Book Review

By: Whitham D. Reeve

Title: ***The Evolution of Radio Astronomy***
Author: James S. Hey
Publisher: Science History Publications (Neale Watson Academic Publications)
Date published: 1973
Status: Out of print
Availability: Used book market (for example, www.abebooks.com) for a few US$

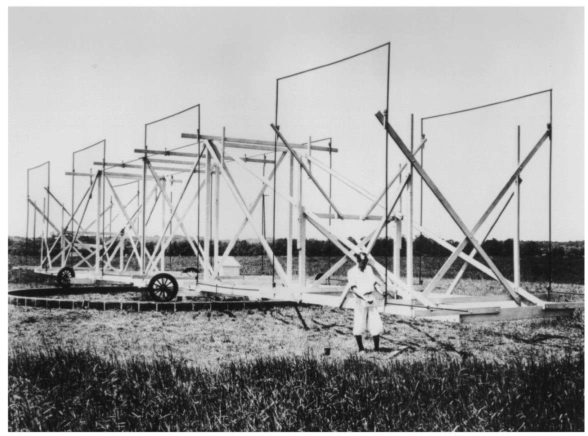
If you read early articles and papers about radio astronomy, you frequently will encounter the name J.S. Hey (full name, James Stanley Hey). Hey was credited with discovering radio emissions from the Sun in early 1942. As with many important discoveries, his was accidental. He had been trying to resolve interference problems in England's defense radar systems during World War II and on one particular day noticed "*the directions of maximum interference recorded by the operators appeared to follow the Sun*." He checked with the Royal Observatory in Greenwich and was told an exceptionally active sunspot was moving across the solar disk, and on the day in question it was on a north-south line passing through the center of the Sun's disk as viewed from the Earth (the central meridian). He wrote a report on his findings but met skepticism from several radio scientists, partly because he was a comparative novice at the time. However, later in 1942, another radar scientist, G.C. Southworth in the USA, used the Sun in testing radar receivers, thus confirming the emissions.

After World War II, advances in radio astronomy accelerated for several reasons. One, large numbers of surplus military radar equipment became cheaply available. This equipment had state-of-the-art microwave receivers and reflector-type dish antennas, perfect for radio astronomy research. Many radar scientists were looking to continue their technical work or just plain looking for work and moved into radio astronomy. Also, the requirements of war put a stop to non-war-related research and, when the war ended, there was a need to catch up. The one exception was in occupied Netherlands, where a few Dutch scientists continued their discussions throughout the war and planned to use German radar equipment almost outside their back door for research when the war ended. By 1973, when Hey's book was published, radio astronomy was only about 40 years old, and he had participated in over 2/3 of it.

One thing that makes this book interesting is that it was written by a pioneer who was unencumbered by 20-20 hindsight. Hey personally knew and worked with many other radio astronomy pioneers and shared additional discoveries with some of them. His book is a blend of "*aspirations, trials, tribulations and successes of the research scientists who have dedicated their efforts to meet the challenge*" of radio astronomy. I enjoy reading books like this – books written by people who actually participated in technical achievements and who saw and reported the successes and failures for what they were at the time. They generally were not bogged down by attempts to paint an unnecessarily large picture or interpret the distant past, as what happens to many contemporary authors burdened by too much information and forced to weed out what they perceive to be the unimportant stuff. On the other hand, most pioneer authors only write about what they think is important (usually their own work), and the reader is not shown other viewpoints. But, as a reader, that is the risk you take and most often it is well worth the risk.

