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Tour of Jodrell Bank

England's famous radio-telescope

Adam Farson

VA7OJ

Jodrell Bank Website

Red-bordered images courtesy Jodrell Bank Observatory. Other images: VA7OJ.

Why radio-astronomy?

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- **Almost all celestial bodies emit electromagnetic radiation.**
  - **Radio (HF to microwave)**
  - **Infra-red (IR)**
  - **Optical (visible light)**
  - **Ultra-violet (UV)**
  - **X-rays**
  - **Gamma rays**
- **Radio astronomy was discovered when early radio researchers detected sky noise.**
  - **Here is a historical overview.**
- **Radio telescopes open up an additional “window” into the universe. They enable us to “see” what our eyes cannot.**
  - **In addition to radio telescopes, X-ray instruments (e.g. Chandra) and UV telescopes such as the University of Virginia ASTRO program, give us additional “senses” of inestimable value in exploring the cosmos.**

Overall view of the 76m main antenna (Lovell Telescope)

Facts & figures

Location: 32km south of Manchester
Fully-steerable dish
Mass of structure: 3200t
Mass of dish: 1500t
Max. height: 89m
Azimuth track diameter: 107.5m
Slew rate: 9°/min AZ, 6°/min EL
Dish diameter: 76.2m
Collecting area: 4560 m^2
Focal length: 22m
***f*-number:** 0.3
Gain: 59 dB at 1.4 GHz
Noise temperature: 15°K
Freq. range: 610 MHz to 5 GHz
Built: 1957 (Mk. I). **Upgraded:** 1969-71 (Mk. IA)
Renamed: 1987 (Lovell Telescope, in honour of Sir Bernard Lovell)

The focus box (at the end of the central pylon) houses the front end (gaseous-helium-cooled HEMT amplifiers and down-converters). These convert the 1.4 and 1.8 GHz radio-astronomy bands to the 155 MHz inter-facility IF. The IF signal is fed via a coaxial-cable link to the signal-processing centre.

Visit to the Jodrell Bank site
19 June, 2009

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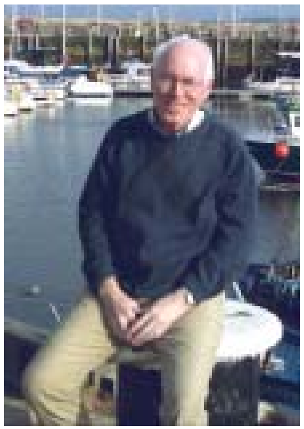

Dr. Brian Austin

Prof. Ian Morison

My friend Brian Austin G0GSF (ex-ZS6BKW) arranged the tour in collaboration with Prof. Ian Morison of Manchester University. Brian and I visited the facility on the morning of 19 June, 2009.

View of main antenna structure

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The main antenna was in stow position, as it was being repainted. The broad rim is part of the new, higher-gain dish surface, which was added in 1967 as part of the Mk. IA upgrade.

Detail of support tower housing elevation drive. The drives were taken from gun-turrets of scrapped Royal Navy warships.

Additional views of main antenna structure

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Detail of azimuth drive and track. The track diameter is 107.5m.

Detail of focus box and pylon. Note coax feedlines.

View of the Mk II telescope
- a part of the MERLIN network

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Facts & figures

Fully-steerable dish
Azimuth track diameter: 12.8m
Elliptical dish: 38.1 x 25.4m
Focal length: 12.2m
Freq. range: 610 MHz to 22 GHz
Built: 1964
Upgraded: 1987

The Mk II telescope is essentially of the same design as the BT Goonhilly I satcom earth station built to relay the first telecom signals across the Atlantic via the Telstar satellite. It was also the first telescope of any type in the world to be controlled by a digital computer.

The Mk II is now part of the Multi-Element Radio Linked Interferometer Network (e-MERLIN), an interferometer array of radio telescopes spread across England.

Receiver in focus box
- RF LNA, mixer, LO, IF, cryostat

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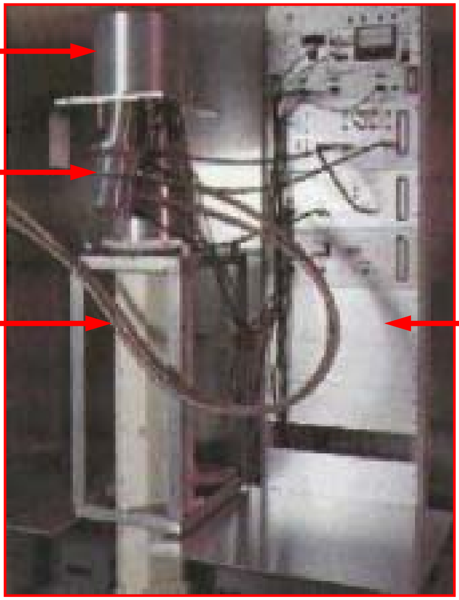
The active devices used in the LNA (low-noise amplifier) are HEMT (high electron mobility transistors) similar to those used in many consumer satellite TV LNA's, but of higher quality with a lower noise figure.

