TOWARD A NATIONAL RADIO OBSERVATORY

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On July 26, 1956, the National Science Foundation announced that the Foundation will proceed with the purchase of a 5,000 acre site for an American inter-university radio observatory. The site, selected for the purpose after an exhaustive search carried on under the auspices of Associated Universities, Incorporated, is located near the towns of Greenbank and Arborvale in Pocahontas County, West Virginia. Congress has appropriated a sum of three and a half million dollars toward the purchase of the land, the design and construction of a 140-foot steerable paraboloid antenna of high precision and some smaller equipment, and the erection of the necessary buildings for offices, shops, laboratories, and some staff housing. Since the Foundation cannot itself operate facilities, studies and negotiations are now under way to determine which group or organization will be best fitted to receive from the Foundation the contract for the management of the new observatory and a decision is expected shortly. Following the award of the management contract, a Director will be selected, the nucleus of a staff will be appointed and the building program should then be able to get under way without delay. Once the new radio observatory is completed and in operation, American radio astronomers will have access to a research facility unequalled anywhere in the world.

In the present article, we shall first trace briefly the background for the development of radio astronomy in the United States and show why it is that this seems like the appropriate time for the National Science Foundation to proceed with the observatory at Greenbank. Next, we shall describe briefly the plans for the new research facility, and, finally, we shall outline some of the problems toward the solution of which the new radio observatory should contribute effectively.

A LITTLE HISTORY

Radio astronomy had its birth in the United States in the early 1930's, when Karl G. Jansky of the Bell Telephone Company discovered radio static reaching us from the direction of the center of our Milky Way system. Some of the basic early discovery work was done in the United States by Grote Reber and by J. C. Southworth. Reber, who began his work in the late 1930's, built himself a 30-foot paraboloid antenna and he was the first one to map the distribution of radio radiation reaching us from various parts of the Milky Way. Southworth's work came at the beginning of the war, and, because of war-time secrecy and confusion, it did not receive the attention it deserved, but he was the first one to detect and observe radio radiation reaching the earth from the sun. In the period immediately following the end of the war, American scientists showed far too little interest in radio astronomy research and the lead was taken by Great Britain, Australia, the Netherlands and Canada. Ten years ago, only one single university - Cornell - devoted major attention to research in radio astronomy and the Naval Research Laboratory in Washington had then only just entered the field.

In 1950 - 51, things began to stir radio astronomy-wise in the United States. Radio studies of the sun were being pursued regularly at Cornell, the Naval Research Laboratory, the National Bureau of Standards and the Carnegie Institution of Washington. Very little work was, however, being done anywhere in the United States in the study of radio radiation reaching us from our Milky Way system and beyond, a field in which the British and Australian groups were forging ahead at a rapid pace. In March 1951, there came the discovery by H. I. Ewen and E. M. Purcell of the Harvard Physics Department of radiation with a wavelength of 21 centimeters reaching us from neutral hydrogen atoms of the spiral arms and the center of our own Milky Way system. In the summer of 1952, Harvard Observatory, with the support of the National Science Foundation and of friends of the G. R. Agassiz Station, initiated its program of Milky Way studies with the aid of the 21-centimeter spectral line of neutral hydrogen and the Naval Research Laboratory and the Carnegie Institution also became active in this new field. At about the same time the Ohio State University program for the construction of large antennas for use in the study of radio radiation reaching us from our own and other galaxies began to hit its stride, and the first Ohio State radio maps of the sky began to appear. By the summer of 1952, six United States centers were conducting research in radio astronomy.

Almost from the day on which the National Science Foundation began operation, the Foundation saw that it had an important function to fulfill in furthering the cause of radio astronomy in the United States. Among the first fairly large grants that were approved, were one to the Agassiz Station Project of Harvard Observatory and one to Ohio State University for research in radio astronomy. In January 1954, the Foundation organized a symposium to survey the future prospects for radio astronomical research in the United States. This Washington symposium was very well attended and it engendered much enthusiasm among astronomers, physicists and electronic engineers. The Foundation intensified its support of radio astronomy, and other organizations, notably the Office of

Naval Research and the Air Force, entered the field. We have now ten United States institutions actively working in radio astronomy and five more have either just entered the field, or are about to do so. The number of active radio astronomers in the United States has increased in the past five years from half a dozen to twenty or more. Programs for graduate study are now actively under way at four universities and we expect three additions to this list this fall. Six doctors degrees in radio astronomy have been awarded in the past three years and the graduate students now in the field number about twenty. Increasingly, American astronomers are expressing a desire to participate in research in radio astronomy.

