The 1974 Nobel Prize in Physics

The 1974 Nobel Prize in Physics was awarded to Sir Martin Ryle and Anthony Hewish for their work in radio astronomy.

Radio astronomy was discovered by K. G. Jansky in 1932 and continued by G. Reber and G. C. Southworth in the early 1940's, but it was not until the end of World War II that it started its remarkable growth. Bursts of radio noise from the sun had demanded an explanation because they might have been noise from German stations jamming the Allied radar systems. J. S. Hey and others provided the true explanation. The end of the war saw the return to their respective research homes of many physicists and radio engineers carrying in their heads the tremendous advances in electronics that the war had produced, and often carrying in their hands considerable amounts of surplus, yet valuable, radio equipment.

Martin Ryle had just joined J. A. Ratcliffe's research group at Cambridge after his student days under Lindemann (Lord Cherwell) at Oxford when the war broke out in Europe. He was at once drawn into the Telecommunications Research Establishment (now the Royal Radar Establishment) where he worked mainly on radar countermeasures. By the fall of 1945 he was back at Cambridge with several wartime friends, all convinced that a new, great field of observational astronomy lay open before them. The same thing happened in several other countries, among them Australia, the United States, the Netherlands, and France.

Most early observations were made of the noise from the sun, but soon the other radio sources discovered grew from a trickle to a flood; many theoretical workers were attracted, the possible cosmological implications of radio observations were recognized (and probably overemphasized), and H. I. Ewen and E. M. Purcell (quickly followed by others) observed the line radiation from atomic hydrogen which H. C. van de Hulst had predicted in a wartime colloquium at Leiden. The floodgates were open, the doubts of some more classical astronomers as to the value of these new results—so rapidly announced, so hotly disputed, and coming from workers whose astronomical credentials were surely, in some cases, at least questionable—were soon lost in the floodwaters. Radio astronomy was accepted as the sister science of optical astronomy, and both turned together to the task of understanding the universe, no matter what the wavelength of the quanta used to observe it. So all astronomers can be proud that Martin Ryle and Tony Hewish are their first Nobel Prize winners.

Ryle and Hewish were honored for their pioneering research in radio astrophysics—Ryle for his observations and inventions, in particular of the aperture synthesis technique, and Hewish for his decisive role in the discovery of pulsars. Ryle is the founder of the Cambridge group of radio astronomers at the Cavendish Laboratory, and Hewish joined the group in 1946.

Aperture Synthesis

The invention, development, and use of aperture synthesis runs as a thread through all Ryle's work. His early studies of radio noise from the sun used the radio analog of A. A. Michelson's stellar interferometer to measure the angular size of the active emitting regions. Ryle realized that any such interferometer observations with a given spacing between the two antennas was in fact a measure of one Fourier transform of the brightness distribution across the radio source. The first measurements were made by simply adding the signals from the two antennas, and showed the interference fringes from the small-diameter sources superimposed on the overall signals from the whole solar disk.

By phase-switching, which is equivalent to moving periodically the fringe pattern of the interferometer on the sky, the signals from the small-diameter sources were separated from the solar disk contribution. This technique, which became standard in observations of discrete radio sources, allowed the amplitude and phase of the interference pattern from a single pair of antennas to be found; this in turn led to aperture synthesis, where the signals from one or more pairs of antennas at various separations and orientations are used to build up a detailed map of the area of sky being observed. So long as the radio signals from the sky are unchanging with time, such a map can be made from observations taken over periods of many days; thus even a single pair of antennas, one fixed and one movable, could be used to synthesize a very large telescope. The extension to earth-rotation synthesis, where the rotation of the earth was used to alter the apparent spacing and orientation of the antenna pair as seen from the radio source, soon followed.

Ryle and his group have used aperture synthesis from the earliest days to make maps of individual radio sources, and they now have the 1-mile and the 5-kilometer antenna systems, which are both able to give essentially high-resolution radio photographs of small areas of sky. The Cambridge group have made a continuing series of surveys of the radio sources in the northern sky. Ryle early realized that many of the discrete radio sources might be far from our own galaxy and that a study of the numbers of sources with intensities above certain levels (the log N–log S relation) might be decisive in choosing between various cosmological models of the universe. The surveys were made first with fairly simple antennas at wavelengths of a few meters, and later, as the effects of confusion became better understood, with larger antennas at shorter wavelengths. In the first stages of this work there were strong disagreements about the experimental results, but these have now been essentially resolved, and log N–log S plots are known to be of considerable importance, although their cosmological significance is still not unambiguous.

Ryle's contributions to radio astronomy go beyond the specific achievements cited in the awarding of the prize. He has designed and built his electronic equipment (and made it work), developed computer programs, built antennas, contributed to the theories of the generation and propagation of radio waves in plasma, and—perhaps most important—helped to teach and inspire many newcomers to radio astronomy. He and his group of permanent associates have seen a generation of radio astronomers grow to maturity, to continue their work all over the world.

