

National Radio Astronomy Observatory
Charlottesville, Virginia

Quarterly Report

April 1 - June 30, 1967

RESEARCH PROGRAMS

Interferometer (three 85-foot telescopes)

During this quarter the three element system was essentially completed. Computer software for operating, monitoring, and recording the system has been essentially completed and tested. Baseline constants and calibration data for the 1200 and 1500 meter spacings have been completed. The use of the three element system has been delayed somewhat due to the return of the parametric amplifiers to the supplier for additional tests. However, it is expected that three element interferometry will begin early in July.

300-foot Telescope

	<u>Hours</u>
Scheduled observing	1992.50
Scheduled maintenance and equipment changes	133.00
Time lost due to: equipment failure	68.00
power	0.00
weather	7.75

The autocorrelation receiver was used by S. Goldstein (University of Virginia) to determine Faraday rotation within a narrow band of frequencies near 142.5 MHz.

Some observations with the autocorrelator at the neutral hydrogen line frequency were as follows:

<u>Observations</u>	<u>Observers</u>
Mapping the galactic plane within a one to three degree strip	G. Westerhout (University of Maryland)
Survey of narrow strip of sky 2° in latitude centered on the zero meridian of longitude running from the north galactic pole to latitude $b = +17^\circ$ to search for possible material coming into the galactic center	F. Kerr (University of Maryland)

<u>Observations</u>	<u>Observers</u>
Investigation of neutral hydrogen in high velocity regions	J. Rickard (University of Maryland)
Hydrogen in absorption in front of the source 3C 10	T. K. Menon
Observations of neutral hydrogen in the direction of stars that have optical interstellar lines of the molecule CN	P. Thaddeus (Institute for Space Studies)

Continuum observations were as follows:

<u>Observations</u>	<u>Observers</u>
Positions of some galactic sources at 1414 MHz to be later used as standard sources for 140-foot observations	W. Altenhoff
Pilot continuum observations at 1414 MHz in the regions of sources W 40 and W 51 in preparation for an extended observing period in the next quarter	A. Maxwell, D. Downes (Harvard)
Dwingeloo Finding List verification at 750 and 1414 MHz	M. Davis
Mapping areas of the complex Cygnus X Region at 750 and 1414 MHz	H. Wendker (University of Illinois)
Mapping M 31 and an HII Region listed in the Sharpless Catalog at 750 and 1414 MHz	J. Dickel (University of Illinois)
Observations at 750 and 1414 MHz to verify sources observed during the Ohio State north galactic survey program	J. Kraus (Ohio State University)
Flux density of sources at 750 and 1414 MHz	I. Pauliny-Toth, K. Kellermann
At 234, 750, and 1414 MHz simultaneously mapped portions of the sun's corona by observing the solar occultation of radio sources. Also observed for verification regions of the sky observed at somewhat longer wavelengths at the Clark Lake, California facility	W. Erickson (University of Maryland)

<u>Observations</u>	<u>Observers</u>
Flux measurements at 750 and 1414 MHz to be used in conjunction with lower frequency measurements made at the 1000-foot Arecibo, Puerto Rico telescope	D. Jauncey (Cornell University)

140-foot Telescope

	<u>Hours</u>
Scheduled observing	1704
Scheduled maintenance and equipment changes	299.5
Time lost due to: equipment failure	125.25
interference	4.00
weather	41.75
power	1.25

The following is a list of programs at 4995 MHz:

<u>Observations</u>	<u>Observers</u>
Polarization and flux density measurements of selected sources	J. Hollinger (Naval Research Laboratory)
Flux density measurements of discrete sources in order to check on variability	K. Kellermann, I. Pauliny-Toth
Mapping HII regions in and near the galactic plane in preparation for recombination line observations near the same frequency	B. Burke (MIT), P. Mezger
Mapping various HII regions in order to find positions and flux densities	W. Altenhoff

