National Radio Astronomy Observatory
Green Bank, West Virginia

Quarterly Report

April 1 - June 30, 1964

RESEARCH PROGRAMS

85-foot Telescope No. 1

	Hours
Scheduled	1102
Equipment installation and scheduled maintenance	270
Time lost due to equipment failure, interference, and weather	342

During this quarter, a 2-cm receiver on loan from the Naval Research Laboratory was used by P. G. Mezger to observe radio sources and to measure the characteristics of the antenna. Naval Research Laboratory personnel also used the 2-cm receiver for polarization measurements.

A 6-cm receiver was installed on the telescope, and was used by P. G. Mezger to study extinction and to do a survey of the Milky Way.

Lost observing time amounted to 15.67 per cent of the quarter, with 11.2 per cent of the lost time due to rainy weather during P. G. Mezger's 2-cm observations.

85-foot Telescope No. 2

	Hours
Scheduled	240.5
Equipment installation and scheduled maintenance	528
Time lost due to equipment failure, interference, and weather	1.5

S. von Hoerner observed lunar occultations at frequencies of 234 Mc, 256 Mc, and 405 Mc, simultaneously. P. G. Mezger measured the characteristics of the antenna at a wavelength of 20-cm.

M. Fagerlin, from the University of Florida, and D. Hogg adjusted the focus and calibrated the pointing of the telescope at the interferometer frequency of 2695 Mc.

Throughout the quarter the telescope and inboard mounted control room have been prepared for interferometer use.

300-foot Telescope

	Hours
Scheduled	1610
Equipment installation and scheduled maintenance	507
Time lost due to equipment failure, interference and weather	146

Y. Terzian (Indiana University) continued observations of H II regions at 234 Mc, 405 Mc, 750 Mc, and 1410 Mc. M. DeJong (Rensselaer Polytechnic Institute) observed normal galaxies at 750 Mc and 1400 Mc. B. Höglund observed at frequencies of 750 Mc and 1400 Mc for the sky survey that he has been working on for some time.

On April 14 the installation of a solid-state, 100-channel, autocorrelation hydrogen-line receiver, with magnetic tape output, was begun. During the several days of installation and testing of this equipment, M. S. Roberts and B. Höglund used the telescope at night with 750 Mc and 1410 Mc equipment.

The autocorrelation receiver was used by D. Williams (University of California) and T. K. Menon to observe hydrogen in absorption. G. Westerhout (University of Maryland) observed the galactic plane, along with B. F. Burke and K. Turner (Department of Terrestrial Magnetism, Carnegie Institution of Washington).

A total of 6.7 per cent of the quarter is attributed to scheduled observing time lost, receiver trouble accounting for 5.9 per cent. Interference resulted in a loss of 0.6 per cent of the quarter, with telescope failures and weather accounting for the remaining 0.2 per cent.

Interferometer

The interferometer is operating at a wavelength of 11 cm, with a baseline of 1200 meters. The first observation was made on June 21, when interferometer fringes were observed on 3C 273. Since that time, fringes have also been observed on 3C 48, 3C 84, 3C 147, 3C 161, 3C 196, 3C 286, 3C 295, 3C 405, and 3C 461. Less positive results exist on other sources.

First indications are that day-to-day phase instability never exceeds 30°. Maximum day-to-day fringe amplitude variations appear to be less than 15 per cent.

The lobe rotation and delay tracking facilities have not yet been utilized, and the digital output system (onto magnetic tape) will be ready by the first week in July. These facilities will be tested and used in the next few weeks.

N. Keen, D. Hogg, and M. Fagerlin are engaged in the observing program using the interferometer.

Millimeter Wave Program

The original 5-foot spun-cast reflector was remounted on the Nike mount in place of the 12-foot reflector, pending a decision by the Kennedy Antenna Division as to the disposition of the 12-foot dish. This was necessitated by the large departure of the surface from a true parabola and by serious temperature effects on the shape of the antenna.

The 5-foot reflector, which was found to possess near-theoretical 3.6 minute beamwidth, is now being used for a brightness distribution study of the moon at various phases and for observations of Venus and Jupiter.