Although Hewish joined Ryle's group in 1946, he started work on the borderline between astronomy and ionospheric physics. There was considerable interest in Ratcliffe's radio group in the effects of the irregular ionosphere on radio waves passing through it or reflected from it. The reflected waves form a moving and changing intensity pattern on the ground, a study of which can tell the size, shape, and speed of motion of the ionospheric irregularities. The effects of the irregular ionosphere on waves passing through it was dramatically shown by the way radio signals from the Cygnus source fluctuated with time. Indeed, there was the possibility that the source itself fluctuated in its emission. As the ionospheric effects became better understood, it became clear to Hewish and others that the main effects at low frequencies were of ionospheric origin, but that some of the intensity fluctuations could also be due to the irregularities in the interplanetary medium.

Hewish showed how the scintillations of a radio source could be related to irregularities in the interplanetary plasma, particularly in the vicinity of the sun, and also to the angular size of the radio source. These two results follow from the theory of the diffraction of plane waves by an irregular, transparent, phase-changing screen, and Hewish was an early contributor to this work. Angular size and structure in the smallest radio sources had always been important and difficult to measure. The use of scintillations to estimate angular size derives from the fact that only the very small sources should scintillate; with sources of larger angular size the scintillations are smoothed out. Thus, the observations could be used to identify the smallest sources and estimate their size. For some years this has been an important method of finding source size, although by now it has been somewhat overtaken by the use of very long baseline interferometers.

In the course of making his observations, Hewish built a number of large fixed-array antennas, which he used with short averaging times to see the rapid intensity changes and with long wavelengths to enhance the effects of the interplanetary medium. In fact, as we now know, his experiment was very well designed to discover pulsars—and it did.

In July 1967, while a new large array antenna was being used at 3.7 meters to study the scintillations of compact radio sources, occasional regular, but ill-defined, trains of short pulses were observed. Jocelyn Bell, a research student working on the experiment, realized that these pulse trains might have an astronomical origin. They might, of course, be locally generated interference, or come from some unpublicized space probe, or be radar

Anthony Hewish (left) and Martin Ryle.

pulses reflected into the antenna, or even be the much discussed signals from another civilization. It took some time to establish the astronomical origin of the signals, and during this time the secret of their discovery was well kept. Although this delay may have irritated some workers, it was probably wise. When the discovery was announced the principal scientific facts were all clear, and the great interest in the pulsars was not confused, as it might otherwise have been, by sensational articles about little green men on other planets.

Further discoveries followed rapidly. It was soon clear that the pulsars were the predicted but hitherto unobserved neutron stars. The extreme accuracy with which the pulse periods could be measured showed that some pulsars are slowing down and that some have small sudden changes in pulse rate. The dispersion of the pulse velocity in the interstellar medium could be used to estimate distances (generally difficult in radio astronomy) and locate the known pulsars within our own galaxy. Only a few weeks ago the first pulsar in a binary system was found; although it is weak it will be invaluable both as a means of finding more about neutron stars and also as a system for testing relativistic mechanics.

The first Nobel Prize for work in observational astronomy has been won by two British scientists. Yet all who have worked in this field in the last 30 years should bask a little in the reflected glory, since the growth of the subject has been due to many workers all over the world. British astronomy has not been without its critics over the past years, and in some branches of the science it is possible to criticize the lack of a sensible long-term policy. But in radio astronomy there has clearly been a policy. British radio astronomy has been supported in the two centers of excellent work, at Cambridge and at Manchester. This has been a concentration of effort and funds; the small but good group at the Royal Radar Establishment has been allowed to lapse. Funds for new instruments have, up to now, alternated between the Jodrell Bank (Manchester) and Cambridge groups. Sir Bernard Lovell has recently completed the improvements to his old, great 250-foot telescope, and Sir Martin Ryle has brought the 5-kilometer synthesis telescope into action. Both observatories are associated with universities which supply excellent graduate students to do research in radio astronomy. There can be no doubt that this pattern has worked well in England, as in a number of other countries. In Australia and the Netherlands also, for example, a concentration of scientific effort into astronomy has been well repaid by the results.

It is possible that this Nobel Prize comes at a turning point in radio astronomy. By extension of the very long baseline interferometer technique, radio sources will be studied with instruments of high sensitivity, and angular structure will be resolved to 10^{-3} arc second. Ryle's telescopes, the Westerbork instrument in the Netherlands, and, in a few years, the Very Large Array in New Mexico will give detailed, accurate radio photographs of thousands of radio objects at a variety of wavelengths. The millimeter end of the radio spectrum has now become heavily used, largely due to the continued advances in microwave techniques, and new spectral lines from numerous molecular species have been discovered.

We may be entering a period of consolidation, of a general improvement in our understanding of the ways in which astronomical objects evolve and the ways in which matter, radiation, and magnetic fields interact to make the astronomical sky. But in radio astronomy we may also have the means to explore the two extremes of the physical universe—the properties of highly condensed matter in objects such as neutron stars, and the cosmology of the universe at its distant edge. If great results follow in these fields it will be pleasant to recall that this Nobel Prize went to two men who helped to show the way.

JOHN W. FINDLAY
National Radio Astronomy Observatory, Charlottesville, Virginia 22901

John Findlay has been active in radio astronomy for many years. He spent a period of years with the Cambridge group shortly after World War II.