The following lists observing programs at 15.375 GHz:

<u>Observations</u>	<u>Observers</u>
Flux density determinations of variable sources	K. Kellermann, I. Pauliny-Toth
Flux density measurements of Mercury and Venus	C. Sagan, D. Morrison (Harvard)
Searching for very short period flux density variations in variable sources	L. Helfer (Rochester University), M. Davis
Telescope tests and pointing measurements	J. Schraml

<u>Observations</u>	<u>Observers</u>
Polarization measurements of Jupiter	J. Dickel (University of Illinois)
Fluxes of elliptical galaxies	D. Heeschen
Mapping of galactic sources	P. Mezger

The following lists observing programs at 2695 MHz:

<u>Observations</u>	<u>Observers</u>
Mapping galactic sources and investigation of atmospheric extinction using the moon	W. Altenhoff
Flux density measurements of sources observed previously at Dwingeloo, The Netherlands	M. Davis
Flux densities of sources	K. Kellermann, I. Pauliny-Toth
Observed the supernova remnant HB 21	J. W. Erkes
Planetary nebulae	M. Kaftan-Kassim (State University of New York; Albany)
Mapping of Cygnus X region	H. Wendker (University of Illinois)
Scintillation of radio sources	W. Altenhoff
Comparison of radio flux density measurements of HII regions with optical measurements	W. Gebel (University of Wisconsin)
Flux density measurements of discrete sources near Messier 31	J. Kraus (Ohio State University)

Long baseline observations were conducted at the 1665 OH line, and continuum observations were made using the Green Bank 140-foot telescope and Haystack (MIT-Lincoln Laboratory) 120-foot antenna to measure angular diameters of OH emitting sources, principally the source Westerhout 3. Line investigators were J. Ball (MIT), A. Barrett (MIT), B. Burke (MIT), J. Carter (MIT), P. Crowther (MIT), J. Moran (MIT), and A. Rogers (MIT). Continuum investigators were C. Bare, B. Clark, M. Cohen (University of California, San Diego), and D. Jauncey (Cornell University).

Long baseline interferometry between the Green Bank 140-foot and the Naval Research Laboratory 85-foot at 610 MHz was accomplished by M. Cohen (University of California, San Diego), D. Jauncey (Cornell), B. Clark, C. Bare, and K. Kellermann.

A search for the C 110 α recombination line was conducted by P. Palmer and B. Zuckerman (Harvard).

Z. Turlo and J. Schraml mapped the sun and 3C 273 at 31.460 GHz.

ELECTRONICS DIVISION--EQUIPMENT DEVELOPMENT

During the past quarter the manpower assignments within the Electronics Division have been divided among the following programs:

Three-Element Interferometer Checkout	24%
Visitor Support and Routine Maintenance	21%
New Autocorrelation Receiver	12%
New Standard Receivers	12%
Millimeter Receiver Development	6%
Very Long Baseline Interferometer	6%
Construction of Multichannel Radiometer	6%
Installation of On-Line Computer at 140-foot Telescope	6%
Interference Protection	4%
Planning of New Programs	3%

The interferometer electronics system has been completed and checked out with the exception of some remaining work on the parametric amplifiers and local oscillator system.

The completion of the 416-channel autocorrelation receiver has been delayed due to difficulty in obtaining delivery of integrated circuits. The receiver should be complete in the fall, 1967.

A Honeywell DDP-116 computer has been installed at the 140-foot telescope. The computer will be used for computation of antenna position, recording of data, data processing, and control of antenna pointing. The program for position indication and data recording is nearing completion.

A multichannel wideband receiver that utilizes an on-line computer for synchronous detection and gain calibration of 50 channels is under construction. Filter banks with bandwidths of 25, 5, 1, and 0.1 MHz have been started.

Construction work is proceeding on a 1-4 GHz tunable radiometer, a 4-feed 21-cm radiometer, 4 new standard radiometers, and additions to the very long baseline interferometer equipment.

