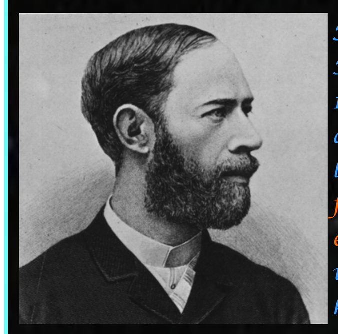
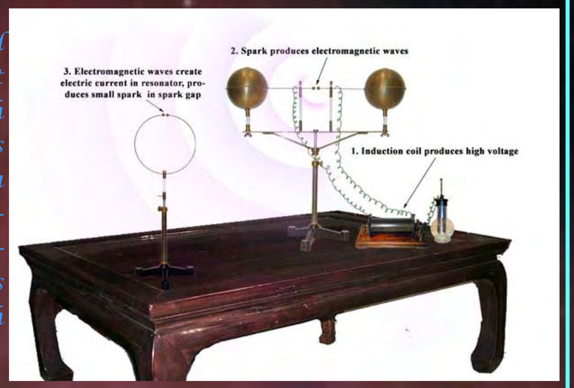
RADIO ASTRONOMY – HISTORY & MODERN DEVELOPMENTS

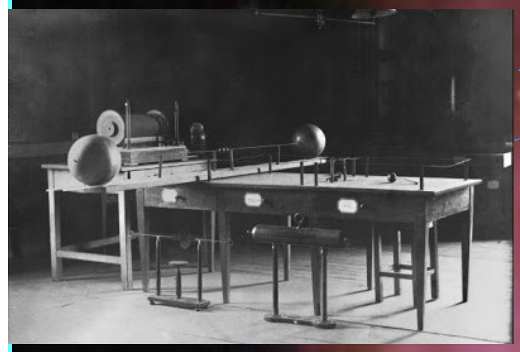
HEINRICH HERTZ



Heinrich Hertz was the first to send and receive radio waves. James Clerk Maxwell had mathematically predicted their existence in 1864. Between 1885 and 1889, as a professor of physics at Karlsruhe Polytechnic, he produced electromagnetic waves in the laboratory and measured their wavelength and velocity. He showed that the nature of their reflection and refraction was the same as those of light, confirming that light waves are electromagnetic radiation obeying the Maxwell equations. The scientific unit of frequency — cycles per second — was named the "hertz" in his honor.

In 1888, Heinrich Hertz built an apparatus that could transmit and receive electromagnetic waves of about 5 meters in length. He used a coil to generate a high voltage spark between two electrodes which served as a transmitter. The detector was a loop of wire with a small gap. A spark at the transmitter produces electromagnetic waves that travel to the detector, producing a spark in the gap. He showed that the waves were polarized, and that they could interfere with each other, just as predicted by theory.



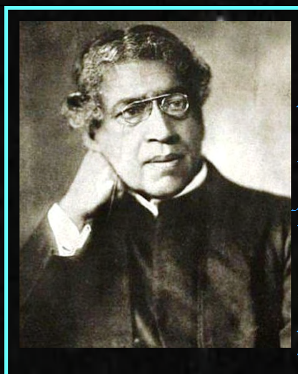


In his work with spark dicharges to create high-frequency oscillations, Hertz remarked that electric charges could get "lost" from his apparatus when illuminated by the bright flashes of the spark. As a by-product of his work on electromagnetic waves, he discovered the photoelectric effect! .

