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National Radio Astronomy Observatory
Green Bank, West Virginia

Quarterly Report

April 1 - June 30, 1965

RESEARCH PROGRAMS

85-foot Telescopes		Hours
Scheduled		1837.5
Equipment installation and scheduled maintenance		216.75
Time lost due to:	equipment failure	78.0
	weather	0.5
	interference	28.75
	power	0.5

The above data reflects the use of the 85-foot telescopes as an interferometer and includes some simultaneous single dish calibration programs by the interferometer group. The interferometer was principally used for three observing programs. Accurate source positions and aperture synthesis programs initiated at Station 2 were continued. The third program, which will be continued for most interferometer spacings, is a visibility survey of a large number of sources. This survey for the most part will be used to select sources for detailed observations involving the other two programs.

On May 26, the 85-2 telescope was moved from Station 5 to Station 4. New front end boxes were installed on both telescopes, which include provision for feed box rotation to enable polarization measurements.

A lunar occultation was observed by S. von Hoerner with the 85-1 telescope while the 85-2 telescope was being readied at Station 4.

300-foot Telescope		Hours
Scheduled		1951.5
Equipment installation and scheduled maintenance		121.25
Time lost due to:	equipment failure	55.75
	weather	6.75
	interference	0
	power	0.5

Observations continued with the cross-polarized 1415 MHz receivers and the 750 MHz off-axis receiver. Investigations were conducted as follows. M. Kaftan-Kassim continued observations of planetary nebulae. P. Mezger evaluated the power pattern of the three antennas on the telescope.

M. DeJong mapped the continuum surrounding selected galaxies. P. Palmer (Harvard) concluded polarization measurements of Mars at 1415 MHz. H. Wendker continued measurements of the Cygnus X complex. Observations of M 31 to supplement University of Illinois investigations were taken by G. Swenson (University of Illinois). F. Ellis (Louisiana State University) concluded his program to map portions of the Galactic Spur.

During this quarter the autocorrelation receiver was re-installed as a hydrogen-line receiver. K. Riegel (University of Maryland) observed neutral hydrogen in the vicinity of HII regions. W. Howard and G. Westerhout (University of Maryland) observed selected galactic clusters. C. Heiles (Princeton University) continued thesis work involving high latitude interstellar clouds. M. Roberts observed extragalactic systems, and G. Herbig (Lick Observatory) observed HI profiles along a declination strip centered on Zeta Ophiuchi.

Two additional off-axis systems operating at 234 MHz and 405 MHz were installed and used by W. Erickson (University of Maryland) for two weeks to observe the solar occultation of Taurus A.

140-foot Telescope

Adjustment of the surface panels, installation of cables, painting of the surface, installation of the remote focussing and feed rotation assembly, installation of telescope position indicators, modification of the declination brakes, test and calibration of drive, control and braking system were completed during this quarter.

S. von Hoerner observed the lunar occultation of two sources at frequencies of 234 MHz, 256 MHz and 405 MHz. A receiver operating at 5009 MHz (6 cm) was installed with the capability of doing either continuum or HII line search observations. P. Mezger began antenna evaluations and M. DeJong began a pointing program. Preliminary data suggests the dish to have 50 $\pm$ 5(m.e.)% aperture efficiency at 5009 MHz. Work is continuing to put the telescope into final operating condition.

Millimeter Wave Program (1 millimeter and sub-millimeter)

A second field trip to Mount Palomar to use the 200-inch telescope at 1.2 mm was successfully completed during the period June 3-8. Confirming measurements were made of the Moon, Mars, and 3C 273; new measurements were made of Saturn, M 17, and 3C 279. In addition, a newly designed method of beam-switching was successfully tried, which effectively doubles the "on" source time and almost completely eliminates receiver output fluctuations due to rapidly varying atmospheric conditions.

Instrumentation for the NRAO 36-foot telescope at 1.2 mm is being carried forward, and should be completed by August 1st. This includes construction of an improved receiver back-end, development and construction of a 2-liter helium dewar to provide 24-hours of observing with one charge of helium, and special liquid helium transferring equipment to allow "in-feed" charging of the dewar.