The United States is doing very nicely by now as far as instrumentation in radio astronomy is concerned. Five years ago the few available American radio telescopes were all rather small instruments, certainly small and relatively ineffective compared to the equipment then in regular use in Great Britain and in Australia. The turning point came with the construction of the 50-foot steerable paraboloid at the Naval Research Laboratory in Washington. It is a fine piece of equipment, which is often admired by travellers who come into or leave the National Airport in Washington, D. C.; since it is mounted on top of the roof of the Laboratory, right across the Potomac from the Airport, it can readily be seen from the air or the ground. Large aperture is important in radio astronomy for two reasons, the first being that we require a receiver of very large area to collect enough of the radiation (which is almost unbelievably weak), and the second being that a paraboloid of large aperture gives a higher angular resolution in the sky than does a small one. The 50-footer in Washington has made already some of the most important contributions to radio astronomy. From it we have learned much that is new about the distribution of radio radiation that reaches us from various parts of the sun and its atmosphere. The 50-footer again was the first instrument to record absorption features from neutral hydrogen observed in the radio spectra of distant discrete radio sources and it can claim at least two other firsts, the discovery of thermal radiation from gaseous nebulae such as the Orion Nebula and most recently from the atmosphere and possibly the surface of the planet Venus.

The largest radio telescope now in operation in the United States is Harvard's 60-foot George R. Agassiz Radio Telescope, but plans for the construction of several even larger ones are already beyond the talking stage. Before long, the Naval Research Laboratory will have an 84-foot radio telescope similar in design to that of Agassiz Station and 60-footers will soon arise at the Carnegie Institution in Washington and at the University of Michigan. At present the most ambitious university-sponsored project is at the California Institute of Technology, where a pair of 90-foot steerable paraboloids to be operated as an interferometer pair is under construction at a site near Bishop in California.

It would take us too far afield to describe in detail how these developments in terms of equipment and personnel have paid off research-wise. A few samples may however be helpful to show that we are really moving ahead.

We have already referred to some of the work at the Naval Research Laboratory. On the other side of Washington, the Carnegie Institution radio astronomers have discovered radio noise from the planet Jupiter, presumably originating by a process not unlike that which produces our thunderstorms, but on a very much larger scale. At Ohio State, the sky surveys have led to a very precise determination of the direction toward the center of the Milky Way system and, as a by-product, thunderstorm effects on Jupiter and Venus have been studied. At the Agassiz Station, the Harvard radio astronomers have learned much that is new about the fine structure of the interstellar medium of neutral hydrogen atoms and quite recently David S. Heeschen has detected there 21-centimeter radiation reaching us from the very distant cluster of galaxies in the constellation of Coma. T. K. Menon's studies of the neutral hydrogen content of the Orion Nebula and its surroundings are proving to be of considerable importance for cosmological studies of stellar evolution.

Since we are concerned primarily with radio astronomy research in the

United States, we have not referred here to research in other parts of the world. We should, however, mention briefly the efforts of our Canadian neighbors. At Ottawa, solar radio astronomy has been practiced for many years and another field in which the Canadians have excelled is radar research on meteors. There are several new developments under way in Canada, which include possibly a 60-foot or 84-foot reflector.

It is against the background of developing research experience and a growing acquaintance with instrumentation that we must see the plan for a national radio observatory. Whereas, four years ago, the construction of a 50-foot paraboloid was considered a major new engineering effort, we contemplate now with at least equal confidence the construction of a 100-foot steerable paraboloid. The step from a 100-foot to a 140-foot paraboloid seems like a relatively modest one and, from the engineering point of view, a safe one.