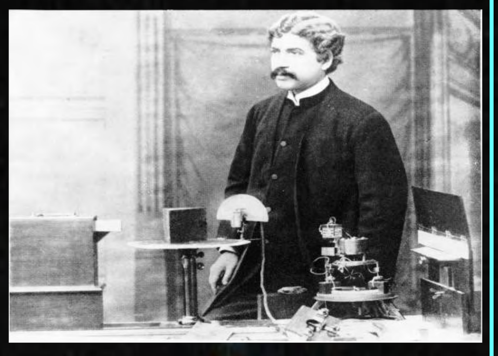
Description of the above photograph :

The experimental apparatus used by Heinrich Hertz to produce and detect electromagnetic waves. The coil in the background on the left produces a high voltage, which feeds an antenna, the two rods with the big spheres at the end, via a spark discharge between the two small spheres at the centre of the rods. This antenna is the prototype of what we call today a Hertzian dipole

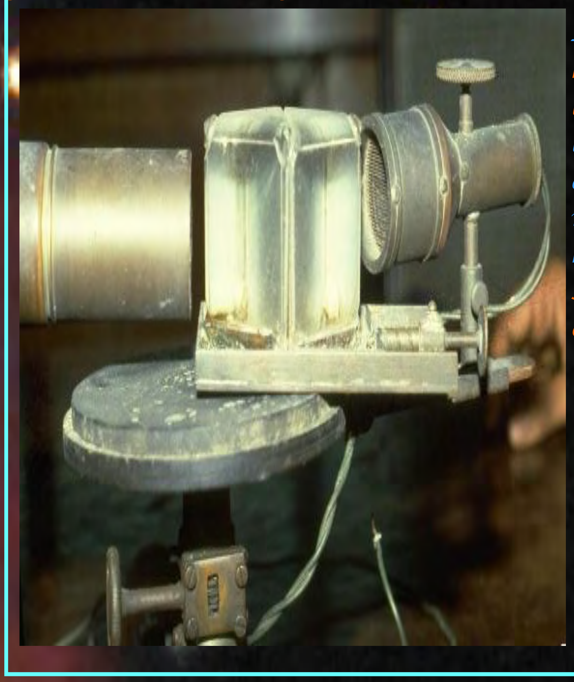
JAGADIS CHANDRA BOSE



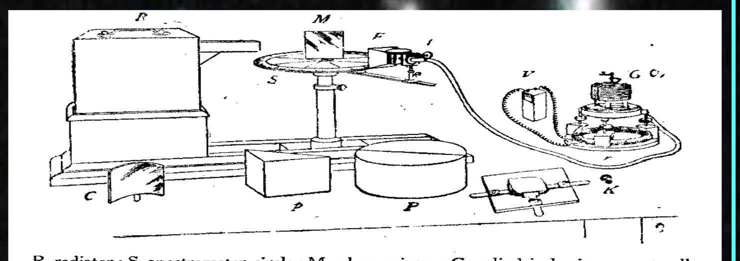
In the year 1895 Prof J.C.Bose in Calcutta publicly demonstrated the ability of the electric rays to travel from the lecture room, and through an intervening room and passage, to a third room 75 feet (23 m) distant from the radiator, thus passing through three solid walls on the way, as well as the body of the chairman (who happened to be the Lieutenant-Governor). The receiver at this distance still had energy enough to make a contact which set a bell ringing, discharged a pistol, and exploded a miniature mine. To get this result from his small radiator, Bose set up an apparatus which curiously anticipated the lofty 'antennae' of modern wireless telegraphy— a circular metal plate at the top of a pole, 20 feet (6.1 m) high, being put in connection with the radiator and a similar one with the receiving apparatus



Bose's demonstration of remote wireless signaling has priority over Marconi. He was the first to use a semiconductor junction to detect radio waves, and he invented various now commonplace microwave components

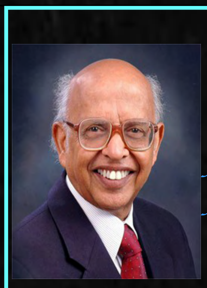


In 1897, Bose described to the Royal Institution in London his research carried out in Kolkata at millimeter wavelengths. He used waveguides, horn antennas, dielectric lenses, various polarizers and even semiconductors at frequencies as high as 60 GHz much of his original equipment is still in existence, now at the Bose Institute in Kolkata. A 1.3 mm multi-beam receiver now in use on the NRAO 12 Meter Telescope, Arizona, US, incorporates concepts from his original 1897 papers.