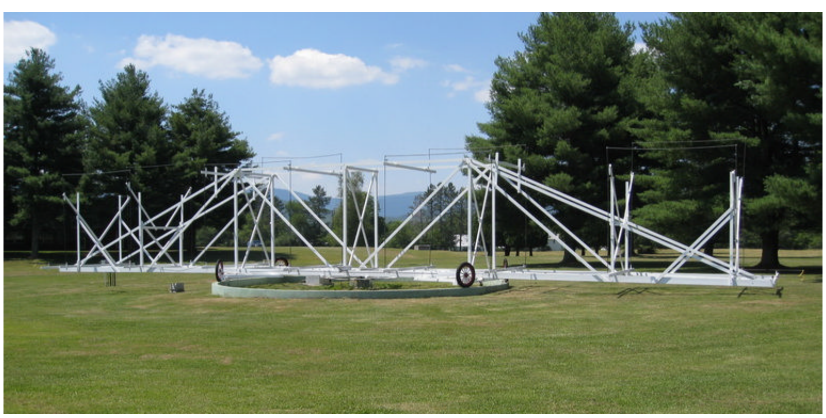
There are 15 pages of references. The references are not arranged by chapter or topic but instead by year. I sometimes found this convenient – I knew what year a discovery was made and could find the original reporting paper. Many of the references are available online from the Smithsonian Astrophysical Observatory (SAO)/NASA Astrophysics Data System at adsabs.harvard.edu/ for free. Hey also included a 4-page glossary with short descriptions of important topics such as power flux density, radio noise, brightness temperature and radio telescope beamwidth and resolution, among others. Putting more technical discussions in appendices or glossaries seems to be a habit of radio astronomy authors. However, unlike some books I have reported in the SARA Journal, Hey's glossary actually is useful.

The subject index has a disappointing length of 1 page, but I found it to be functional despite its length. Like many books written by scientists there is a name index of 4 pages. The length of the name index indicates the many people who participated in important discoveries through about 1970. The entire book is only 214 pages long and will not crush your chest when you try to read it in bed.



Hey's book has no math and is well illustrated. He mentions many historic radio observatories. I have provided geographic coordinates in footnotes so that readers of this review can use GoogleEarth to see an aerial view of them. Overall, Hey's book is easy to read, and his explanations of technical topics such as synchrotron radiation, interferometers and hydrogen line (21 cm line) emission are thoughtful and easy to follow.

Chapter 1, The Beginning of Radio Astronomy, discusses the very early radio astronomy pioneers, Karl Jansky and Grote Reber – two of the few radio scientists for which Hey provides first names. Jansky accidentally discovered the galactic background radiation in 1932 while studying the arrival directions of atmospheric noise using a very unusual antenna (above-right, image source NRAO). Unfortunately, a copy of Janky's original paper is available only for a fee from IEEE Xplore at: ieeexplore.ieee.org/Xplore/. A reconstruction of his antenna is on display at the National Radio Astronomy Observatory (NRAO) at Green Bank, West Virginia (left).[1] It is interesting that Jansky made no further contributions to radio astronomy except to extend his discussion of his 1932 discovery a couple years later.



Grote Reber was a radio

[1] Jansky replica antenna at 38° 25' 53.67"N, 79° 48' 58.53"W

engineer in Illinois who recognized the importance of Jansky's discovery and set out in 1937 to learn more about it at his own expense and in his spare time. He built his own radio telescope but did not have immediate success. Reber was persistent and, finally, in 1939 detected emissions from the Milky Way galaxy – on purpose. He published his work in 1940 and, as expected, met with the same skepticism as Hey would meet three years later with solar emissions. Eventually, Reber was recognized as a great pioneer of radio astronomy. The hand-cranked antenna from his original radio telescope is on display at NRAO Green Bank (below-right) within view of Jansky's antenna.[2]

Chapter 1 includes discussion of Hey's solar emissions discovery and also some interesting details of his other work with radar to track the German V1 and V2 rockets that were aimed at England starting in 1943. They had no initial detection success except for a "*wild shot that nearly hit the watching radar*." However, he did notice transient echoes from a height of about 60 miles (100 km) at a rate of 5 to 10 per hour, which led to frequent false alarms in the radar warning system. It was not until after the war ended that Hey was able to pursue this phenomenon, which was caused by echoes from the ionized trails of meteors. This chapter also includes a description of 1946 radar experiments to bounce radio waves off the Moon as well as detection of the Moon's radio emissions. Some of the discoveries took place immediately prior to or during World War II but the results were not published until after the war ended in 1945.