A few words should be added here about the at least equally spectacular developments in electronic engineering. In radio astronomy one generally has a choice between two methods for increasing the research potential of one's equipment, either to build larger dishes of greater precision, or to develop and improve the electronic apparatus used in receiving, amplifying and recording the very weak radiations that reach us from outer space. Radio astronomers left to themselves would be able to do little toward effectively improving the electronic situation, but here we are backed up by the rapidly growing great industry of electronic engineering. American radio astronomers have already benefitted very much by the happy accident that they are doing their research in a country in which there is much emphasis on research in electronic engineering.

Radio astronomy is obviously a very expensive science and it seems beyond the power of a single university or governmental laboratory to promote as a part of a much larger total effort the support and development of a radio telescope with an aperture in excess of that now being built by the California Institute of Technology. Since large equipment must soon become available if radio astronomy is to continue to grow in this country, the natural solution is to envisage a future inter-university radio observatory, sponsored and supported by the National Science Foundation and with equipment more powerful than that at any of the collaborating institutions. The first suggestion for the creation of such an observatory came from Harvard Observatory and the Massachusetts Institute of Technology about three years ago, and the National Science Foundation then requested Associated Universities, Incorporated (the same organization that has been responsible with such signal success for the operation of the Brookhaven National Laboratory) to make a feasibility study for the establishment of an inter-university radio observatory, to be located preferably within three hundred miles of Washington, D. C. This preliminary study has now been completed and the next step is to proceed with the purchase of the land, to arrange for a management group, to appoint a Director and the first staff members, and to start building with a minimum of delay.

THE RADIO OBSERVATORY AT GREENBANK

In the feasibility study for a national radio observatory, Associated Universities, Incorporated and the National Science Foundation, and the scientists, who worked with them, had to find an answer to several questions. The first was: are there sufficient major problems in radio astronomy to the solution of which the proposed national observatory would contribute? Second, provided the answer to the first question is an unequivocal "Yes", what type of instrument, or instruments, and what sort of an organization, might be expected to suit best the needs of American radio astronomers? Third, will it be possible technically to construct the instrument that seems desired at a cost which does not place it wholly out of reach? And, fourth, if we decide to go ahead, where would be the most suitable place in the United States to house the new national radio observatory?

The symposium of January 1954 gave in a way already an affirmative answer to the question of justification and the scientific developments since then have fully justified the conclusion that radio astronomy cannot progress effectively without very large and expensive equipment. After long deliberation, the choice fell upon a steerable precision paraboloid with an aperture of 140-foot as the first instrument to be constructed for the national radio observatory. The large metal, solid surface or wire mesh, dish in the shape of a paraboloid does for radio astronomy just about what the very large paraboloidal reflectors, like the 200-inch Hale reflector on top of Mount Palomar, do for optical astronomy. In radio astronomy, we are dealing at best only with very weak signals and since we wish to study the properties of these signals with highest possible precision, it is absolutely essential that we have a large collecting surface and that we squeeze all of the radiation impinging upon that surface into a single spot at the focus of the instrument. In optical and in radio astronomy, the paraboloidal shape is the ideal one for the purpose of collecting and focusing weak radiations from space. The second reason why large aperture is essential is that, with high mechanical precision of the instrument, the larger aperture provides for the greater resolution in the sky. If there were side by side in the sky three full moons each of them emitting radio radiation at a wavelength of 21 centimeters, then our 24-foot radio telescope at Agassiz Station would see the three of them as one single blur, but with our 60-footer we would begin to come near "seeing" each moon as a separate radio emitter, and with a 140-foot telescope we would have sufficient resolution to study the radio radiation from each moon-sized object separately. Our radio eyes give at best only a very fuzzy impression of what there is in the radio sky and unless we go to great aperture we shall probably never see the details really well.