Two new very low noise parametric amplifiers have been ordered for wavelengths of 6-cm and 2.85-cm. These units are cryogenically cooled with a closed-cycle refrigerator and will provide extremely high sensitivity at these wavelengths.

THE NRAO MILLIMETER WAVE ANTENNA

The 36-foot telescope was turned over to the NRAO by the manufacturer in May. Cables for the receiving system and air-conditioning facilities for

the frontend boxes have been installed. A frontend mount, with capabilities of remote focussing and polarization control, has been mounted and aligned. A 9.5 mm radiometer is presently being installed.

ANTENNA DESIGN STUDIES

The Largest Feasible Steerable Telescope (LFST)

Work has continued at a rather low level of effort on the 600-foot Sugar Grove design. An attempt is being made to bring some of the features of the design up-to-date and to modify the performance to make it compatible with the needs of radio astronomy.

The Very Large Array (VLA) Project

E. J. Blum of the Paris-Meudon Observatory has joined the VLA project for six months to work on general theoretical problems of correlator arrays. R. H. MacPhie of the University of Waterloo visited the project for five weeks and prepared a report on the effects of finite bandwidth on interferometer performance.

Studies were continued or instituted on the following topics:

1. The variation of atmospheric water vapor with geography and altitude, and its effects on long baseline interferometer performance
2. Array configurations, particularly complementary arrays for improving the performance of a VLA having an insufficient number of antennas
3. VLA electronics, particularly the local oscillator system and the IF distribution system
4. VLA antenna design

A request for proposals has been published for the design of the structural and mechanical part of the VLA antenna element, and a prospective bidders' conference was held, attended by approximately 15 industrial firms. Stanford Research Institute completed its study of a possible VLA antenna and submitted the final report.

PERSONNEL

Appointments

W. Y. Wong	Scientific Programmer Analyst II	April 10, 1967
R. H. MacPhie	Visiting Associate Scientist	April 24, 1967
J. M. Payne	Electronics Engineer	May 1, 1967
H. van der Laan	Visiting Scientist	May 8, 1967
R. H. Hjellming	Visiting Assistant Scientist	June 5, 1967

D. L. Thacker	Electronics Engineer	June 19, 1967
R.C.P. Gordon	Research Associate	June 29, 1967
K. J. Gordon	Graduate Junior Research Associate	June 29, 1967

Terminations

Z. Turlo	Research Associate	April 28, 1967
V. Boriakoff	Electronics Engineer	April 28, 1967
R. Davies	Junior Research Associate	May 12, 1967
V. Scott	Photographic Technician	May 31, 1967
R. H. MacPhie	Visiting Associate Scientist	June 2, 1967

K. I. Kellermann, Assistant Scientist, is on a four month leave of absence, beginning May 1, 1967.

NRAO SUMMER STUDENT PROGRAM

In December 1966 the Observatory mailed announcements of the summer student program to over 265 departments of astronomy, physics, mathematics, and electrical engineering. Over 90 students responded, and of these 15 graduate and 16 undergraduate students were chosen to participate in the program. Again the National Science Foundation is supporting 12 of our undergraduate students as part of its Undergraduate Research Participation Program.

The lecture series has been modified this year so that a series of three core (introductory) lectures precedes more detailed lectures by staff members on various aspects of their research programs.

Twenty students are resident in Charlottesville and 11 are resident in Green Bank. Temporary housing is available at each site for Charlottesville students who assist in observing at Green Bank or for Green Bank students who are using the computer at Charlottesville.

The summer students are assigned to members of the resident staff and participate in the research efforts of their advisors as junior research colleagues. Each student is selected on merit based on (1) college grades, (2) recommendations from college advisors, and (3) his letter of application. The quality of the students is exceptional; the median student stands at the 98.5 percentile of his high school graduating class. The following table shows the roster of summer students with their university, academic level, and hometown.