F. J. Low spent the month of June at the University of Arizona, using an improved 11 micron radiometer in conjunction with the Arizona 28-inch optical telescope. Excellent results were obtained from observations of Mars, Venus, Jupiter, Saturn, and about 30 stars. The 28-inch telescope, plus the NRAO radiometer, gives a signal-to-noise ratio of about ten thousand to one on Venus. The radiometer appears to have a higher effective sensitivity than any other 11 micron detector extant by about a factor of 100.

ELECTRONICS DIVISION - EQUIPMENT DEVELOPMENT

The autocorrelation receiver was tested in the laboratory, installed on the 300-foot telescope and put into operation. Operation was limited to frequency bands of 2.5 Mc and 625 kc because of delay in the delivery of the remaining filters.

A digital output system using magnetic tape recording has been built for use on the 20-channel hydrogen-line receiver.

The interferometer radiometer has been installed on the two 85-foot telescopes and put into operation on the 1200 m baseline. The very low noise parametric amplifiers have not yet been delivered, and the present system noise temperature is about 250°K. Sufficient cable has been received to extend operation to 1500 m baseline, but the condition of some of the cable seems doubtful.

The maser dewar manufacturer (Sulfrian) has not yet succeeded in making a satisfactory dewar for the maser. Delivery date for the dewar seems uncertain.

The three occultation radiometers were installed and tested on the 85'-2 telescope with unsatisfactory results caused by instability in the parametric amplifiers. The isolation in the amplifier circulators was found to be insufficient, and they were returned to the manufacturer for adjustment. The digital output system for the receivers has been built.

A digital position readout system for the 85'-2 telescope was built and installed on the telescope. A similar system for the 85'-1 telescope is under construction.

A 1420 Mc low noise front end was assembled and installed on the 300-foot telescope for use with the autocorrelation receiver and the 20-channel receiver. Noise temperature was 130°K.

An automatic temperature control system for maintaining constant temperature in the telescope front ends has been designed. Fabrication of several of these systems has begun.

The ignition interference receiver was installed at the guard house and a system to control automobile interference has been initiated.

The following internal reports were issued during the report period.

No.	Title	Author	Date
30	The Characteristics of the 300-Foot Telescope at 10 cm Wavelength	J. Baars and P. Mezger	May 1964
31	Digital Output Unit for the Lunar Occultation Receivers	N. Keen	May 1964
32	AIL Parametric Amplifier, Model 2877	D. Ross	May 1964

CONSTRUCTION

Interferometer

The interferometer is structurally, mechanically and electrically completed. On May 18, the telescope was lifted off its pads for the first time and let down again. On June 1, the unit was again lifted and moved 4 feet 6 inches on its concrete pads, then brought back and reset to 1/32 inch. To facilitate towing, a bulldozer is used at the north end and an aircraft towing vehicle at the south end. Roadways are 90 per cent completed, and should be 100 per cent completed by the end of July. A trailer, received through surplus, was completely remodeled and wired to accommodate electronics' systems for the interferometer.

Jansky Telescope

Reconstruction of the Jansky telescope at the entrance to the Observatory has been completed, and the telescope is now connected both electrically and mechanically.

Airstrip

Specifications for paving the airstrip have been prepared. Pending approval for the paving, the surface has been reconditioned from the effects of the winter season and permanent drainage ditching has been completed. The airstrip is now in reasonably frequent use for small planes, for which it was designed. Electrical lines have been laid and connected in the barn next to the airstrip to provide power for the radio beacon which is to be installed at this site soon.

THE NRAO MILLIMETER WAVE ANTENNA

Historical

The development of the helium-cooled germanium bolometer by Dr. F. J. Low at Texas Instruments in 1961 coincided with the start of millimeter wave radio astronomy at NRAO. Dr. F. D. Drake used one of Low's earlier bolometers with a 5-foot Kennedy spun-cast dish on the NRAO SCR-584 mount, which had originally carried an X-band 12-foot dish. This mount was not precise enough for good observations, but with it the bolometer and radiometer techniques at 1.2 mm were tested, using the sun and the moon as sources.