R, radiator ; S, spectrometer-circle ; M, plane mirror ; C, cylindrical mirror ; p, totally reflecting prism ; P, semi-cylinders ; K, crystal-holder ; F, collecting funnel attached to the spiral spring receiver ; t, tangent screw, by which the receiver is rotated ; V, voltaic cell ; r, circular rheostat ; G, galvanometer.

GOVIND SWARUP



Dr Govind Swarup is an internationally well known pioneer in the field of radio astronomy. In addition to his many research contributions, he is also known for building ingenious, economical and powerful observational facilities for front-line research in radio astronomy, namely, the Ooty Radio Telescope (ORT) in South India and the **Giant Metrewave Radio Telescope (GMRT)** near Pune, that are amongst the largest in the world.

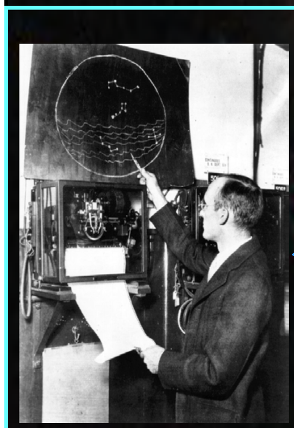
Some of his pioneering contributions are: discovery of Type U solar radio bursts, gyro-radiation model for microwave radio emission from solar active regions, a modulation technique for phase adjustment of large antennas and studies of radio galaxies and quasars. From lunar occultation observations using the ORT, high angular resolution studies (about 1 to 10 arc sec) of more than 1,000 weak radio galaxies and quasars were made for the first time in the world by him and his students during 1970s. He discovered a relation between the angular sizes of radio sources and their flux density which provided an independent support for the Big Bang model and evidence against the Steady-State model of the Universe.

OOTY RADIO TELESCOPE (Operational from 1971)

Prof Swarup with Radio Astronomers at GMRT during its construction.

Left-most) V. Radhakrishanan ,
(Centre) G. Swarup ,
(Right Most) J. Narlikar (@ GMRT)

KARL JANSKY



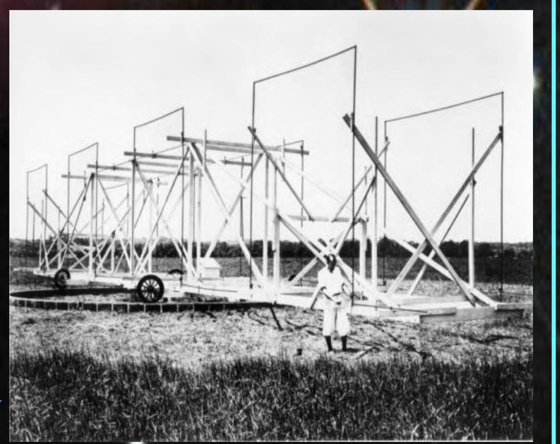
Karl Guthe Jansky was an American physicist and radio engineer who in August 1931 first discovered radio waves emanating from the Milky Way.

He is considered one of the founding figures of radio astronomy.

Jansky graduated with a degree in physics from the University of Wisconsin, and joined the staff of the Bell Telephone Laboratories in Holmdel, NJ, in 1928.

Bell Labs wanted to investigate using "short waves" (wavelengths of about 10-20 meters) for transatlantic radio telephone service. Jansky was assigned the job of investigating the sources of static that might interfere with radio voice transmissions .

He built an antenna (pictured below) designed to receive radio waves at a frequency of 20.5 MHz (wavelength about 14.5 meters). It was mounted on a turntable that allowed it to rotate in any direction, earning it the name "Jansky's merry-go-round". By rotating the antenna, one could find what the direction was to any radio signal.