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Graduate Students

<u>Name</u>	<u>Academic Year</u>	<u>Institution</u>	<u>Hometown</u>
James Cook	3	Ohio State University	Jefferson, Ohio
Arthur Davidsen	1	University of Texas	Austin, Texas
Karen Heere	2	University of California, Berkeley	Livingston, N. J.
Bruce Hermann	2	University of Illinois	Downers Grove, Ill.
Philip Honsberger	2	Ohio State University	Sycamore, Ohio
Peter Jarecke	2	University of California, Los Angeles	Fort Lauderdale, Fla.
Robert Korsan	1	Carnegie Inst. of Tech- nology	Union, N. J.
George Patton	2	West Virginia University	Westover, W. Va.
George Purcell	1	California Inst. of Tech- nology	Dayton, Ohio
David L. Roberts		Case Inst. of Technology	Annandale, N. J.
Robert H. Rubin		Case Inst. of Technology	E. Cleveland, Ohio
Robert Sanders	1	Princeton University	Lake Jackson, Texas
Myron Smith	1	University of Arizona	E. Northport, N. Y.
Joe Waters	1	M.I.T.	Clarksville, Tenn.
Thomas R. Williams	1	Wake Forest	Hickory, N. C.

Undergraduate Students

Richard Casaburi	3	Rensselaer Polytechnic Institute	Rego Park, N. Y.
Kwong W. Chu	4	M.I.T.	Tuskegee, Ala.
Charles Clendening	3	Case Inst. of Technology	Eastlake, Ohio
Marc Damashek	3	Amherst College	New York, N. Y.
Leona Dryden	3	Radcliffe	Hyattsville, Md.
Daniel Held	3	Columbia University	New York, N. Y.
Philip Hodge	4	Case Inst. of Technology	Bloomington, Ind.
Richard Keen	3	Northwestern University	Havertown, Pa.
Curtis A. Knight	4	M.I.T.	So. Berwick, Me.
Charles Kohler	4	University of Florida	Naples, Fla.
John Lester	4	Northwestern University	La Mesa, Calif.
Michael Olshansen	3	University of Michigan	Grosse Pointe Woods, Mich.
John Rehr	4	University of Michigan	Carlisle, Pa.
Terrence Sejnowski	3	Case Inst. of Technology	Cleveland, Ohio
David Shaffer	3	Carnegie Inst. of Tech- nology	Huntingdon, Pa.
Neal Stoltzfus	4	University of Illinois	Morgantown, Pa.

OBSERVATORY COLLOQUIA

The NRAO colloquium program during the past fiscal year is outlined below. The scientific staff usually invite the speakers, who generally talk on topics of current interest in radio astronomy or closely allied fields. The University of Virginia, Department of Astronomy, also invites speakers to participate in their own colloquium series. These series are announced jointly and well attended by our staff, university physicists and astronomers, and by students. The 25 outside speakers listed below visited the NRAO in our colloquium series.