The Rise of Radio Astronomy, chapter 2, takes the reader through about 1949. The intervening years saw the use of an experimental *horticultural* site at Jordell Bank in England for radio astronomy purposes because it was an electrically quiet location.[3] A famous radio astronomy observatory eventually was built there and is described in more detail in chapter 4. Although Hey was more familiar with radio astronomy activities in England than anywhere else, and he understandably spends much more time discussing them than any other country's, he does briefly mention the important contributions of radio scientists in Australia and the Naval Research Laboratory in the USA.[4] By comparison, researchers in the USA were slow to jump on to the radio astronomy band wagon, so there was not much to discuss for the USA until the early 1950s.

In 1946, scientists had noticed that when their radio telescopes were pointed in one direction in the sky, toward the constellation Cygnus (the "Swan"), the received noise level often varied irregularly, usually with a period of a few seconds. It was at this time that J.G. Bolton and his co-workers in Australia chose the nomenclature for strong celestial radio sources, which still is used to this day. The nomenclature designates the source by the constellation in which it is found

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[2] Reber's antenna at 38° 25' 49.42"N, 79° 49' 2.48"W
[3] Jordell Bank at 53° 14' 10.72"N, 2° 18' 31.50"W
[4] NRL at 38° 49' 40.14"N, 77° 1' 33.24"W

followed by a letter, with A being the strongest. Thus we call the most powerful radio source in the constellation Cygnus, Cygnus A. Of course, many more radio sources have since been discovered than there are letters in the alphabet, but the names given for the early discoveries still are used today.

Chapter 3 is aptly named Two Crucial Years, 1950–1. A number of basic discoveries were made during this period. For one, it was found that the variations noted above for Cygnus A, and also for Cassiopeia A, were not due to the source itself but due to modulation of the emissions by the Earth's ionosphere as the radio waves passed through it (called scintillation). For another, in 1950, H. Alfvén and N. Herlofson in Sweden proposed that synchrotron radiation could be responsible for intense radio emission from discrete celestial radio sources. Synchrotron radiation is radio emission caused by very high-speed electrons (more specifically, speeds approaching the speed of light) moving in a magnetic field. This type of radiation had been proposed on theoretical grounds as early as 1912.

Of great interest to radio astronomers, both professional and amateur, are hydrogen line emissions. Most of the gas in our galaxy is hydrogen. Much of it is cold and gives off no light at all. However, it was predicted that the hydrogen emits non-thermal radiation at a frequency close to 1,420 MHz, or 21 cm wavelength, the so-called neutral hydrogen line. Optical telescopes cannot be used to observe toward the middle of the Milky Way – toward Sagittarius (the “Archer”) – because of interstellar dust. However, the 1,420 MHz radio waves penetrate the dust. Hey discusses the work of H.I. Ewen and E.M. Purcell at Harvard in the USA, who found the predicted 21 cm wavelength hydrogen line in 1951. They used a hand-built plywood and copper 1,420 MHz horn antenna (their original horn antenna is on display at NRAO Green Bank West Virginia, photo above right). As a result of this discovery and its later exploitation, radio astronomers were able to build up a more complete idea of what the whole galaxy is like and to confirm its shape as thought to exist through optical astronomy.

Hey discusses another important discovery made in England in 1951. Investigators there used a 218 ft (66 m) fixed parabolic dish antenna with 2 deg beamwidth to determine that radio emissions from the Andromeda nebula, discovered the year before, covered a much larger area than the visible spiral galaxy itself. This led to the notion that not all celestial radio sources are discrete and not all radio sources correspond to visible light sources found through optical astronomy.

In chapter 4, Radio Telescopes and Observatories, Hey describes some of the hardware used at observatories up to about 1970. Unfortunately, his entire focus is on the antennas associated with the radio telescopes and he mentions in only a couple paragraphs the maser and parametric amplifiers used in the receivers and says nothing at all about the data recording and processing methods used at that time. The maser and parametric receivers, along with the antennas, is what enabled many of the discoveries. They could not have been made with just the big antennas. Nevertheless, it is interesting to see the evolution and application of large dish antennas, which evolved directly from the antennas used in World War II radar systems. Another important development was the interferometry techniques used to improve the resolving power of radio telescope antennas.