After the decision to proceed with a paraboloid had been made, there was still a wide variety of instruments that could be considered. The planning for the American instrument had to be done, bearing in mind that one very large radio telescope is already under construction in Great Britain, the 250-foot steerable reflector for the Jodrell Bank Station near Manchester in England, and that another one, for Australia, is in the planning stage, presumably to be of comparable size. Because of the special interests of the radio astronomers now active in the United States, it was decided not to attempt the very largest instrument for the national radio observatory, but rather to concentrate at first upon a reasonably large one with, however, a surface of very high precision. There is general agreement among American radio astronomers that our first really big instrument must work very well at the wavelength of 21 centimeters, that of the famous hydrogen line, and that it is quite desirable to construct our radio telescope with sufficiently tight surface tolerances to permit its use without appreciable error for the recording of radio radiation with a wavelength as short as 7 to 10 centimeters. This means that the surface of the reflector should not deviate from a true paraboloid at any point by much more than one centimeter, or about two-fifths of an inch, and that this precision of surface must be maintained at all positions of the giant reflector. If we wish to use the instrument for the recording of radio radiation with wavelengths of 10 centimeters and less, we require also a very high precision of setting for the instrument and, along with this requirement, we must insist also on a very high precision of following. The tolerances for positioning and following should probably be between twenty and thirty seconds of arc, which means that we must be able to point our instrument with an error no greater than one-sixtieth part of the moons diameter and that we must be able to follow the motion of the object in the sky with comparable accuracy.

The above requirements presented a real challenge to the construction engineers and even now we cannot say that we have begun to solve all of the relevant problems. But it is already clear from the preliminary studies that have been made to date that with persistence and care and at a cost of the order of about two million dollars it should be possible to construct the instrument that we have described above. Sometime in the future, a whole article may be devoted to a description of the technical problems that are involved and to the decisions and choices that all of us interested in the realization of the project have had to face, but this would lead us now too far off our main topic. Suffice it to say that at the moment there are several good potential designs, each of them probably possible of realization, but the selection of the best and most suitable from among these designs is still a very difficult and responsible task.

For example, there is by no means agreement as to the type of mounting for the very large dish that will prove most suitable. Some favor the traditional type of alt-azimuth mounting, not unlike that of the 50-footer at the Naval Research Laboratory or the 250-footer now going up in Manchester, England, whereas others, including the writer, feel that there is much to be said for exploring with care the possibilities of an equatorial design, similar in principal to the design used customarily for large optical telescopes and applied with success to the 60-foot George R. Agassiz Radio Telescope. These are matters for competent engineers to decide and the astronomers, physicists, and electronic engineers can do little more than to state their minimum requirement.

While the principal emphasis will initially be on the 140-foot steerable reflecter, American radio astronomers are not losing sight of the potential usefulness of different sorts of equipment. At a well-equipped optical astronomical observatory, the large reflector may be the most impressive instrument, but there are generally a variety of special-purpose telescopes along with it. On Mount Palomar, for example, the 48-inch Schmidt with its large sky coverage is a powerful search instrument, which often serves as a guide to the astronomers working with the 200-inch Hale reflector. In the same way, a national radio observatory must think in terms of search equipment and various special-purpose radio telescopes. The large instrument now under construction at Ohio State University is the prototype for a future very much larger search instrument, which, at selected wavelengths, should be able to record radiations reaching us from radio sources far beyond those accessible to the 140-foot precision instrument. Ingenious instruments of great power have also been designed to search for and study discrete radio sources of very small angular dimensions and to pinpoint their positions with accuracy. The interferometer pair of telescopes now under construction for the California

Institute of Technology is an example of such a piece of equipment and so, according to a totally different design, is the "Mills Cross" at the Carnegie Institution of Washington, an instrument that provides a very narrow pencil beam for search purposes. Still other types of equipment have been built and are being proposed for special studies of the radio radiation from the sun. Some of these types of equipment will undoubtedly have to be erected in due time at the national radio observatory, but others may well be located near university, governmental or Foundation observatories or laboratories where they are especially wanted. The large paraboloid has the advantage over most of its competitors that it is an all-purpose instrument, capable of receiving and focussing radiation over the entire range of accessible radio wavelengths, and adaptable for use with many different varieties of electronic receiving and recording equipment. The large paraboloidal reflector is therefore an ideal instrument for an inter-university radio observatory. Sensitive electronic equipment built and tested in a preliminary fashion at a university observatory or laboratory, can be brought to the central radio observatory to operate on one of the finest high resolution radio telescopes in the world.