After recording signals from all directions for several months, Jansky identified three types of static:

1. nearby thunderstorms
2. distant thunderstorms
3. a faint steady hiss of unknown origin.

Jansky spent over a year investigating the third type of static. It rose and fell once a day, leading Jansky to think at first that he was seeing radiation from the Sun.

But after a few months of following the signal, the brightest point moved away from the position of the Sun. The signal repeated not every 24 hours, but every 23 hours and 56 minutes. This is characteristic of the fixed stars, and other objects far from our solar system. He eventually figured out that the radiation was coming from the Milky Way and was strongest in the direction of the center of our Milky Way galaxy, in the constellation of Sagittarius.

The discovery was widely publicized, appearing in the New York Times of May 5, 1933.

Jansky wanted to follow up on this discovery and investigate the radio waves from the Milky Way Galaxy in more detail. He proposed to Bell Labs to build a 100 foot (30 meter) diameter dish antenna. But Bell Labs had the answer they wanted about static: the static was not a problem for transatlantic radio communication. Jansky was assigned to another project and did no more radio astronomy.
Many scientists were fascinated by Jansky's discovery, but no one followed up on it for several years. It was during the great depression, and observatories could not afford take on any new projects.

Two men who learned of Jansky's discovery in 1933 were of great influence on the later development of the new study of radio astronomy: one was Grote Reber, who singlehandedly built a radio telescope in his back yard in 1937 and did the first systematic survey of radio waves from the sky.

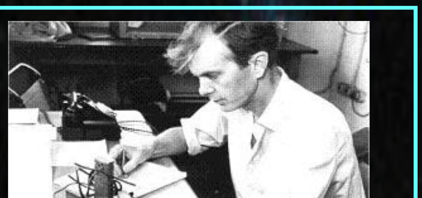
The second was John Kraus, who, after World War II, started a radio observatory at Ohio State University and wrote a textbook on radio astronomy, which is still the "bible" for radio astronomers.

In honor of Jansky, the unit used by radio astronomers for the strength (or flux density) of radio sources is the *jansky* (1 Jy = 10^{-26} W m^{-2} Hz^{-1}).

The crater Jansky on the Moon is also named after him .

The Very Large Array Radio astronomy observatory was recently renamed to " The ***Karl G. Jansky Very Large Array***" .

MARTIN RYLE



Ryle was one of the most important pioneers of radio astronomy. His major contributions concerned the practical implementation of the principles of aperture synthesis, resulting in enormous increment in angular resolution and sensitivity for radio astronomical observations. These revealed the detailed radio structures of galactic and extra-galactic radio sources for the first time and established the strong evolution of the source population with cosmic epoch.

Ryle worked on radar and radio systems for the RAF during World War II, at the Telecommunications Research Establishment. After the war, he worked at Cambridge on stellar catalogues, helping to produce the ***Third Cambridge Catalogue (1959)*** -- this was the first catalogue to include a quasar. Most importantly, he invented a method, aperture synthesis, to measure weak radio sources using multiple radio telescopes whose position can be changed in relationship to each other.

This had the effect of simulating a much larger telescope. For this he was the first astronomer awarded the Nobel Prize, in 1974.

Aperture synthesis has had a profound impact on radio astronomy and studies of the universe. The main advantage of aperture synthesis is resolution. Since resolution depends inversely on the diameter of the telescope one can imagine the construction of a radio telescope that was extremely large, so that its diameter could compensate for the long wavelengths to produce a reasonable resolution. Fortunately, radio astronomers can accomplish this goal using an array of radio antennas. This is done by observing the same source simultaneously with a number of antennas and combining the detected signals with a method called "cross correlation."
The result of this method is an effective resolution that is equal to that of a telescope whose diameter equals the largest distance between antennas in the array.