Subsequently, in October 1962, Dr. Low joined the NRAO staff, and since then has made observations with his bolometer at 1.2 mm and at 11 microns. Various instruments have been used at NRAO, mainly the 5-foot dish on a new mount and a 36-inch mirror for 11 microns. Low has also observed at 11 microns with the 82-inch telescope at the McDonald Observatory and with a 28-inch telescope at the University of Arizona.

By the early part of 1962, it was evident that instrumental developments were promising enough to warrant the use of a larger and more precise dish. Accordingly, a request for funding of a telescope of about 30 feet in diameter was made in 1962 and this request was subsequently approved by the National Science Foundation for inclusion in the FY 1964 budget.

Preliminary Planning and Studies

By the beginning of FY 1964, the size of the new antenna has been set at 36 feet, with a long focal length ($f/D \sim 0.8$) to simplify the quasi-optical problems of using a bolometer. The requirement to observe in the 1.2 mm window set a stringent need for high surface accuracy and for a very precise pointing precision. In addition to the telescope itself, the choice of a suitable site and of possible ways of protecting the instrument from wind, solar heating, and precipitation had to be examined. Progress during the first part of FY 1964 was made along all these lines, but none of the funds for the telescope were committed. It was in the early part of that year that the decision was taken to embark on a program of development and testing of more conventional millimeter wave techniques, in addition to the bolometer detector. Dr. P. G. Mezger had joined the NRAO staff, and he began the study of broadband crystal mixer radiometers and other possible techniques for use down to wavelengths as short as 3 mm.

A summary of the progress made on the telescope project by the spring of 1964 follows.

(a) Site selection.

To avoid as much water vapor as possible, a high, dry site is desirable. Estimates of the water vapor content of the total atmosphere over Green Bank and over other parts of the USA were made. A simple instrument was built (based on a design by the Weather Bureau) for measuring total water vapor. F. Bash spent several weeks in the winter of 1963-64 testing sites with this instrument. Three desirable sites are currently under consideration: the High Altitude Observatory at Climax, Colorado (3394 meters), a location on the Catalina Mountains near Tucson, Arizona (at about 2600 meters), and the Kitt Peak National Observatory (at about 2050 meters). Further administrative and logistic studies will be needed before a final decision is reached.

(b) The telescope.

The early planning of the telescope design was influenced by the fact that a mount, probably suitable for pointing a 36-foot dish to the required accuracy, had already been developed by RCA for a highly precise tracking antenna. Considerable effort was expended by the NRAO staff in investigating the possible use of this mount with a separately designed dish. The dish could be either a space-frame structure or a machined aluminum casting. Both types were examined and shown to be technically feasible. However, by March 1964, it also became clear from discussions with several potential suppliers that it might be possible technically and economically to purchase the complete telescope to an Observatory performance specification. Accordingly, on March 19, 1964, a letter and the following specification was sent to eight possible suppliers requesting proposals by May 15, 1964.

Technical Specifications for the N.R.A.O. Millimeter Wave Telescope

I. Antenna

Diameter = 36' = 11 meters
F/D = 0.80
Surface and shape errors:

The following specifications should be met under conditions of no wind and in a uniform ambient temperature of 20°C.

(a) Dish at zenith.

(i) r.m.s. surface error should be 2.0×10^{-3} inches, measured as departures from the design parabolic surface. Measurements of at least 300 points approximately equally spaced over the surface should be used in determining this surface error.

(ii) Measured focal length, F_o = 28' 10" ± 1.0 inch.

(b) Dish at 15° elevation.

(i) Largest r.m.s. departure from the paraboloid of best fit should not exceed 2×10^{-3} inches. However, some degradation at low elevation may be acceptable. 300 points should again be used to ascertain these deviations.

(ii) Focal length of best fit paraboloid = F_o ± 0.040 inch.

II. Feed Support

Instrument load will not exceed 200 pounds. Total deflection of feed should not exceed 0.080 inch. Shadowing of dish can be as large as 5 per cent.

III. Mount

Pointing accuracy.

Under conditions of no wind and a uniform ambient temperature, it shall be possible to position the axis of the best fit parabolic surface to a required point in the sky anywhere within the stated range of elevation and azimuth to an r.m.s. accuracy of 2" of arc. To achieve this it may be necessary to calibrate the gravity deflections of the structure. Therefore, these deflections must be reproducible to 2" of arc.