The following programs are being carried out in the sub-millimeter region (6-300 microns):

a) Construction of a dual bolometer photometer for the 6-20 micron region was completed and initial observations made. These indicated a substantial improvement in overall system efficiency over the single detector method of observing.

b) Initial observations were made in the 20 micron window (18-20 microns) of several planets, a few stars, and the moon. The lunar data indicates the presence of several hot regions in the dark portion of the moon which apparently are not cooling at the same rate as the surrounding regions.

c) Discovery of what appears to be true infrared stars. These objects have very faint visual magnitudes (above 22^m), but are very bright in the infrared. Observations at several wavelengths in the 2-20 micron region indicates a temperature of about 700°K for the brightest. To date about 60 of these objects have been detected.

d) The services of a U-2 type aircraft have been made available to the University of Arizona, and construction of a receiver to measure the absolute temperature of the sun above 95% of the atmosphere is underway.

ELECTRONICS DIVISION - EQUIPMENT DEVELOPMENT

The autocorrelation receiver has been installed on the 300-foot telescope. The receiver and auxiliary equipment have been operating satisfactorily. Also, during this quarter two low-frequency systems were installed on the 300-foot telescope to observe the Taurus A occultation by the Sun.

Lunar occultation equipment, consisting of 3 radiometers operating on 234 MHz, 256 MHz, and 405 MHz, were installed for use on the 140-foot telescope.

A 5000 MHz (6 cm) receiver has now been mounted on the 140-foot telescope. This receiver is being used for pointing and efficiency measurements. Plans call for the installation of receivers at 2 cm and 11 cm during the next quarter. The 2 cm system will provide information on the surface panel accuracies and panel alignment.

The revised interferometer system continues to operate satisfactorily. Rotating feeds have been installed after some mechanical difficulty. With the exception of a new parametric amplifier, installation of any new equipment, including the phase lock loop, will be deferred until new feed supports are installed which will permit interchangeability with 140-foot type systems. Construction of a digital system to allow the recording of 85-1 telescope position data is in progress.

The control computer (DDP-116) and auxiliary equipment for the 36-foot telescope, ordered from Computer Control Corporation, is scheduled to be shipped during the third week of August.

Projects have been started to construct two wide band tunnel diode radiometers for the 140-foot telescope. The systems will operate on 5000 MHz and 15.375 MHz, respectively.

The following Electronics Division Internal Reports were issued during the past quarter.

No.	Title	Author	Date
46	Antenna Temperature Measurements of the Aero Geo Astro Modified Horn Reflector	James Dolan	April 1965
47	Interferometer Digital Output System	Claude Bare	April 1965

THE NRAO MILLIMETER WAVE ANTENNA

Telescope and Dome Fabrication--Rohr Corporation

Fabrication of the dome was essentially complete by early June and the components, after a pre-erection test at Rohr, were shipped to Kitt Peak.

The main components of the telescope, the base structure, and the yoke were completed by Rohr by early June. During June the fabrication of the dish had proceeded to the point where the surface aluminum panels, which had been pre-formed to the correct shape, were being welded onto the backup structure. This back-up structure had already been made, placed on the 50-foot machine, and the upper edges of the ribs and support members had been machined to the correct shape to accept the dish surface.

The welding of the surface panels proceeded slowly, since it was necessary to control the deformation of the dish during welding.

On-Site Work at Kitt Peak

The foundation work for the telescope and the dome was essentially complete by early June. The control and observing building, which is within the dome, was also completed.

Erection of the dome was started in the first week of June and proceeded satisfactorily, although a state-wide strike of operators has caused some delay. By the end of June the main structural members of the dome were erected.

The first road access to the site was by a temporary road made for us by the KPNO staff. A permanent access road, which takes off from the main Kitt Peak access road some way below the picnic area road, and which runs direct to the site, has been built. This road is 1135 feet long, wide enough to permit the movement over it of the 36-foot dish, and with a maximum grade of 14%.

Plans for moving the dish to the site over the state roads of California and Arizona are essentially complete. Both states will permit the movement, although in size the load is probably bigger than any previously moved load. The weight is, of course, only modest. A special trailer has been modified to carry the dish. The move to the site will take several days.

Electric power at the site on Kitt Peak is at present being supplied from a 75 KVA generator lent to us by Kitt Peak. Difficulty is being experienced in getting a good bid on the installation of a permanent power line.

Miscellaneous

William Terrell has been selected to be the first telescope operator of the 36-foot, and he has already moved to Tucson. A small office building has been provided us by KPNO and is being set up for occupation in early July.

ANTENNA DESIGN STUDIES

The Largest Feasible Steerable Paraboloid

The engineering group met in May in Charlottesville and will meet again on July 9. Progress has been made on the study of the floating sphere antenna and on the azimuth steerable transit with limited elevation movement. A request has been made that the large body of design and study work done for the 600-foot Sugar Grove instrument be made available to the group for study.