To map distant radio sources as quasars, Ryle developed the technique of aperture synthesis. By using two radio telescopes and changing the distance between them, he obtained data that, upon computer analysis, provided tremendously increased resolving power. In the mid-1960s Ryle put into operation two telescopes on rails that at the maximum distance of 1.6 km (1 mile) provided results comparable to a single telescope 1.6 km in diameter. This telescope system was used to locate the **first pulsar**, which had been discovered

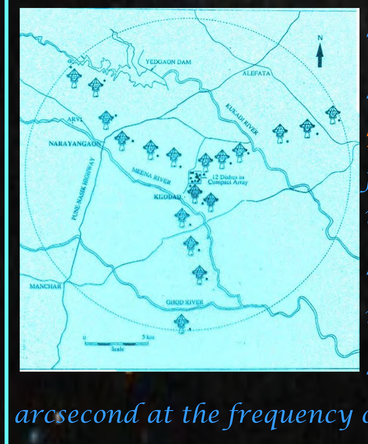
GMRT : GIANT METREWAVE RADIO TELESCOPE

Giant Metrewave Radio Telescope (GMRT), is an array of radio telescopes at metre wavelengths. It is operated by the National Centre for Radio Astrophysics, a part of the Tata Institute of Fundamental Research. At the time it was built, it was world's largest interferometric array.

GMRT is one of the most challenging experimental programmes in basic sciences undertaken by Indian scientists and engineers.

The GMRT is located around 80 km north of Pune at Khodad.

The GMRT contains 30 fully steerable telescopes. There are fourteen telescopes randomly arranged in the central square 1 km by 1 km in size, with a further sixteen arranged in three arms of a nearly "Y"-shaped array each having a length of 14 km from the array centre.



The GMRT is an interferometer which uses a technique known as aperture synthesis to make images of radio sources.

The GMRT operates in six frequency bands centered at 38, 153, 233, 327, 610, and 1420 MHz
Each antenna is 45 metres in diameter with the reflector made of wire rope stretched between metal struts in a parabolic configuration. This configuration works because of the long wavelengths (21 cm and longer) at which the telescope operates. Each antenna has four different receivers mounted at the focus. Each individual receiver assembly can rotate so that the user can select the frequency at which to observe.

The multiplication or correlation of radio signals from all the 435 possible pairs of antennas or interferometers over several hours will thus enable radio images of celestial objects to be synthesized with a resolution equivalent to that obtainable with a single gigantic dish 25 kilometer in diameter!

The maximum baseline in the array gives the telescope an angular resolution (the smallest angular scale that can be distinguished) of about 1 arcsecond at the frequency of neutral hydrogen (1420 MHz).

The metre wavelength part of the radio spectrum has been particularly chosen for study with GMRT because man-made radio interference is considerably lower in this part of the spectrum in India. Although there are many outstanding astrophysics problems which are best studied at metre wavelengths, there has, so far, been no large facility anywhere in the world to exploit this part of the spectrum for astrophysical research. Although GMRT will be a very versatile instrument for investigating a variety of radio astrophysical problems ranging from our nearby Solar system to the edge of the observable Universe, two of its most important astrophysical objectives are:

⇒ To detect the highly red-shifted spectral line of neutral Hydrogen expected from proto-clusters or proto-galaxies before they condensed to form galaxies in the early phase of the Universe.

⇒To search for and study rapidly-rotating Pulsars in our galaxy.

GROTE REBER

He was instrumental in investigating and extending Karl Jansky's pioneering work, and conducted the first sky survey in the radio frequencies.

His 1937 radio antenna was the second ever to be used for astronomical purposes and the first parabolic reflecting antenna to be used as a radio telescope. For nearly a decade he was the world's only radio astronomer.

During the world war II, he uncovered a mystery that was not explained until the 1950s.
The standard theory of radio emissions from space was that they were due to black-body radiation, light (of which radio is a non-visible form) that is given off by all hot bodies. Using this theory one would expect that there would be considerably more high-energy light than low-energy, due to the presence of stars and other hot bodies.
However Reber demonstrated that the reverse was true, and that there was a considerable amount of low-energy radio signal. It was not until the 1950s that synchrotron radiation was offered as an explanation for these measurements.

