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THE ROLE OF THE GIANT STEERABLE TELESCOPE IN RADIO ASTRONOMY

Some Milestones in the History of Radio Astronomy

Optical astronomy has been practiced for some two thousand years and, by comparison, radio astronomy has an exceedingly short history.

Radio astronomy began in the 1930's with the discovery by Jansky of the Bell Telephone Laboratories that residual noise signals were coming from the direction of the Milky Way. This was followed up by Grote Reber, who in a remarkable individual effort at his home in Illinois studied the radiation at considerably higher frequencies. There was much speculation as to where this radiation came from, and at the time there was reason to suppose that it came not from the stars but from the very tenuous matter in interstellar space. To Reber belongs the credit of building the first of the steerable paraboloids, an instrument 31 ft in diameter, which is preserved to this day at the National Radio Astronomy Observatory, Green Bank, W. Va.

The next important steps were taken soon after the end of World War II in Europe and Australia, when the two-element interferometer was introduced to give improved resolution at the rather long wavelengths then employed. Perhaps the most significant finding of this era was the discovery by Bolton that much of the noise from outer space came from discrete sources, a small number of which he was able to identify with comparatively well-known optical objects like the Crab Nebula.

This indicated that signals were coming not, as previously supposed, from matter in interstellar space but from discrete objects, many of which turned out to be of a nebular character, and many of which were outside the local galactic system.

The next exciting development came soon afterward from the optical astronomers. They found that the second strongest radio source in the sky, namely that in the constellation Cygnus, came from an exceedingly faint nebulosity with a red shift of one-third the velocity of light—at that time the most distant object known to mankind. This indicated the possibility that many of the radio sources much weaker than that in Cygnus, and so far not identified with optical objects, might well be beyond the range of the largest optical telescopes. Thus, far from being in a fledgling state, radio astronomy gave promise of penetrating to parts of the universe that had never previously been sounded.

The next basic discovery was made here in Massachusetts by Ewen and Purcell, who, in 1951, detected radiation from hydrogen in the ground state, on a frequency of 1420.5 Mc/sec. This discovery marked the opening of still another epoch in radio astronomy; it provided a tool for recognizing the presence of hydrogen, the most abundant element in the universe, and for measuring the velocity of this hydrogen relative to the earth by means of the Doppler shift.

To this discovery must be added the detection some 10 years later of radiation from the OH radical by Barrett and his co-workers here at MIT, followed soon afterward by the discovery of the recombination lines of helium and hydrogen and another as yet unidentified element.

The study of line radiation is now one of the most important and productive branches of radio astronomy. Along with the long-standing spectral observations of optical astronomy it has become the most powerful method of studying the constitution and abundance of elements in the universe. The great bulk of observational work on line radiation has been done by means of the steerable telescope, which is likely to remain the basic instrument for studies of this type.

Finally, I want to refer to the latest milestone, the discovery of quasars, the so-called quasi-stellar objects: that is, radio signals from objects that appear to be genuine starlike objects, as distinct from the radio galaxies that have become so familiar to us in the past 20 years. The excitement of this discovery is based on:

1. The red shifts found in many quasars now range up to 0.8 of the velocity of light. If one assumes that red shift is proportional to distance, it places them at a distance in excess of 10,000 million light years.

2. If the red-shift assumption is correct, the quasars are by far the brightest and most energetic bodies known to man. Their source of energy is so great that it cannot readily be accounted for by nuclear processes, and a great wave of speculation is in progress in an attempt to explain it.

3. If the red shift is not proportional to distance, most alternative explanations of the quasar's behavior run into serious difficulties and we have to admit that there is no satisfactory physical description of the behavior of quasars at this moment.

Quasars are a vast enigma, therefore, and the problems are certainly not clarified by recent observations. Their discovery has created great excitement in the astronomical world and the mystery, when resolved, is certain to revolutionize our concepts of how the universe is constituted.

The first accurate determination of the position and structure of a quasar came from the 210-ft telescope at Parkes, followed soon afterward by an optical identification and a determination of red shift from Mount Palomar. The number of properly identified quasars is now several hundred, mostly in the northern sky. Several hundred more exist in the southern sky, but their identification awaits the construction of optical telescopes of adequate power in the southern hemisphere.

Instrumentation for Radio Astronomy

Radio telescopes exist in a bewildering array of types. The layman is invariably confused by the different varieties and we have to admit that the radio astronomers are often confused too.

Radio telescopes may be classified into two broad types:

1. The steerable telescope, usually parabolic in shape.
2. The spaced arrays or unfilled aperture arrays, derived orginally from the two-element interferometer.

This is not the place to consider the relative merits of the two types.[1] It is sufficient to say that they are not competitive with one another—both have an important role to play in the future development of radio astronomy.

The choice between them is dictated almost entirely by one's requirements. Exaggerated claims are made for both types from time to time, but when the special pleading is stripped away, it will always be true to say that the steerable paraboloid is the general-purpose instrument, adaptable to any form of radio or radar astronomy, while arrays are special-purpose instruments, in the design of which great emphasis is placed on one objective, like the highest possible resolution. This is usually obtained at the sacrifice of some other characteristics, like ability to observe over a broad spectral range, or to receive signals in real time.

It follows that the unexpected discoveries of radio astronomy are more likely to come from the general-purpose instrument, which can be quickly adapted to new techniques and new discoveries as the science develops. There is less chance of a new discovery with an instrument that is specially designed with one preconceived purpose in mind.

If our purpose, therefore, is the widest possible range of astronomical studies covering source surveys, the spectra of sources over a wide frequency range, line radiation, polarization, and radar astronomy, there is only one choice, and that is the steerable telescope. If the purpose were different—for example a sky survey with the highest possible resolution or rapid-scan spectroscopy of the sun—the choice would also be different.

Fifteen years ago, the design of large radio telescopes was at a rudimentary level and few engineers had been introduced to the subject. Today the first generation of giant instruments exists and comprehensive measurements of their engineering performance have been collected. The remarkable agreement that exists between the calculated and the measured performance of some of these telescopes, notably the Haystack, the Parkes, and the Goldstone dishes, makes it clear that the design criteria are well understood and that larger instruments are entirely feasible.

My personal guess is that a diameter of 400 to 450 ft is attainable in the near future. However, such telescopes will only be built by employing the best engineering talent and the utmost sophistication in design. In 1952, the number of talented engineers involved in radio telescope design could be counted on the fingers of one hand. It is enormously encouraging that today the number actively engaged amounts to several hundred and most of them are represented in this Symposium.

Reference

1. J. P. Wild, "Instrumentation for Radio Astronomy," *Physics Today* **19** (No. 7), 28 (July 1966).