The front end (LNA/1st mixer) is cryogenically cooled to 15°K.

Local oscillator (LO) signals generated in the Receiver Racks are fed to the LO & PSU rack via low-loss coaxial cable runs.



The radio receiver in the focus box is kept cooled to 15°K by a gaseous-helium cryostat. This ensures that the very weak signal from the sky is not swamped by noise generated in the front end. The RF signal is down-converted to an IF in the VHF range, and sent via a coaxial cable run to the signal processing centre. The processed signal is sent to the observing room, where it is available to the astronomer.

Noise Temperature, Noise Figure and G/T

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- **The LNA's are cooled to 15° Kelvin (15°K) = -258°C.**
  - **0°K = -273°C (absolute zero). Room temp. = 17°C = 290°K.**
  - **This minimizes the LNA's contribution to receiver system noise.**
  - **Noise temperature T is mathematically related to noise figure NF.**

- **$T = 290 \text{ X } (10^{(NF/10)} - 1)$ °K**
  - **If T = 15°K, NF = 0.22 dB**
  - **Compare a good 70 cm preamp: NF = 1 dB, T = 75°K**
  - **Average HF receiver: NF = 12 dB, T = 4306°K**

- ***System noise temperature* is higher than LNA noise temperature due to RF feed loss and other factors.**
- ***G/T* (gain/system noise temp. ratio) is figure of merit for radio telescopes and satellite earth station antennas.**
- **Further study of G/T**

Lovell Observing Room

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- **This is where the observations made by the 76m Lovell and 13m radio telescopes are controlled and the radio signals collected by them processed and stored for later analysis. The Observing Room houses:**
  - **The Receiver Racks**
  - **The Control & Monitoring Terminals**
- **The 13m telescope is used for observing the [Crab Pulsar] in the constellation Taurus.**

The 13m radio telescope

Receiver racks
- LO sources, IF distribution

The receiver racks contain several computer-controlled frequency synthesizers (upper left in the receiver rack). These control the observing frequencies used by the telescopes by providing local oscillator (LO) feeds which are sent to the receivers in their Focus Boxes. The frequency bands being observed by them are then down-converted to an IF. These IF signals, two for each telescope, are then brought to the Observing Room via low-loss coaxial RF cables.

Receiver racks
- signal handling

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In the receiver racks, the IF bandwidths are determined by plug-in filter modules and their amplitudes set by computer controlled attenuators. Signal handling at this point is determined by the observations that are being undertaken, but in all cases the final output will be digitized and transferred to the Observing Room computer, called Arthur. The data is stored on disc and may be plotted out for monitoring purposes.

Depending on the nature of the observing program, the signal can be used in many ways. Its strength and polarization can be measured; these are two basic properties of electromagnetic waves. A spectrogram can be captured and much more information deduced about the source of emission. In most cases the processed signals are stored on magnetic tape or disc for later analysis on Jodrell Bank's network of powerful computers.

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The Lovell Observing Room

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- **This is where the observations made by the 76m Lovell and 13m radio telescopes are controlled and the radio signals collected by them processed and stored on the computer named Arthur for later analysis.**
- **The stored data are regularly transferred onto Exabyte tapes for transfer to the off-line data analysis computers.**