Reber was the first to see radio from supernova remnants in Cassiopeia, though it was several years before other scientists figured out the explanation for them.

Working for his own, Reber published his first radio map of the Milky Way in 1939 in the same *Proceedings* as well as in *Nature*, confirming Karl Jansky's observations made in 1933.

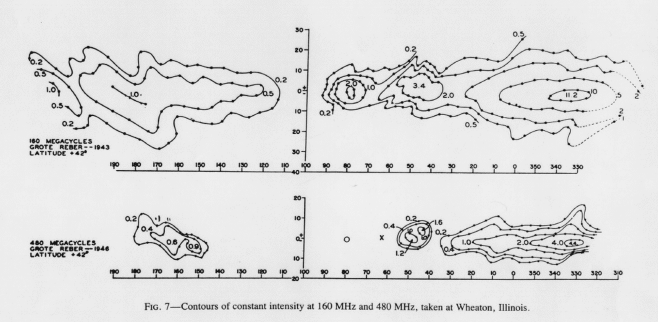
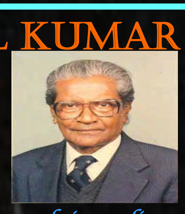


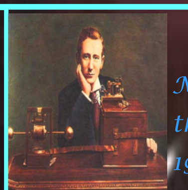
FIG. 7—Contours of constant intensity at 160 MHz and 480 MHz, taken at Wheaton, Illinois.

MRINAL KUMAR DASGUPTA



M.K. Dasgupta was the doyen of research in radio astronomy in India and the co-discoverer of the double radio-galaxy Cygnus A .He was the research student of famous radio astronomer R. Hanbury Brown along with Roger Jennison in the early 1950s. They worked to design and fabricate a long baseline post-detection correlator radio interferometer at Jodrell Bank. The basic idea was to compare the fluctuations in the intensity of the source, enabling long baselines. For this purpose, they built two independent receivers at a frequency of 125 MHz with a bandwidth of 200 KHz. After a square law detector, the signals were filtered with a 2 KHz filter and their cross correlation was measured as a function of baseline between the antennas. This was tried on two of the strongest radio sources known, namely Cygnus A and Cassiopeia. They found that as the baseline was increased up to 20 km, two large maxima in signal amplitude appeared in the case of Cygnus A, whereas a single maximum appeared for Cassiopeia, thus indicating that Cygnus A was not a simple source. The separation of the two 'radio lobes' was about 1'28". This was how the classical double radio source structure of radio galaxies was discovered, one of great importance in radio astronomy, leading ultimately to the idea of relativistic jets of plasma in two opposite directions emanating from the nucleus (which is now conjectured as a large accreting object or a black hole).

GUGLIELMO MARCONI



Marconi improved radio transmission and receiver designs and developed the first practical systems for long distance communication by radio. In 1901 he was the first to send and receive signals across an ocean, from Newfoundland to Cornwall. As a result of his pioneering efforts, commercial radiotelephone service became available in later years. In the 1930s the Bell Telephone company was working on improving their transatlantic telephone service when they assigned Karl Jansky to investigate sources of radio static, leading to his discovery of radio waves from the milky way.

NIKOLA TESLA

In 1899, the eccentric Nikola Tesla, in accord with many other plans of his, planned to build a tower in a experimental station at Colorado topped by a copper ball that he would turn into a sensitive radio telescope. While investigating atmospheric electricity in 1900, Tesla noted repetitive signals that he deduced must be coming from a non-terrestrial source. Although Tesla mistook this to be radio communication from intelligent beings living on Venus or Mars it may have been the earliest observation of an astronomical radio source (A 1996 analysis indicated Tesla may have been observing Jovian plasma torus signals)