Tracking accuracy.

Under conditions of no wind and a uniform ambient temperature, it shall be possible to produce a constant rate of rotation of either axis by applying a constant torque to the appropriate output shaft for any rate within the specified ranges. The total positional error should not exceed 2" of arc in a period of 10 minutes. The minimum step caused by stiction and gear train compliance should not exceed 2" of arc.

Tracking rates:

Azimuth: 0.05 deg/minute to 1.5 deg/minute

Elevation: 0.01 deg/minute to 0.3 deg/minute

Slewing rates.

0 to 20 deg/minute for both axes

Azimuth range.

0 to 360°

Elevation range.

From zenith to 15° elevation angle on both sides of the zenith

Drive and control system.

Either servo controlled torque motors or digitally controlled stepper motors may be used. In either case, a small digital computer will be used to compute the coordinate transformations required for sidereal tracking.

IV. Indicators

Digital encoders are required on both axes accurate to ± 2" of arc with a digit interval of 2" of arc.

V. Operational and Survival Conditions

The entire telescope will be enclosed in a modified astrodome which rotates in synchronism with the telescope azimuth. This enclosure fully protects the instrument from bad weather and allows full sky coverage in good weather. However, the inside temperature will approximate the outside temperature which may range during operation from -30°F to +90°F. Performance of the telescope should not vary appreciably over this range except during rapid temperature changes.

VI. The Telescope Enclosure (The astrodome)

Until an actual telescope design was available, the exact design of an astrodome could not be completed. The desirable characteristics of such an enclosure may be summarized:

Enclosure when closed. The enclosure should completely cover and protect the telescope when observations are not being made. Under these conditions it should withstand:

(i) Winds up to 90 miles per hour

(ii) Snow or ice loads of 20 lbs per square foot on horizontal or near horizontal surfaces

(iii) Ambient temperatures from -30°F to +120°F

Enclosure when open.

(i) The enclosure should permit of radio observations at 1.2 mm and longer wavelengths through an aperture 40 feet square centered on and approximately normal to the telescope beam.

(ii) Limited provision for optical viewing from the radio telescope mount through the opening is required.

(iii) The enclosure should shield the radio telescope from sun and wind when observations are being made. For example, a thin plastic sun-shield over the enclosure opening would be desirable. The enclosure should be painted with a good low-temperature-rise paint. For wind protection, it would be desirable that a 25 mile per hour wind blowing tangentially to the aperture opening should not lead to air motions around the telescope of more than 5 miles per hour.

Preliminary designs for an astrodome meeting these requirements have been obtained from Pittsburgh-des Moines Steel Company and from the Electronics Space Structures Corporation, and designs have also been suggested by the NRAO engineering group.

Progress to Date.

(a) Telescope proposals

Since March 1964, attention has been concentrated on the proposals for the supply of the telescope. Responses to the letter of March 19 were received from six companies, of which three proposals were for the complete instrument. Two were for the supply of the dish alone, and one for the mount alone. A preliminary evaluation of these proposals was made at a meeting at NRAO on May 26. In general the present status of the proposals is that technically any one of three proposed telescopes would meet the NRAO requirements. The basis of choice between the proposals will be estimates of the differences of performance due to differences of design, manufacturing technique, and cost differences.

ANTENNA DESIGN STUDIES

TRG Study

The final report from TRG, Incorporated, East Boston, on the feasibility and preliminary design of a Cassegrain system for the 300-foot transit telescope has been received. This study was carried out to examine the probable electrical and mechanical characteristics of the antenna if it were to be used as a Cassegrain and also to answer questions about the desirability of Cassegrain design for large dishes of 300 feet or greater aperture. The report shows that structural modifications to the 300-foot to support a 20-foot diameter sub-dish would be possible, but would involve considerable strengthening of the feed support legs. This would be quite a complex task since many members would have to be replaced and the feed support is not easily accessible from the ground.

Electrically the performance of the 300-foot as a Cassegrain would be satisfactory over the frequency range down to about 600 Mc/s. At lower frequencies serious spill-over loss occurs unless the feed design is changed. The feed mainly considered was a horn, of length about 50 feet, with its vertex at or near the dish vertex. A log-periodic feed might also be possible.