1.4 GHz front end
cryogenically cooled to 15°K

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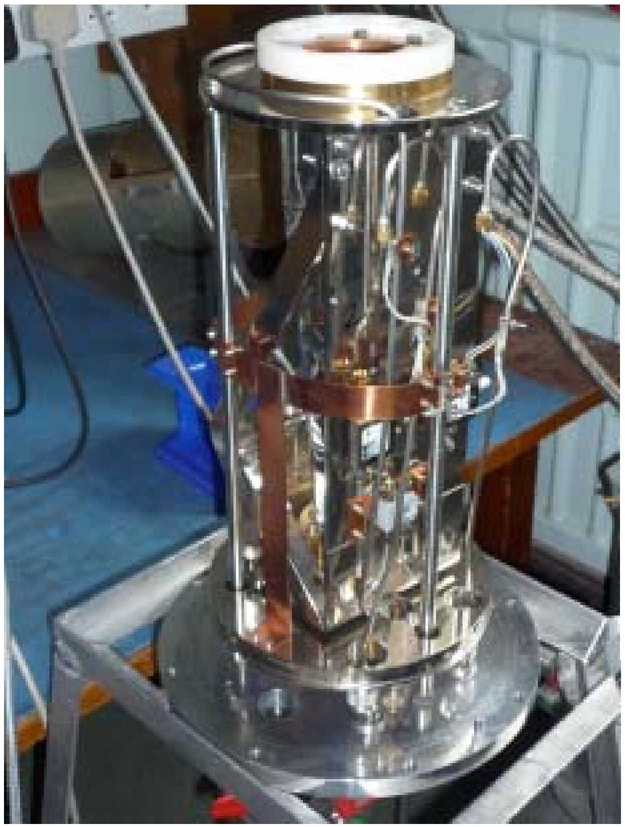
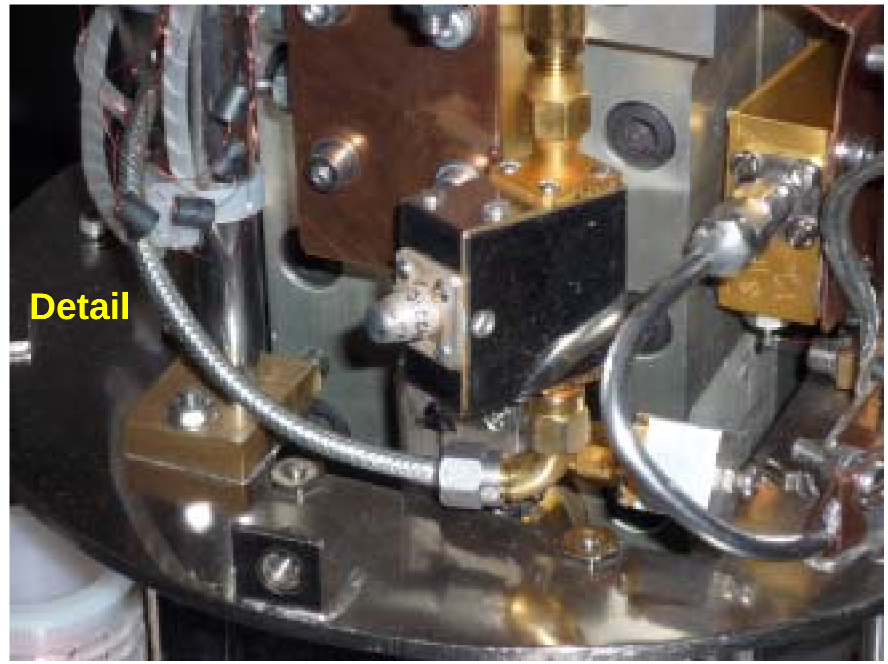


Complete front end

Front end in cryogenic vessel

1.8 GHz front end
cryogenically cooled to 15°K



- **A preselection filter at the LNA input filters out cellphone signals in the 1.9 GHz mobile band.**
- **The LNA uses ultra-low-noise HEMT transistors.**
- **The white Teflon spool blocks heat conducted on the power wires from reaching the cooled electronics.**

5 GHz front end

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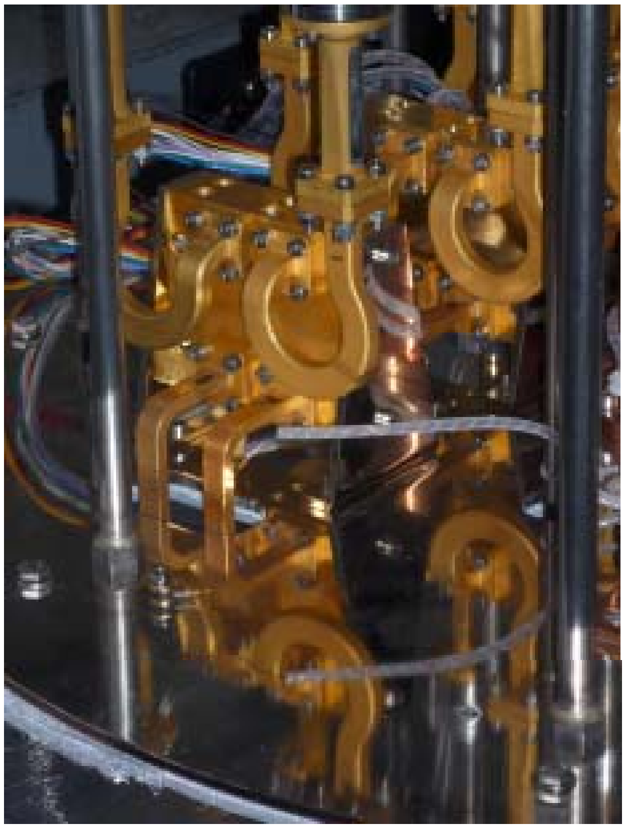
Partially assembled