The Very Large Antenna Array Project

Studies of appropriate array configurations have continued. It will be some time before a definite choice of configuration can be made, since there are so many parameters to be considered in making an analytical optimization. Many specific examples are being investigated in an effort to understand the consequences of various choices of parameters. Computer programs have been written and tested to compute hour-angle tracks in the Fourier Transform (F.T.) plane for various array configurations and to determine the degree to which a configuration fills the F.T. plane with sampling points. Studies of the desirable degree of redundancy in sampling are also under way.

The National Bureau of Standards (CRPL) has demonstrated a phase-stable tropospheric radio link for transmitting local-oscillator signals over long distances. The project has been carried out under contract with the NRAO in support of a proposed long-baseline interferometry program to study the effects of the atmosphere on phase coherence over long distances, since a cable transmission system for the local oscillator signals (as used in the present NRAO interferometer) would be prohibitively expensive for the distances contemplated. The pilot project at NBS-Boulder was established to determine whether or not the requisite phase stability could be achieved by a phase-compensated radio link. The project has been entirely successful;

phase synchronization to within three degrees (peak-to-peak) has been demonstrated for periods of several hours at a time on a number of different occasions. Thus, the feasibility has been demonstrated of operating a phase synchronized radio interferometer with baselines of the order of 15 km. There appears to be no reason why much longer baselines could not be achieved.

Three suitable proposals for supplying the 40-foot portable paraboloid have been received from industrial firms, and it is anticipated that a contract will be negotiated shortly. This instrument will be used in conjunction with one of the 85-foot dishes at Green Bank and a radio-link system as discussed above, to study atmospheric effects on long-baseline interferometers. Once the problem is sufficiently well understood, a second 40-foot dish may be acquired to provide a portable site-testing interferometer for the very large antenna array.

Site selection studies were initiated by a visit to the Florida Everglades by Swenson, at the invitation of Dean S. F. Singer of the University of Miami. Surprisingly, the site is attractive in several respects, particularly with regard to structural characteristics, accessibility to the amenities of Miami, low latitude, and isolation from local sources of radio noise. Unknown factors, which may be all-important, are prevalence and severity of high winds (hurricanes) and the influence of local tropospheric conditions on phase coherence over long baselines.

PERSONNEL

Dr. Kenneth Kellermann, a recent NSF post-doctoral fellow, CSIRO, Division of Radiophysics, has accepted a three year appointment as Assistant Scientist. Dr. Kellermann's interests are in radio source spectra and planetary radio astronomy.

Mr. Frank Bash, an astronomy student at the University of Virginia, is undertaking his Ph.D. thesis research work here. This research involves a survey of about 200 bright 3C sources with the interferometer for the purpose of gathering statistics on source size and separation.

Mr. Kurt Riegel and Mr. Aage Sandqvist, students at the University of Maryland, are spending several weeks here on guest appointments. Mr. Riegel is doing his Ph.D. thesis research work on 21 cm observations of HII regions. Mr. Sandqvist is assisting Dr. G. Westerhout in his HI survey of the galaxy.

Dr. David R. W. Williams, University of California, Berkeley, was here during the quarter on a guest appointment, working on hydrogen line absorption measurements in collaboration with Dr. Menon.

Attached as an appendix is a list of the undergraduate and graduate students working here this summer. Four of the undergraduate students: Jerome L. Cross, Hermann Flaschka, Katherine Moyd, and Andrew Tanenbaum, are assigned to the National Science Foundation Undergraduate Research Participation Program.

Mr. F. J. Callender has accepted a position with the University of Hawaii, in their budgeting and management division, and left the Observatory on June 15.

Mr. John Gallagher, Chief Accountant, left the Observatory to accept a position as controller with an automobile parts manufacturing company in Tappahannock, Virginia.

Mr. Michael Kaiser, Programmer in the Computer Group, accepted an appointment with the programming staff of Wolf Research and Development Company, College Park, Maryland, and has now left the Observatory.

Mr. Richard Bird, Programmer in the Computer Group, left the Observatory to accept a programming position with an independent telephone company in Tampa, Florida.

Upon the completion of the 140-foot telescope construction, Peter H. Good, Technical Photographer, accepted employment with Brookhaven National Laboratory.