From the study it seems safe to conclude that for the existing 300-foot, the advantages of somewhat better accessibility to electronic equipment at the dish vertex are more than outweighed by the structural changes needed, by the considerable size of the feed required, and by the loss of low-frequency performance.

In general, the conclusions of the study do not encourage the use of Cassegrain systems for very large dishes (greater than 300 feet).

Rohr Corporation

In view of the considerable national interest in a fully-steerable parabolic antenna, a design study contract for a 100-meter dish has been arranged with the Antenna Division of Rohr. The study will continue the design already started by Professor H. F. Weaver at Berkeley and will compare this type of design (which is closely similar to the Parkes 210-foot) with the design for a 210-foot now under fabrication by Rohr for NASA. Professor Weaver and the NRAO are following the progress of this work. Professor A. E. Lilley, of Harvard College Observatory, is also interested in the outcome of the study.

PERSONNEL

Dr. W. E. Howard III, formerly associate professor of astronomy at the University of Michigan, was employed on June 1st jointly as assistant to the director and associate scientist.

Mrs. Rama C. Menon, after a four months leave from the Observatory, has been re-employed in the electronics division as research associate.

Mr. D. M. Haxton, a recent graduate of the State University of Iowa, has been employed in the computer group as a programming analyst.

Dr. G. Westerhout, of the astronomy department, University of Maryland, is doing hydrogen-line studies on the autocorrelation receiver during the summer.

Eight undergraduates, majoring in either physics, astronomy, or mathematics, are spending the summer here under the National Science Foundation's Undergraduate Research Participation Program. We also have seven graduate students working here thus summer under the Observatory's graduate student program. All these students are assisting staff scientists and engineers in various programs. A lecture series is being offered to these students.

In addition to the eight undergraduates under the UGRPP, there are nine undergraduates working during the summer in the computer group, electronics, engineering, and public education divisions.

NRAO REPRINT SERIES A

No.	Title	Author	Reference
1	The Telescope Program for the National Radio Astronomy Observatory at Green Bank, W.Va.	R. M. Emberson and N. L. Ashton	Proc. of the IRE 46, No. 1, Jan. 1958.
2	Noise Levels at the National Radio Astronomy Observatory	J. W. Findlay	Proc. of the IRE 46, No. 1, Jan. 1958.
3	Extragalactic 21-cm Line Studies	D. S. Heeschen and N. H. Dieter	Proc. of the IRE 46, No. 1, Jan. 1958.
4	Radio Resolution of the Galactic Nucleus	F. D. Drake	Sky and Telescope 18, No. 8, June 1959.
5	National Radio Astronomy Observatory	R. M. Emberson	Science 130, No. 3385, pp. 1307-1318, Nov. 13, 1959.
6	Radio Astronomy Receivers	F. D. Drake	Sky and Telescope 19, No. 1 and 2, Nov. and Dec. 1959.
7	Astrophysics	Otto Struve	Encyclopaedia Britannica, 1961.
8	Spectroscopy, Astronomical	Otto Struve	Encyclopaedia Britannica, 1961.
9	Radio Emission from the Planets	F. D. Drake	Physics Today 14, No. 4, 30-34, April 1961.
10	Project Ozma	F. D. Drake	Physics Today 14, No. 4, 40-42, 44, 46, April 1961.
11	Vertical Incidence Doppler Ionogram	J. W. Findlay	IRE Proc. 49, July 1961.