Complete, with waveguides

5 GHz front end details



Waveguides and wiring

Feed horns

Gaseous helium cryogenic refrigerator

22 GHz front end

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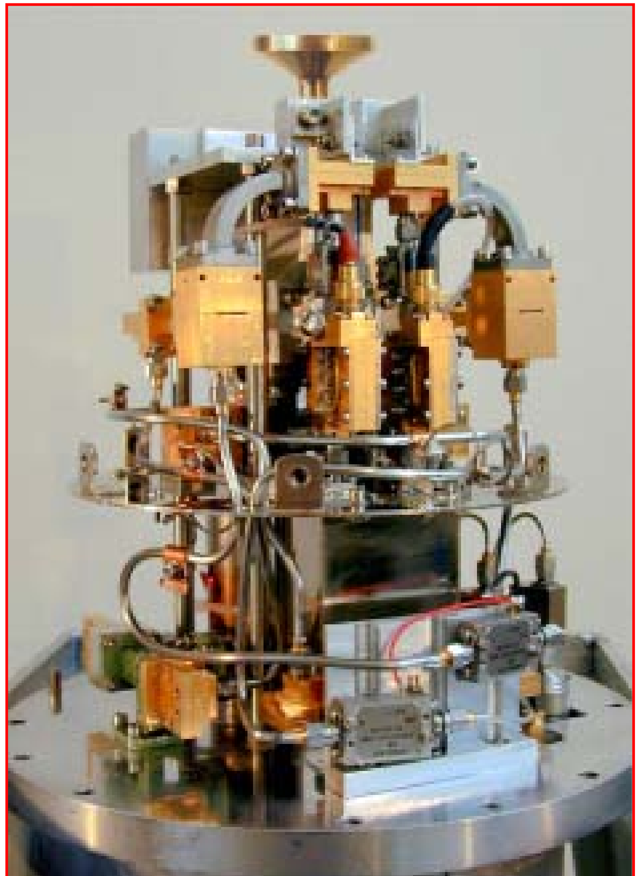
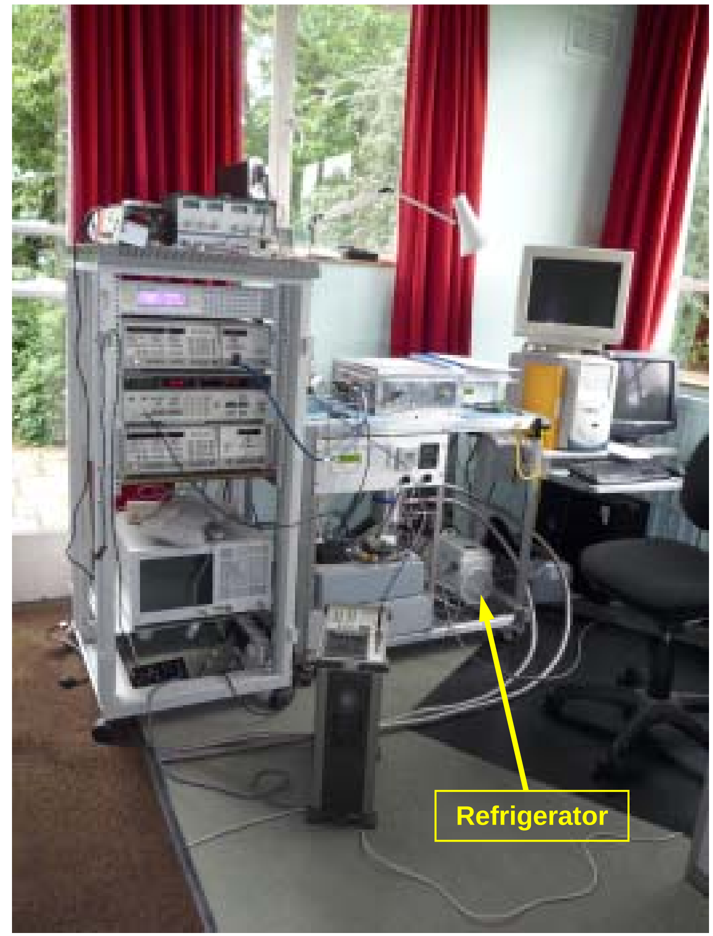


A 22 GHz receiver (front end) for use in the [MERLIN] network of radio telescopes.

Receiver test stand



Signal processing centre
*incl. equipment for VLBI**

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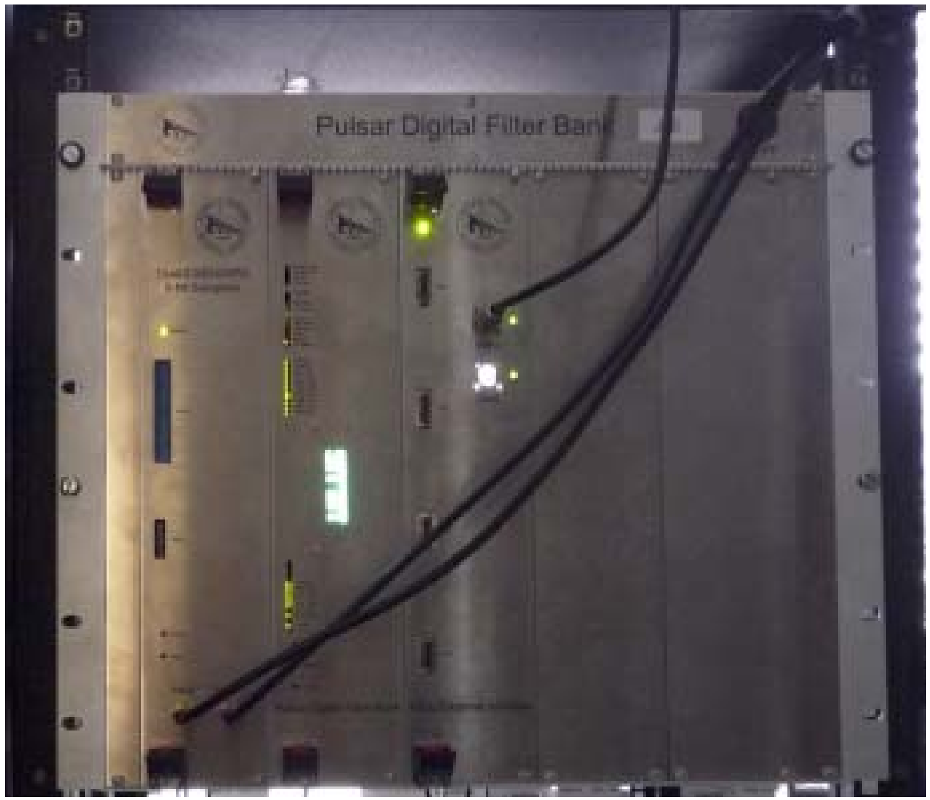
* **VLBI = Very Large Baseline Interferometer, a technique for linking multiple radio telescopes together to form a vast synthetic telescope with very high resolution.**