Where was the national radio observatory to be located? Many different considerations went into the problem of site selection and here the radio astronomers of the United States will for ever be indebted to Dr. Richard M. Emberson of Associated Universities, Incorporated, who conducted a most through search, which led to the present site selection. The preferred site was to be somewhere within relatively easy reach of the universities and research centers in the Northeast, Midwest and the Southeast. It should be at a place where there would be maximum freedom from radio interference, which is already limiting severely the operation of many radio telescopes now in existance. It should be in a region free from hurricanes and high winds and preferably at a place without excessive snowfall. All these requirements seem to point toward a site a few hundred miles to the southwest or west of Washington, D. C. To prevent excessive interference, a radio observatory - in marked contrast to an optical observatory, almost always on a mountain top - should be in a flat and shallow valley, preferably surrounded by mountains rising 1500 feet or more above the floor of the valley. The site should ideally be separated by two or three mountain ridges from centers of civilization and industry (prime sources for disturbing man-made radio noise!), so that the more disturbing man-made signals will bounce off the mountain sides before they reach the site of the radio observatory. The rather remote valley near Greenbank and Arborvale in West Virginia (at an altitude of 2600 to 2700 feet) seems to be the answer to the radio astronomers' prayers. One has a valley with at least 5000 acres of relatively flat land. The nearest large town is Elkins, West Virginia (about 50 miles), which has an excellent airport but which produces fortunately relatively little disturbing radio noise; mountains that rise to over 4500 feet shield Greenbank from Elkins. An astronomer can start in the morning from Boston or New York, Chicago or Cleveland, Ottawa or Toronto, New Orleans or Memphis, proceed by plane to Elkins and by car to Greenbank, to arrive in Greenbank sometime toward the middle of the afternoon. Radio noise at Greenbank is at present minimal; the intensity of the disturbing radio noise appears on the average to be less than one-tenth of one percent of the existing noise at the site of the 50-foot radio telescope on top of the Naval Research Laboratory in Washington. The National Forest that covers the hill surrounding the Greenbank site offers excellent protection against the unexpected appearance of man-made noise and the state of West Virginia has been most cooperative in its plans to enact further protective legislation. All in all, the Greenbank - Arborvale valley looks like the Shangri-la of the radio astronomers of the eastern United States.

RESEARCH OBJECTIVES

It is extremely difficult to define the research objectives for an inter-university radio observatory of a national character. The research program for the 140-foot reflector will not be set by the Director and staff of the new radio observatory, but it will express directly the wishes of the visiting scientists from the cooperating university groups. It is expected that each year there will be at Greenbank at least as many visiting scientists as permanently resident staff members, and the understanding is that the permanent staff members will spend about half of their available time assisting the visitors in the carrying out of their investigations. Initially, the principal emphasis will be on the 140-foot reflector, but we have already noted that in the future there will almost certainly be at Greenbank additional specialized equipment for solar research, radio interferometers and pencil-beam apparatus, and possibly also a large search instrument of the variety now being built at Ohio State University. If the 140-foot reflector proves to be a really successful instrument, and a productive one, then there may arise a demand for a larger precision steerable paraboloid; apertures of 250-feet and 600-feet are not out of the question (the United Nations building in New York is just about 600 feet high). In the present article, we shall limit ourselves, however, specifically to programs that seem to be within reach of a 140-foot steerable paraboloid reflector.

Research on the properties of neutral hydrogen through the 21-centimeter line will surely rank high on the first list of projects for the new radio observatory. Our existing radio telescopes with apertures up to 60-feet have already demonstrated conclusively that it lies within the power of a 140-foot instrument to take up seriously the task of unravelling the cloud structure of the interstellar gaseous medium. With a really narrow pencil-like beam, we can probe for fine structure in the distribution of the 21-centimeter radiation over the sky and it should become possible to locate small and dense concentrations of neutral atomic hydrogen, which may be gas clouds on the way to condensing into young stars. For future studies of stellar evolution, it is most necessary that we examine all known star clusters and stellar associations for associated neutral atomic hydrogen gas, and it is equally important that we should know to what extent certain observed peculiarities in stellar atmospheres are associated with nearby excess interstellar neutral atomic hydrogen. Another topic for future research in which the large radio telescopes can help effectively is that of locating the regions near the central plane of our Milky Way system which are devoid of neutral hydrogen gas. We want to know also how much of the neutral hydrogen resides in the very rarified regions between the spiral arms of our Milky Way system.