APPENDIX A

Students at NRAO, Summer 1965

Undergraduate Program

Richard L. Branham	Georgetown University
Jerome L. Cross	Carnegie Institute of Technology
Hermann Flaschka	Georgia Institute of Technology
Nancy H. Remage	Wellesley College
Leon M. Morrison	University of Florida
Katherine Moyd	Cornell University
Anita Petelinek	Notre Dame College
James A. Steppe	North Carolina State College
David W. Stowe	University of Wisconsin
Andrew Tanenbaum	Massachusetts Institute of Technology
Michael F. Thorpe	University of Manchester (England)
David Klein	Carnegie Institute of Technology

Graduate Program

John M. Comella	Cornell University
Robert R. Davies	University of Wisconsin
Michael Dewey	University of Michigan
Philip E. Heckman	University of Chicago
Norman J. Johnson	University of Michigan
Amar Maheshwari	University of Chicago
Theodore Schoenbeck	Ohio State University
Rebecca Gordon	University of Michigan
Kurtiss Gordon	University of Michigan

APPENDIX B

A list of Observatory reprints issued since June 30, 1964. See the NRAO Quarterly Report for April 1-June 30, 1964, for reprints issued prior to June 30, 1964.

Series A

No.	Title	Author	Reference
26	Lunar Observations at 10 and 1.2 mm	Frank J. Low	A.J. 69, No. 2, March 1964
27	West Ford and the Scientists	J. W. Findlay	Proc. IEEE, 52, No. 5, May 1964
28	A Radio Survey of Galaxies	D. S. Heeschen C. M. Wade	Astron. J., 69, No. 4, 1964
29	Radio Telescopes	J. W. Findlay	IEEE Trans. on Mil. Elec.,MIL-8, Nos. 3-4, 1964
30	Requirements for Cosmological Studies in Radio Astronomy	S. von Hoerner	IEEE Trans. on Mil. Elec.,MIL-8, Nos. 3-4, 1964
31	Thermal Galactic Sources	T. K. Menon	IEEE Trans. on Mil. Elec.,MIL-8, Nos. 3-4, 1964
32	Determination of the Galactic Rotation Parameters from Cepheid Radial Velocities and Their Variation with the Distance Scale	W.E. Howard, III and J.G. Kirk	A.J., 69, No. 8, 1964
33	Infrared Brightness Temperature of Saturn	F. J. Low	A.J., 69, No. 8, 1964
34	Absolute Spectra of the Strongest Nonthermal Radio Sources in the Wavelength Range Between 2 and 100 cm	J.W.M. Baars, P.G. Mezger, and H. Wendker	A.J., 69, No. 8, 1964
35	Properties of Galaxies: Color-Magnitude Diagram	Craig Chester and Morton S. Roberts	A.J., 69, No. 8, 1964
36	Recent Discoveries in Radio Astronomy	Morton S. Roberts	Physics Today, Feb. 1965
37	The Polarization of the Thermal Radiation of the Moon at 14.6 GHz	J.W.M. Baars, P.G. Mezger, N. Savin and H. Wendker	Astron.J., 70, No. 2, 1965

No.	Title	Author	Reference
38	National Radio Astronomy Observatory	D. S. Heeschen	Astron. J., 70, No. 2, 1965

Series B

36	10-cm Observations of Jupiter 1961-1963	F. N. Bash, F. D. Drake, E. Gundermann, C. Heiles	Ap. J., 139, No. 2, February 1964
37	Radio Observations of M 33	V. R. Venugopal	Astron. Soc. of the Pacific, 75, No. 446, 1963
38	Lunar Occultations of Radio Sources	S. von Hoerner	Ap.J., 140, No. 1, July 1964
39	Radio Astronomy	J. W. Findlay	Annals of the N.Y. Acad. of Sci., 116, Art. 1, pp. 5-9.
40	Operating Experience at the National Radio Astronomy Observatory	J. W. Findlay	Annals of the N.Y. Acad. of Sci., 116, Art. 1, pp. 25-37
41	Radio Observations of the Galaxy and Extragalactic Sources	David E. Hogg	R.A.S.C. Jourl., 58, No. 5
42	The Radio Structure of IC 443	David E. Hogg	Astrop. J., 140, No. 3, Oct. 1964
43	New Infrared Photometry of ϵ Aurigae	F. J. Low and R. I. Mitchell	Astrop. J., 141, No. 1, 1965
44	The Infrared Brightness of α Leonis and λ Orionis	F. J. Low	Astrop. J., 141, No. 1, 1965
45	The Spectrum of 3C 273	F. J. Low and	Astrop. J., 141, No. 1, 1965
46	Radio Observations of Planetary Nebulae	T. K. Menon and	Astrop. J., 141, No. 2, 1965
47	A Radio Investigation of NGC 1265 and NGC 1275	J.W.M. Baars,	Nature, 205, No. 4970, Jan. 1965.