Pulsar Digital Filter Bank



This digital filter was supplied by the Australia Telescope National Facility. It incorporates two 8-bit ADC's (analogue/digital converters) sampling at 2 Gsps (2 X 10^9 samples/sec.)

Typical signal-processing boards

Analogue

Digital

- **These are typical PC boards as used in signal-processing equipment at Jodrell Bank.**

e-MERLIN data converters

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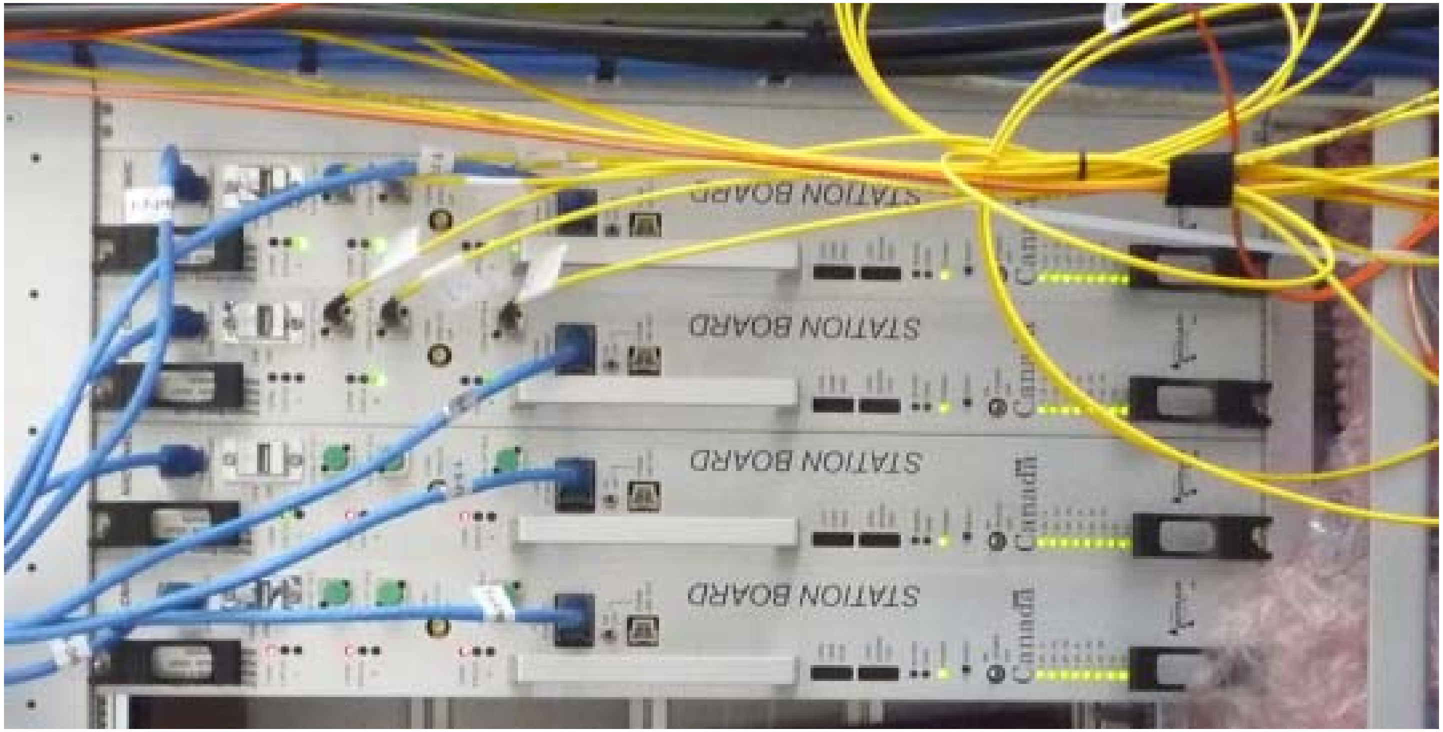