The new large precision radio telescope should have a stimulating effect upon electronic development. One should always bear in mind that a large piece of hardware such as our 140-foot radio telescope is useful to science only to the extent to which the electronic apparatus attached to it produces a precision record. The electronic apparatus that is now being used for 21-centimeter research is remarkably good, but with a given radio telescope we would be able to obtain far better and more significant scientific results if the sensitivity of the recording equipment could be increased three or ten-fold, if the inherent instrumental radio noise fluctuations could be reduced by a factor of ten and if we could be absolutely sure of the level of zero intensity of radio noise reaching us from outer space. The effectiveness of a large radio telescope depends on three elements: the quality of the mechanical apparatus, the quality of the electronic apparatus, and the quality of the scientific personnel that plan the programs and operate the equipment. One may well defend the thesis that it is a wise policy to match every dollar spent on mechanical apparatus with one dollar for electronic research and development, and another dollar for scientific salaries.

The radio astronomer interested in 21-centimeter research can now explore effectively our own Milky Way system and, thanks to the fact that the 21-centimeter radiation passes undisturbed through the dust clouds of our system, we have already penetrated to parts of our Milky Way that seemed for ever out of reach by the traditional optical techniques of observation. Until about a year ago, there was no observation of 21-centimeter radiation from beyond our Milky Way system, but since then A. E. Lilley and E. F. McClain at the Naval Research Laboratory in Washington have discovered absorption effects from neutral atomic hydrogen in the Cygnus Radio Source at a distance of approximately 200,000,000 light years from the sun, and we have already noted that D. S. Heeschen at the Agassiz Station has discovered 21-centimeter emission from the Coma cluster of galaxies at a distance of approximately 75,000,000 light years from the sun. This is just the beginning. The Great Spiral in Andromeda has not yet been "seen" 21-centimeter-wise, but it should succumb very soon. There is some hope that our radio telescopes with apertures of 60 to 100-feet may be able to detect it and it will almost certainly be within reach of the 140-footer. Our southern neighbors in Australia really have a corner on the market as far as extra-galactic research is concerned, since they have in their sky the two nearby satellite galaxies to our own Milky Way system, the two star clouds of Magellan. The results obtained to date by the optical astronomers at the Commonwealth Observatory and the radio astronomers in Sydney give some indication of the rich rewards that lie in store once we can record and study the 21-centimeter radio radiation from the Andromeda Nebula and other galaxies beyond our Milky Way system.

Before we leave the 21-centimeter field, two points remain to be noted.

First, the radio astronomer who attempts to interpret his 21-centimeter records finds it necessary repeatedly to call on assistance from the optical side, and now the time seems to have arrived where the optical astronomer must in turn go to the radio astronomer for information to interpret his optical date. In other words, radio astronomy is not a separate science, but it is just one of many techniques for the study of the universe. It so happens that today the 21-centimeter radio astronomer is the only one who has observational access to the most common type of interstellar gas, neutral atomic hydrogen. For the future, great scientific results may be expected from a proper blending of the radio astronomical and optical techniques of observation. The Greenbank staff members should plan on making frequent trips to the great optical observatories in the western United States and, vice versa, our pure optical brethren will be able to benefit tremendously from a close association with the radio astronomers.

Second, the results of the past year on the neutral hydrogen associated with the Cygnus source and the Coma cluster of galaxies show that radio astronomical studies have important contributionsto make to the theory of the expending universe. The features that were observed at the Naval Research Laboratory and at the Agassiz Station are all shifted in wavelength relative to the normal wavelength of the 21-centimeter line. This shift is almost certainly caused by the recessional velocities of the very distant galaxies. It has been very encouraging to note that the shifts in radio wavelengths that are predicted on the basis of the recessional red shifts measured with the optical telescopes at Mount Palomar and Mount Wilson

Observatories, are just about the right ones observed at the radio wavelength of 21-centimeters. In other words, radio astronomical data have already provided an important basic check on the properties of the expanding universe and more such checks are sure to follow.