It became obvious as a practical matter that a single dish antenna could not be built with the same resolution as optical telescopes in use at that time. On the other hand, two or more antennas separated by some distance, the farther the better, provide much better resolution. By using a very long baseline (separation between antennas), researchers at Jordell Bank were able to attain sub-arc-second angular resolution. In 1962, the baseline reached 114 km at a frequency of about 160 MHz (1.9 m wavelength), thus providing about 1 arc-second resolution. The baseline later was extended to 127 km and the frequency increased to 1,420 MHz (21 cm wavelength), which provided an angular resolution of about 0.1 arc-second. Still higher frequencies provided 0.025 arc-second resolution, thus surpassing some optical telescopes of that time frame.

Parabolic dish antennas were not the only type used. Hey discusses the Mills Cross antenna, which was first built by B.Y. Mills near the Molonglo River east of Canberra ACT, Australia in 1967.[5] Surprisingly, most of the funds for this antenna came from the US National Science Foundation. The Mills Cross consisted of fixed cylindrical parabolas arranged along a line about 1 mile (1.6 km) long. The parabolas had a line of 408 MHz dipoles at their focus. By building two lines at angles to each other, a variety of fan beams could be focused on a part of the sky at a certain declination. Since the antennas were fixed, the Earth's rotation provided the necessary transit motion.

In Ohio USA, J. Kraus designed and arranged the construction of a fixed double-reflector type antenna called the "Big Ear".[6] One of the reflectors was flat and could be tilted, thus allowing for reception from different declinations. Larger versions of Kraus's antenna were built at Nancay, France and Zelenchukskaya. Russia.[7] Other radio telescopes sprouted up around the world – in Russia, Canada, Germany and Netherlands. Hey provides very little information on these and, instead, focused on those in England and USA, presumably because those were the ones to which he had easy access and was most familiar.

The next three chapters, The Solar System (chapter 5), Radio Waves in the Galaxy (chapter 6) and Radio Galaxies, Quasars and Cosmology (chapter 7) go into detail about discoveries made across the broad groupings named in the titles. Hey provides many interesting illustrations, including contour maps, spectrum charts, and radar maps, all of which makes the descriptions of the work more interesting.

The solar system provides two of the most powerful radio sources we can receive on Earth, the Sun, by far the more powerful of the two, and Jupiter. The Sun has been studied using a number of techniques, including total power receivers, interferometers and radars. It was found there is a radio quiet Sun and radio active Sun depending on the sunspot cycle. Optical observations of the Sun are difficult because of the intensity of its light, so radio observations added much to our knowledge. Detailed investigations in 1950 yielded the classifications of Type I, II and III bursts

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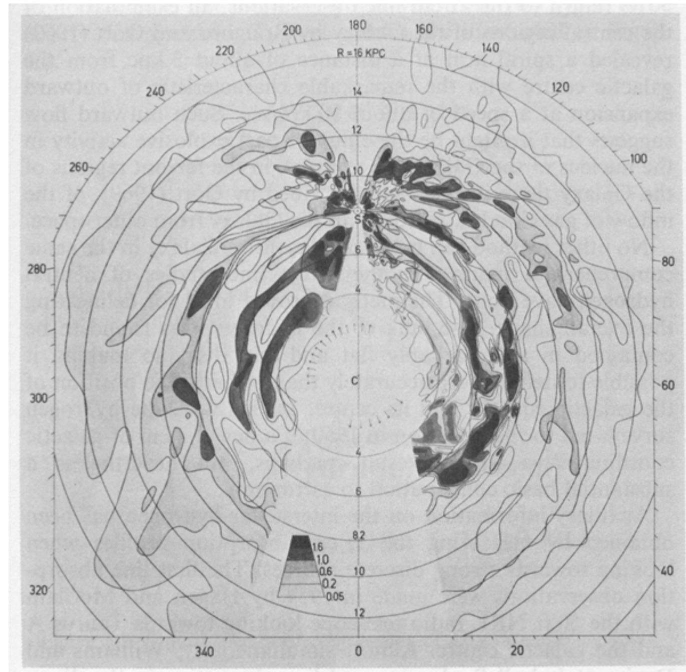
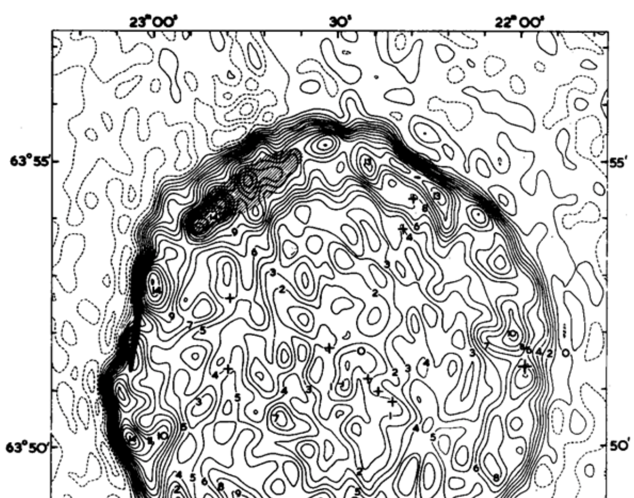
[5] Mills Cross at 35° 22' 15.53"S, 149° 25' 28.57"E
[6] Big Ear near at 40° 15' 3.36"N, 83° 2' 57.96"W
[7] Nancay antenna at 47° 22' 14.09"N, 2° 11' 50.66"E and Zelenchukskaya antenna at 43° 49' 33.49"N, 41° 35' 11.61"E