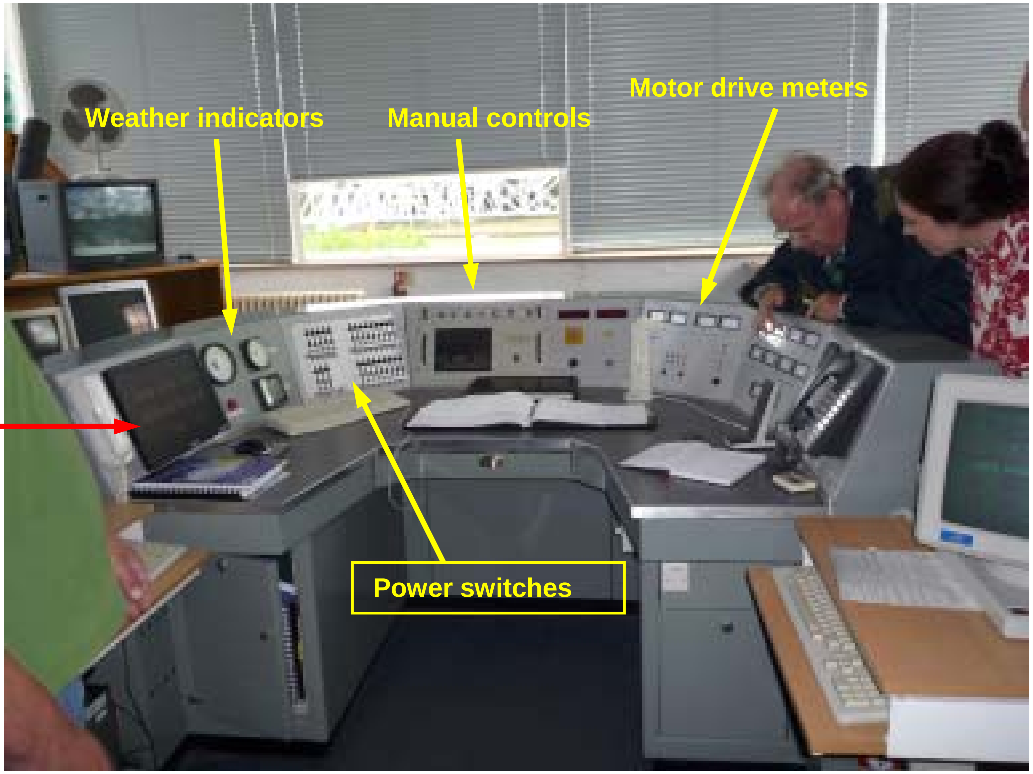
These Station Boards (fast optical/LAN converters) are part of the <u>e-MERLIN</u> network. They link the Mk II telescope at Jodrell Bank to the Dominion Radio-Astronomical Observatory (<u>DRAO</u>) in Penticton BC.

The control room

The heart of Jodrell Bank. Here the duty controller runs the giant 76m Lovell Radio Telescope and monitors the operation of our other telescopes both at Jodrell Bank and our remote sites.

It also houses the weather station and the clock which keeps Jodrell Atomic Time.

View of control desk



Initially, the controller drives the telescope manually. When it is ready for use he will place it in "Remote Control" which hands control of the telescope to the computer system carrying out the observations.

Lowell Telescope drive display

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This summary display presents to the duty controller all the electrical parameters of the 76m Lowell Telescope's motor drives.

Weather station & clock
(to left of control console)

The Jodrell Bank clock is derived from a 5 MHz hydrogen maser, and is synchronized to UTC bu continuous comparison with 4 GPS clocks. The clock is accurate to within 10 nS. The weather station monitors wind speed and direction, barometric pressure, temperature and humidity.

Some radio images:

Quasar 3C273 (Quasar = quasi-stellar object)

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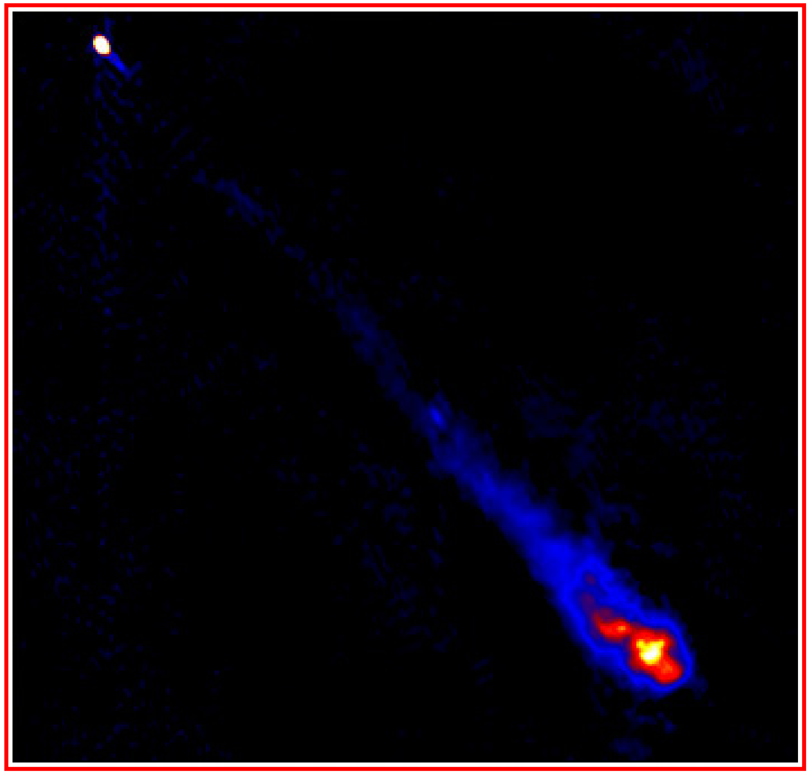