The 140-foot reflector will be able to make significant contributions to the studies of the radio continuum, that is the whole band of frequencies of the radio spectrum now within reach. The new large reflector should prove especially useful for the study of the radio-brightness distribution as a function of wavelength in the radio spectra of many discrete sources. The high angular resolution of the 140-foot paraboloid will here be especially helpful. Because of the simplicity of interpreting records obtained with a paraboloid, the new large reflector should also be able to pinpoint radio sources quite precisely, and thus help considerably in the optical identification of the relevant objects in space. The fact that the 140-foot reflector is to be an instrument of high precision as far as surface tolerances are concerned will be most helpful in the centimeter wavelength range; the new radio telescope promises to open up the whole field of research of thermal radiation of gaseous nebulae in the centimeter range.

One should bear in mind that for the present we have only one single identified spectrum line, the 21-centimeter line of neutral hydrogen, in the radio spectrum. There should be numerous other lines, but these are too weak to be detected with present-day equipment. However, when we combine the increasingly more sensitive types of electronic apparatus that will be built in the years to come with the powerful large receiving area of the 140-foot reflector, we should be able to search hopefully for other radio spectrum lines. High on the preferred list are now a radio radiation from the OH molecule near a wavelength of 18 centimeters and a spectrum line for the deuterium atom (heavy hydrogen) near 90 centimeters wavelength.

While the major justification for a paraboloid antenna with an aperture of 140-feet or more rests upon its research potential for galactic and extra-galactic studies, an instrument of this sort has great possibilities for solar research and for studies of the solar system.

In studies of the radio radiation from the sun, much attention is being paid these days to very rapid variations which are observed at the time of solar outbursts or flares. The large paraboloid can serve here two purposes. The first is that it should assist considerably in the pin-pointing of these eruptions and make it possible to identify with precision the optical equivalents of certain radio outbursts. Second, much attention is now being paid to the very rapid changes in intensity distribution over the radio spectrum that occur as an outburst or flare makes its effects felt in higher and higher layers of the sun's atmosphere. The very large aperture and receiving area of the 140-foot reflector will make possible ultra-high-speed recording of the resulting radio radiations, which is something for which the astrophysicists and theoreticians in the solar field are now clamoring.

We should finally not overlook the great potential value of the large paraboloidal reflector for studies of the planets. We have already mentioned earlier in this article the recent discoveries of radio radiation from the atmospheres of the planets Jupiter and Venus, caused in part by a phenomenon resembling giant thunderstorms. In the case of the planet Venus, the pure thermal radiation from the outer parts of the planet has now been detected at the Naval Research Laboratory. Further studies of Venus and Jupiter are certainly in order and the high angular resolution of the 140-foot reflector should assist immeasurably in producing clear and undisturbed signals. Other planets, notably Mars and Saturn, should be added to the list for observation.

Ever since the day on which the first terrestrial radar signals were reflected off the surface of the moon and received with a time delay of about two seconds, radio astronomers and electronic engineers have dreamed about the time when it would be possible to bounce signals off one of the planets, with Venus, Mars and Jupiter on the preferred list. We have purposely avoided dealing with radar astronomy in the present article; it concerns itself with the study of radio pulses sent out from the earth and reflected by objects in space. At the moment electronic techniques are not yet capable of pruducing the sort of signal, very powerful, in a very narrow wavelength band, and of very short duration, needed for work on Venus and Mars but once electronic research and the electronic industry provide us with the necessary tubes, the 140-foot reflector looks like the ideal instrument for initial tests.

There appears to be ample scientific justification for the construction now of a 140-foot precision paraboloidal reflector and scientists everywhere will look forward to the time when the first fruits of scientific research will be produced by the new instrument.

WHAT SHALL WE NAME THE OBSERVATORY?

Since the present article is wholly in the nature of an informal and unofficial progress report, it does not seem out of order to mention here a suggestion that has been made regarding the naming of the new radio observatory at Greenbank in West Virginia. At a meeting this spring of the advisory group of Associated Universities, Incorporated, President Lloud V. Berkner made the suggestion that the observatory should be named the KARL G. JANSKY OBSERVATORY, in honor of the American discoverer of radio astronomy. There has as yet been no formal action on this suggestion, but it is one which thus far seems to have met with universal approval from those who have considered the question of a name. May the Karl G. Jansky Observatory soon come into being and may it be a credit to American science!