sec

Today.....

- About 2000 pulsars known, mostly in near half of our Galaxy
- Spinning, compact stars.
- Pulsar period = period of rotation of star
- $1.39\text{ms} < P < 8\text{s}$; $B \sim 10^5 - 10^{10}$ T
- Neutron (rich) stars: R =12 km
- $M = 1.4 – 2.0 M_{Sun}$, ($1 M_{Sun} = 2 \times 10^{27}$ tonnes)

Today contd

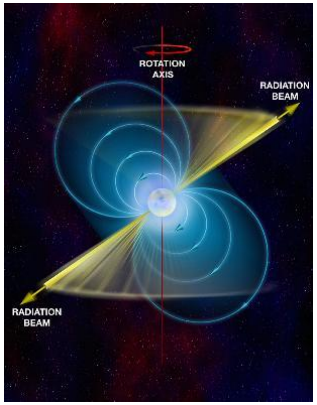
- $10^{-12} > dP/dt > 10^{-21}$; the period of a typical pulsar has increased by about 1 second since the age of the dinosaurs!
- Serve as clocks for experimental relativity
- Few x 10^5 active PSRs in Galaxy

Today…..

- Broad-band, but steep spectrum radio emitters. Few optical/X-ray emitters.
- Fermi satellite discovering gamma-ray pulsars
- HESS Cerenkov gamma ray array finding pulsar wind nebulae (like Crab nebula).

Today contd.

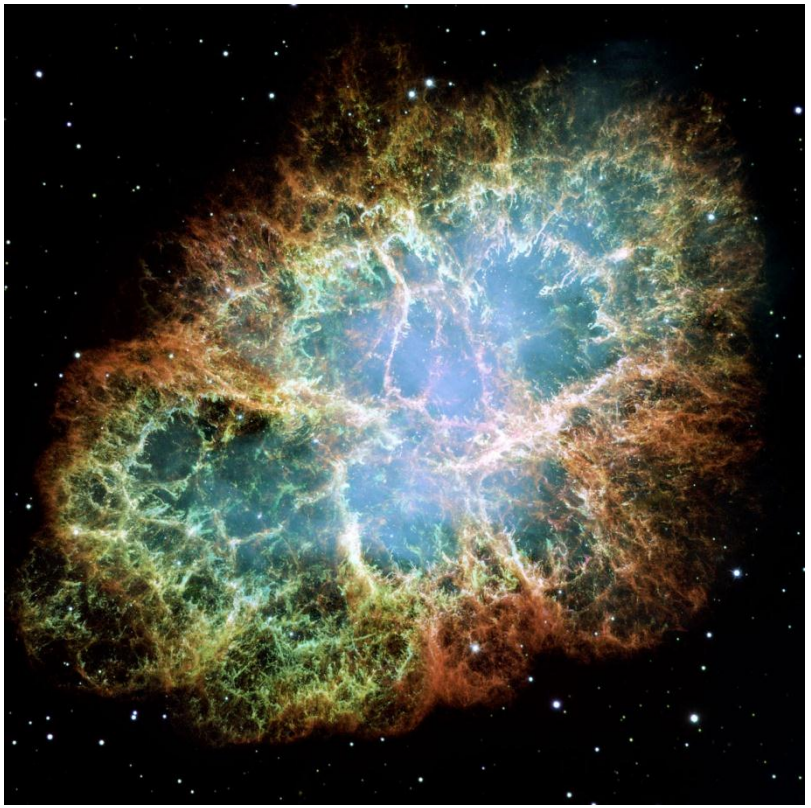
- Field still has not stabilised – significant and surprising results still rolling in
- Unresolved issues:
  - Rotational energy loss, radiation mechanism, wind
  - Population (magnetars, intermittent…)
  - B, velocity, mass
  - Evolution
  - ……



Pulsars *nearly* discovered!

Crab Pulsar almost discovered...

- Bell and Hewish - measurement of the angular diameter of the compact source in the Crab nebula. Using IPS. Integration time 0.1s (P=.033s). March 1967 paper.



Crab PSR almost discovered II

- Late summer 1957; an Open Night at McDonald; 82 inch (Struve) telescope trained on Minkowski's star. Elliott Moore (newly graduated from Chicago) was assisting.
- Female visitor –

  'That star's flashing'
- No instruments existed to provide follow-up.

Crab Pulsar – almost - III

- E-mail message received by ATNF, June 2007 from Charles Schisler:
- “As a USAF technician during a one year period back in 1967-68 at a Ballistic Missile Early Warning Site in Alaska I discovered fourteen pulsing signals on our extremely powerful radars….”

Crab PSR almost discovered IV

- **Sue Simkin (NRAO) – Oct/Nov 1967**
- **Carnegie Image Spectrograph, Kitt Peak 84-inch telescope.**
- **Lo Woltjer asked her to take a spectrum of Minkowski's star.**

• Spectrum dull, but Sue observed flickering, or as if there were waves going out from it.

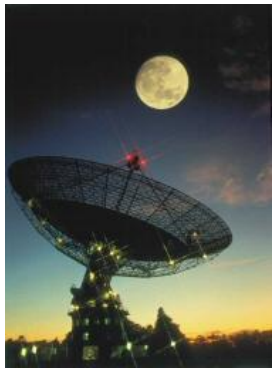
•LW said it couldn't be, but when PSR discovered said it must have been.

PSR 0329+54 almost discovered

- 408 MHz survey (Europe)
  using large telescopes
- Last week of observing;
  one pen-recorder misbehaving
- Early hours of morning, that pen recorder started rhythmically sweeping
- Observer said ‘Damn!’ and thumped pen recorder – behaviour stopped!

PSR0329 +54 contd

- Observer said 'Good!', put on his coat and went home!..... He had made the first observation of PSR 0329+54.
- No entry in log book
- Following the discovery of the first pulsars (which did not include 0329+54) no search of their data for pulsars.



Tribute to Franco Pacini - insight

- A few months before discovery of pulsars announced Pacini published paper in Nature
- On how Crab Nebula energized by a neutron star with large magnetic field, inclined to spin axis.
- Magnetic dipole radiation at rotation period cannot escape plasma; energy and momentum dumped in nebula.

Factors that lead to discovery

Key factors in the discovery

- Our own telescope and receiver – I understood its behaviour
- As a research student I had time/space to follow-up anomalies; imposter syndrome
- One of the first observations with a short time constant (new area of phase space)
- Not aware of other observers likely to make and announce the discovery before us

Key factors, contd

- We had a good address – a reputable laboratory.
- This was not one of the objectives, or targets of the programme
- If we had computerised the search, would the pulsars have been discovered?
- Low frequencies and the time domain have long been neglected!

The End