This is a radio image (made with the UK's MERLIN network of telescopes operated from Jodrell Bank) of Quasar 3C273 showing a high-speed jet being ejected from the region around the black hole (top left).

More radio images:
The M82 starburst (star cluster)

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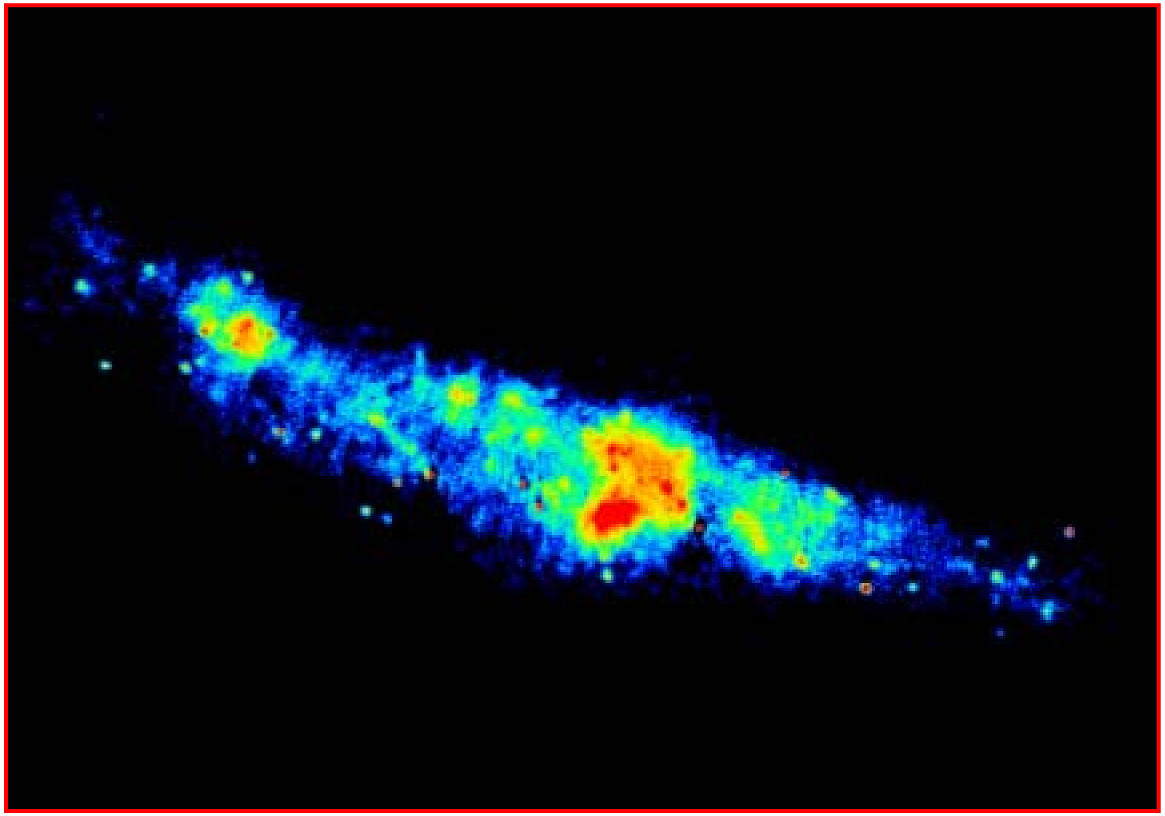

M82, a starburst galaxy undergoing a high rate of star formation. This is a radio image made recently with the UK's MERLIN network of telescopes operated from Jodrell Bank, linked to the Very Large Array (VLA) in the USA.