on the basis of their dynamic spectra. Additional classifications, Type IV and V, were added in 1958 and 1959. What makes the Sun attractive to amateur radio astronomers is the relative ease with which its emissions can be detected.



Although all the planets have been studied to some degree, Jupiter was the first planet to be observed by radio. Its emissions were discovered by accident. A Mills Cross antenna, using the same basic principles as already described but with 22 MHz dipole antennas, was built near Seneca Maryland in the USA, and used by B. Burke and K. Franklin in 1955 to survey radio sources at 22 MHz.[8] They noticed occasional interfering bursts of noise, which they studied over a period of months. They determined the bursts occurred about the same sidereal time, indicating a celestial source. On a hunch they plotted Jupiter's position over the period of their observations and found a precise correspondence. News of the discovery led another investigator, C.A. Shain in Australia, to re-examine recordings he made in 1951, in which he had experienced what he thought was interference. His analysis showed periodic variations in the bursts with a marked peak at each planetary rotation.

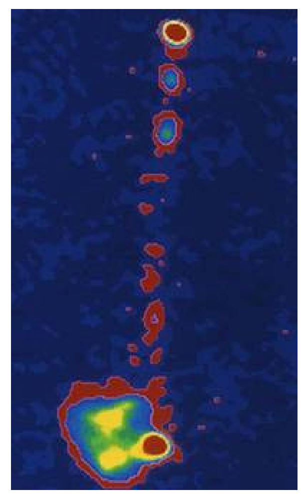


The chapter Radio Waves in the Galaxy describes the efforts to study the 21 cm hydrogen line from the northern and southern hemispheres in 1954 and 1959 These studies were combined and provided the first full-galaxy radio map of neutral hydrogen in the Milky Way (above-right, figure 6.1). The map clearly shows the spiral arms. Another interesting and very powerful radio source is the supernova remnant, or SNR. SNRs are the result of a star reaching the end of its life and exploding. The explosion blows out a huge shell of hot gas, and it is this gas shell that sends out radio waves (left, figure 6.4). The shell also emits light, so it can be observed by both optical and radio astronomers.

[8] Roadside marker at at 39° 4' 53.70"N, 77° 22' 21.75"W

Hey describes the many other types of radio sources in our galaxy. These include so-called radio stars, emission nebula, flare stars and pulsars. He provides easy-to-understand descriptions of each type, usually a paragraph or two. However, he devotes a couple pages to pulsars. Pulsars were first discovered in 1967 by Cambridge post-graduate student Jocelyn Bell as she processed charts associated with an unrelated project to study twinkling radio sources. She noticed recurrent signals when the antenna was pointed in a certain direction. Further study revealed a precise timing interval of about 1 second. It also was found that the pulses were dispersed such that the lower frequencies arrived later than the higher frequencies. This dispersion could be attributed to scattering of the radiation by interstellar electrons and, if so, could provide an indication of the pulsar distance.