Speaker	Institution	Date
Kenneth C. Freeman	University of Texas, Austin	Aug. 2, 1966
Ray Sachs	University of Texas, Austin	Aug. 3, 1966
Robert M. Hjellming	Case Institute of Technology	Aug. 18, 1966
David Buhl	University of California, Berkeley	Aug. 23, 1966
Barry M. Lasker	Mount Wilson and Palomar Observatories	Sept. 29, 1966
John G. Bolton	C.S.I.R.O., Sydney, Australia	Oct. 31, 1966
Malcolm P. Savedoff	University of Rochester	Nov. 10, 1966
Jan Högbom	Sterrewacht te Leiden, The Netherlands	Nov. 16, 1966
R.A.R. Parker	University of Wisconsin	Dec. 8, 1966
Marcello Ceccarelli	Instituto Di Fisica "A Righi," Bologna, Italy	Jan. 20, 1967
R. R. Daniel	Tata Institute of Fundamental Research, Bombay, India	Feb. 1, 1967
I. S. Shklovski	Sternberg Astronomical Insti- tute, Moscow, U.S.S.R.	Feb. 6, 1967
R. Ebert	Würzburg, Germany	Feb. 13, 1967
Paul W. Hodge	University of Washington	March 23, 1967
Riccardo Giacconi	American Science and Engineer- ing, Inc.	March 30, 1967
William G. Mathews	University of California, San Diego	April 13, 1967
James Terrell	Los Alamos Scientific Labora- tory, University of California, San Diego	April 27, 1967
Alan T. Moffet	California Institute of Tech- nology	May 1, 1967
Alan E.E. Rogers	M.I.T., Lincoln Laboratory	May 2, 1967
Emile J. Blum	Meudon Observatory, University of Paris, Meudon, France	May 11, 1967 and June 22, 1967
Geoffrey R. Burbidge	University of California, San Diego	May 23, 1967
W. Miller Goss	University of California, Berkeley	May 24, 1967

Speaker	Institution	Date
George A. Seielstad	California Institute of Technology	June 6, 1967
K. Wrum	Goddard Space Flight Center	June 7, 1967
A. P. Henderson	University of Maryland	June 29, 1967

A list of Observatory reprints issued since June 30, 1966.

Series A			
No.	Title	Author	Reference
53	Thermal Detection Radiometry at Short Millimeter Wavelengths	F. J. Low	Proc. IEEE, <u>54</u> , No. 4, April 1966
54	Observations of the Hydrogen Recombination Line $\lambda_{110}-\lambda_{109}$ Emitted from Galactic HII Regions	P. G. Mezger	A.J., <u>71</u> , No. 3, April 1966
55	Structure of 3C 444 from Observations of Lunar Occultations	Marvin L. DeJong	A.J., <u>71</u> , No. 5, June 1966
56	The Detection of the Thermal Radio Emission from Uranus and Neptune at 1.9 cm	K.I. Kellermann I.I. Pauliny-Toth	A.J., <u>71</u> , No. 6, August 1966
57	Observations of Interplanetary Scintillations at 1400 Mc/sec	D. E. Hogg and T. K. Menon	A.J., <u>71</u> , No. 6, August 1966
58	The Distance of Tycho's Supernova from 21-cm Absorption Measurements	T. K. Menon and D.R.W. Williams	A.J., <u>71</u> , No. 6, August 1966
59	Variations in the Flux Densities of Radio Sources	I.I.K. Pauliny-Toth and K. I. Kellermann	A.J., <u>71</u> , No. 6, August 1966
60	Cooled Loads as Calibration Noise Standards for the mm-Wavelength Range	R. C. Menon, N. P. Albaugh, J. W. Dozier	Proc. IEEE, <u>54</u> , No. 10, October 1966
61	On Grating Plateaux of the Conformal Array--A Class of Planar Nonuniformly Spaced Arrays	Y. L. Chow and Y. L. Yen	IEEE Trans. Ant. & Prop., <u>AP-14</u> , September 1966
62	Fine Structure of the Radio Source Cygnus A	C. M. Wade	Phys. Rev. Letters, <u>17</u> , November 1966
63	Upper Limit to the Neutral Hydrogen Density in the Halo Regions of Spiral Galaxies	Morton S. Roberts	Phys. Rev. Letters, <u>17</u> , December 1966
64	A Single-Sideband-Double Sideband Interferometer Receiver for Radio Astronomy	Karel H. Wesseling	IEEE Trans. Ant. & Prop., <u>AP-15</u> , March 1967