No.	Title	Author	Reference
12	The Search for Signals from other Civilizations	S. von Hoerner	Science 134, No. 3493, pp. 1839-1843, Dec. 8, 1961.
13	National Radio Astronomy Observatory - Report	O. Struve	A.J. 66, 465, Nov. 1961.
14	A Study of the Region of M 17 at a Wavelength of 3.75 cm	R. W. Hobbs	A.J. 66, No. 9, Nov. 1961
15	Radio Galaxies	D. S. Heeschen	Scientific American Vol. 206, 41-49, March 1962.
16	Protecting the Science of Radio Astronomy	J. W. Findlay	Science 137, pp. 829-835, Sept. 14, 1962.
17	National Radio Astronomy Observatory - Report	D. S. Heeschen	A.J. 67, 777, Dec. 1962.
18	The 300-foot Radio Telescope at Green Bank	J. W. Findlay	Sky & Telescope 25, No. 2, Feb. 1963.
19	Fluctuation Component of Atmospheric Noise Temperature	Torleiv Orhaug	Proc. of the IEEE 51, No. 3, March 1963.
20	The 300-ft. Transit Telescope at the National Radio Astronomy Observatory	J. W. Findlay	A.J. 68, No. 2, March 1963.
21	Radio Observations of Supernovae Remnants	D. E. Hogg	A.J. 68, March 1963, No. 2.
22	Measurements of Radio Sources in the 3C Catalogue	D. J. Crampin, C. M. Wade, D. S. Heeschen, I.I.K. Pauliny-Toth	A.J. 68, No. 2, March 1963.
23	Structure of NGC 5128	Hugh M. Johnson	A.J. 68, No. 2, March 1963.
24	Meteorological Conditions and Radio Astronomy Observations at X-Band	V. R. Venugopal	J. of the Atmospheric Sciences, Vol. 20, No. 5, pp. 372-375, Sept. 1963.
25	National Radio Astronomy Observatory - Report	D. S. Heeschen	A.J. 68, No. 9, Nov. 1963, No. 1314.

NRAO REPRINT SERIES B

No.	Title	Author	Reference
1	Neutral Hydrogen Emission from the Hercules and Corona Borealis Cluster of Galaxies	D. S. Heeschen	PASP 69, No. 409, August 1957.
2	Neutral Hydrogen in M32, M51, and M81	D. S. Heeschen	Ap. J. 126, No. 3, Nov. 1957.
3	Radio Astronomy and the New National Observatory	R. M. Emberson	Trans. of the N.Y. Academy of Sciences Series II, 22, No. 6, pp. 419, 425, April 1960.
4	Radio Astronomy: A Window on the Universe	J. H. Oort	American Scientist 48, No. 2, June 1960.
5	Wavelengths of Absorption Lines in the Spectra of Beta Canis Majoris Stars	O. Struve and V. Zebergs	Ap. J. 132, No. 1, July 1960.
6	A Color-Absolute Magnitude Diagram for Extragalactic Radio Sources	D. S. Heeschen	PASP 72, No. 428, Oct. 1960.
7	Spectroscopic Features of β Lyrae	Otto Struve and MaryJane S. Wade	PASP 72, No. 428, Oct. 1960.
8	Observations of Radio Sources at Four Frequencies	D. S. Heeschen	Ap. J. 133, No. 1, Jan. 1961.
9	Photometry and Radiometry of Gaseous Nebulae	D. E. Osterbrock and R. E. Stockhausen	Ap. J. 133, No. 1, Jan. 1961.
10	A Note on the Brighter Pleiades (Correspondence to the Editors of "The Observatory")	O. Struve and MaryJane Wade	The Observatory 80, No. 919, pp. 229-232.
11	The Radial Velocity of Sigma Scorpii	O. Struve, J. Sahade and V. Zebergs	Ap. J. 133, No. 2, March 1961.