The studies of radio sources beyond our galaxy are described in chapter 7. As methods and radio telescopes improved, so did radio maps of the more powerful sources such as the Andromeda Nebula. Much of this improvement was achieved by using better noise standards, better antenna calibration and many observations of the same source with different setups and equipment. Hey discusses “normal galaxies” and “radio galaxies,” the difference being that radio galaxies have far greater output at radio frequencies than normal galaxies. He describes the steps taken by radio astronomers to explain these phenomena but a lot of it was speculation at the time and still is today.



Quasars, or quasi-stars (also 'quasi-stellar radio' source) are unusual radio sources (right, source NRAO). According to Hey they were discovered in 1963. The first quasar was found by collaboration with an optical observatory. The position of a radio source coincided with an unusual blue star whose spectral lines were unrecognizable. Further investigations showed the object actually was a double-source, one of which coincided with the blue star. The other source had a faint jet associated with it. It was determined that the spectral lines indicated a very distant source. Of great interest was the conclusion that these quasars emitted radio powers comparable to the strong radio galaxies. A number of techniques and very detailed studies were required to make the necessary measurements and draw these conclusions.

The final subject in chapter 7 is of fundamental importance, and Hey devotes three pages to it – Cosmic Background Radiation, or CBR (also called microwave background radiation and cosmic microwave background, among other names). He describes the events and participants. As with many discoveries in radio astronomy, the CBR was measured while researchers were involved in an unrelated project. In this case, measurements were being made by R. Wilson and A. Penzias in 1965 on receivers to be used with the early communications satellites. The measurements yielded an excess noise temperature of about 3.5 kelvin (their original paper "The Measurement of Excess Antenna Temperature at 4080 Mc/s" is available from articles.adsabs.harvard.edu/full/1965ApJ...142..419P). This value was very close to the value predicted by theoretical studies of the early formation of the universe, the Big Bang theory (the current value is closer to 2.7 kelvin).

The final chapter in this book is chapter 8, The Scope of Radio Methods in Astronomy. The title states "radio methods" but there is no discussion of methods at all. Instead, it is a thoughtful discussion of how radio astronomy has contributed to our knowledge of the universe. Hey says "*The knowledge gained by radio astronomy can be divided between those areas where the role of radio has been to supplement basic information derived by optical astronomy and those aspects where previously unknown and predominantly invisible phenomena have been revealed by radio*." For the first area, he gives as examples the added knowledge of visible surfaces of the Moon and planets, solar chromosphere and flare stars. The second area is much greater and includes Jupiter emissions, interplanetary plasma, galactic distribution of neutral hydrogen, zones of high-energy particles and magnetic fields in radio galaxies, quasars, and many others.

As I was writing this review, I came to realize that ***Evolution of Radio Astronomy*** is much more than a history of radio astronomy to 1970. It is a very worthwhile book for anyone interested in learning about celestial radio sources, how they are thought to work and the processes of discovery. The book answers the basic questions: who, what, when, why, where and how. The descriptions of the physical processes involved in celestial radio emissions alone make this book a worthwhile purchase, and its purchase price is nothing to squawk about. It was written by one of the pioneers with hands-on experience who knew many of the other pioneers. Its only drawback is balance, which is understandable when you take national pride into account – if you stand the book on its edge it will tilt toward England.

Biography – Whitham D. Reeve

Whitham Reeve was born in Anchorage, Alaska and has lived there his entire life. He became interested in electronics in 1958 and worked in the airline industry in the 1960s and 1970s as an avionics technician, engineer and manager responsible for the design, installation and maintenance of electronic equipment and systems in large airplanes. For the next 37 years he worked as an engineer in the telecommunications and electric utility industries with the last 32 years as owner and operator of Reeve Engineers, an Anchorage-based consulting engineering firm. Mr. Reeve is a registered professional electrical engineer with BSEE and MEE degrees. He has written a number of books for practicing engineers and enjoys writing about technical subjects. Since 2008 he has been building a radio science observatory for studying electromagnetic phenomena associated with the Sun, Earth and other planets.