More radio images:
The Gravitational Lens

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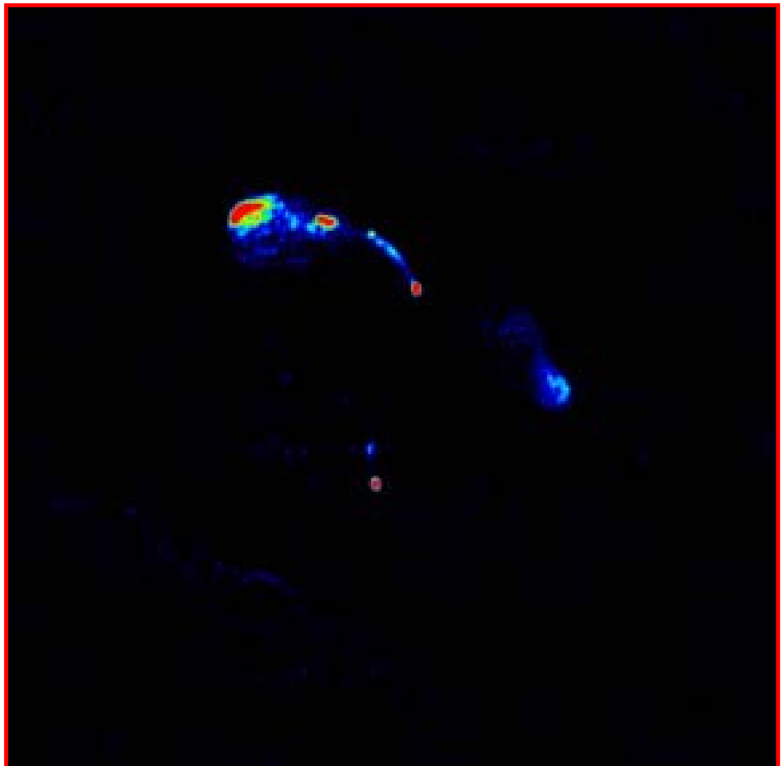

The first gravitational lens, the so-called "double quasar", discovered in 1979. This confirmed Einstein's prediction that light would be bent around massive objects, allowing detection of otherwise invisible matter. This is another MERLIN radio image.

More radio images:

The Moon from Luna 9, 1966

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First photo taken from the surface of the Moon in February 1966 by the Soviet lunar lander Luna 9 and received with the radio telescope at Jodrell Bank.

A cosmic icon of utter beauty:
The Crab Nebula (courtesy NASA)

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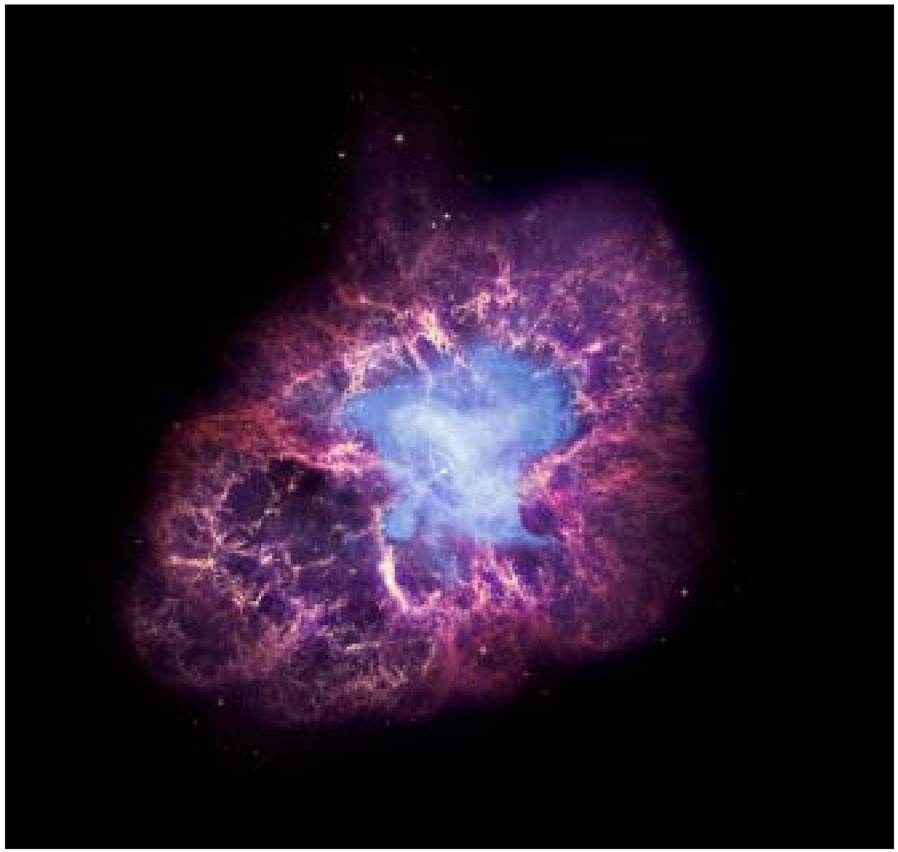

NASA composite image of the Crab Nebula, using imagery from Hubble (yellow/red), Chandra X-ray (blue) and the Spitzer Space Telescope (purple). It is a neutron star left over from the Constellation Taurus supernova of 1054 C.E.

Links for further study

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- http://www.jodrellbank.manchester.ac.uk/
- http://en.wikipedia.org/wiki/Jodrell_Bank_Observatory
- http://www.nasa.gov/
- http://www.nrao.edu/
- http://www.radiosky.com/ra01.html
- **Additional reference:**
  - **Brian Austin GØGSF: "The Beginnings of Radio Astronomy in England - A tribute to Stanley Hey MBE FRS (1909 - 2000)."** ***Radio Bygones*** **No.96, Aug./Sept. 2005, pp.24 - 31.**