No.	Title	Author	Reference
12	A Possible New Radio Galaxy in the Virgo Cluster	C. M. Wade	The Observatory 80, No. 919, pp. 235-236.
13	The Nonconstancy of the Adiabatic Invariants	Peter O. Vandervoort	Annals of Physics 12, No. 3, March 1961, pp. 436-443.
14	The Spectra of the B8 Component of Beta Lyrae	O. Struve and V. Zebergs	Ap. J. 133, No. 2, March 1961.
15	The 140-foot Radio Telescope of the National Radio Astronomy Observatory	O. Struve, R. M. Emberson, J. W. Findlay	PASP 72, No. 429, Dec. 1960.
16	The Position-Determination Program of the National Radio Astronomy Observatory	F. D. Drake	PASP 72, No. 429, Dec. 1960.
17	Secular Variation of the Flux Density of the Radio Source Cassiopeia A	D. S. Heeschen and B. L. Meredith	Nature 190, No. 4777, pp. 705-706, May 1961.
18	The Spectrum of the B8 Component of Beta Lyrae. II	Otto Struve and V. Zebergs	Ap. J. 134, No. 1, July 1961.
19	Sound Waves Trapped in the Solar Atmosphere	F. D. Kahn	Ap. J. 134, No. 2, Sept. 1961.
20	Radio Observations of the Peculiar Galaxy M82	C. R. Lynds	Ap. J. 134, No. 2, Sept. 1961.
21	The Character of the Equilibrium of a Compressible, Inviscid Fluid of Varying Density	Peter O. Vandervoort	Ap. J. 134, No. 3, Nov. 1961.
22	Evolution of Gaseous Nebulae	F. D. Kahn and T. K. Menon	Proc. Nat. Acad. Sci. 47, No. 11, pp. 1712-1716, Nov. 1961.
23	Protecting Frequencies for Radio Astronomy. (Commission V. On Radio Astronomy)	J. W. Findlay	URSI Information Bulletin No. 124 (1961)
24	The Wavelengths of Helium Lines in the Spectrum of 21 Aquilae	O. Struve, G. Wallerstein, V. Zebergs	PASP 73, No. 432, June 1961.

No.	Title	Author	Reference
25	A Contour Map of IC 443 at 1400 Mc/s	James F. Wanner	PASP 73, No. 431, April 1961, pp. 143-146.
26	Some Features of M84 and M87 Observed at 10 cm Wavelength. (To the Editors of "The Observatory")	C. M. Wade	The Observatory 81, No. 924, pp. 202-203, 1961.
27	A Study of the Rosette Nebula NGC 2237-46	T. K. Menon	Ap. J. 135, No. 2, March 1962, pp. 394-407.
28	Sound Waves Trapped in the Solar Atmosphere	F. D. Kahn	Ap. J. 135, No. 2, March 1962, pp. 547-551.
29	Catalogue of Dark Nebulae	B. T. Lynds	Ap. J. Supplement Series, Vol. VII, No. 64, May 1962, pp. 1-52.
30	Physical Conditions in the Orion Nebula	T. K.Menon	Ap. J. 136, No. 1, July 1962, pp. 95-99.
31	On the Evolution of Galaxies	Otto Struve	Symposium on Stellar Evolution. La Plata Observatory, Argentina, pp. 291-306, 1962.
32	Microwave Spectrum of Saturn; 10-cm Observations of Venus near Superior Conjunction	F. D. Drake	Nature 195, No. 4844, pp. 893-894, Sept. 1962.
33	The Spatial Distribution of Supernovae in Galaxies	Hugh M. Johnson and John M. MacLeod	PASP Vol. 75, No. 443, April 1963, pp. 123-132.
34	The Polarization and Intensity of Thermal Radiation from a Planetary Surface	C. E. Heiles and F. D. Drake	Icarus, Vol. 2, No. 4, Nov. 1963, pp. 281-292.
35	A High Resolution Radio Map of the Cygnus X Region	E. M. Pike and F. D. Drake	Ap. J. 139, No. 2, Feb. 1964, pp. 545-550.

STUDENTS AT NRAO DURING THE SUMMER 1964

Hugh Aller	University of Michigan
Philip Atanmo	University of Connecticut
Dennis Baker	University of California
Greg Burrowes	University of Maryland
Michael Coleman	West Virginia Institute of Technology
Edward Conklin	Yale University
Martin Ewing	Swarthmore College
Mark Fagerlin	University of Florida
Virginia Fagerlin	University of North Carolina
Margo Friedel	University of Michigan
Nadine Gillispie	Glenville State College
William Gebel	University of Wisconsin
Robert Havlen	University of Rochester
Joseph Marshall	Potomac State College
Mary Meacham	Notre Dame College
June Myles	Hollins College
William Ogden	University of Kentucky
Charles Rightmire	Davis & Elkins College
Norman Savin	Massachusetts Institute of Technology
William Sheets	West Virginia University
Melvyn Viner	University of Toronto (Canada)
Lloyd Walker	University of Chicago
Francis Wells	Vanderbilt University
Bryon Wicks	Manchester University (England)