No.	Title	Author	Reference
65	Design of Large Steerable Antennas	S. von Hoerner	A.J., <u>72</u> , No. 1, February 1967
66	National Radio Astronomy Observatory	D. S. Heeschen	A.J., <u>71</u> , No. 9, November 1966
<u>Series B</u>			
63	Radio Emission from a Number of Possible Supernovae Remnants	D. E. Hogg	Ap.J., <u>144</u> , May 1966
64	A High-Resolution 21-cm Hydrogen Line Survey of the Andromeda Nebula	Morton S. Roberts	Ap.J., <u>144</u> , May 1966
65	Positions and Flux Densities of Radio Sources	I.I.K. Pauliny-Toth, C.M.Wade, D. S. Heeschen	Ap. J. Suppl., <u>XIII</u> , May 1966
66	Internal Structures and Spectra of 3C 273 from Lunar Occultations	S. von Hoerner	Ap.J., <u>144</u> , May 1966
67	Radio Source Fringe Visibilities with an Interferometer of 21500-Wavelength Baseline	B. G. Clark and D. E. Hogg	Ap.J., <u>145</u> , July 1966
68	The Planetary Nebula NGC 3242	May A. Kaftan-Kassim	Ap.J., <u>145</u> , August 1966
69	B. Joint Discussion on the Orion Nebula	T. K. Menon	Trans. International Astronomical Union, Vol. <u>XIIB</u> , 1966
70	A Search for Radio Emission from the Star Alpha Orionis	K.I.Kellermann and I. I. K. Pauliny-Toth	Ap.J., <u>145</u> , September 1966
71	Observations of the Radio Emission of Uranus Neptune and Other Planets at 1.9 cm.	K.I.Kellermann and I.I.K. Pauliny-Toth	Ap.J., <u>145</u> , September 1966
72	A Model for Variable Extra-Galactic Radio Sources	H. van der Laan	Nature, <u>211</u> , September 1966

No.	Title	Author	Reference
73	The Absolute Radio Luminosity and Surface Brightness of Extragalactic Radio Sources	D. S. Heeschen	Ap.J., <u>146</u> , November 1966
74	Reduction of Tropospheric Noise Fluctuations at Centimetre Wavelengths	J.W.M. Baars	Nature, <u>212</u> , October, 1966
75	A Search for Radio Emission from Blue Stellar Objects and Seyfert Galaxies	K.I. Kellermann I.I.K. Pauliny-Toth	Nature, <u>212</u> , November 1966
76	On the Structure of Stellar Clusters after Relaxation	S. von Hoerner	International Astronomical Union Symposium No. 25, 1966
77	Variations in the Radio-Frequency Spectra of 3C 84, 3C 273, 3C 279 and other Radio Sources	I.I.K. Pauliny-Toth and K.I. Kellermann	Ap.J., <u>146</u> , December 1966
78	On the Interpretation of Radio Source Spectra and the Evolution of Radio Galaxies and Quasi-Stellar Sources	K.I. Kellermann	Ap.J., <u>146</u> , December 1966
79	Angular Sizes of Quasi-stellar Radio Sources	D. E. Hogg	Nature, <u>212</u> , December 1966
80	Measurements of the 1.9 cm Thermal Radio Emission from Mercury	M.A. Kaftan-Kassim and K.I. Kellermann	Nature, <u>213</u> , January 1967
81	Least-Squares Fit of a Gaussian to Radio Sources	S. von Hoerner	Ap.J., <u>147</u> , February 1967
82	Galactic HII Regions I. Observations of their Continuum Radiation at the Frequency 5 GHz	P. G. Mezger and A. P. Henderson	Ap.J., <u>147</u> , February 1967
83	Galactic HII Regions. II. Observations of Their Hydrogen 109 α Recombination Line Radiation at the Frequency 5009 MHz	P. G. Mezger and B. Hoglund	Ap.J., <u>147</u> , February 1967
84	Variations in the Flux Density of Some Quasi-stellar Sources	K.I. Kellermann I.I.K. Pauliny-Toth	Nature, <u>213</u> , March 1967

No.	Title	Author	Reference
85	Lunar Occultations of Two Radio Sources	Marvin L. DeJong	Ap.J., <u>148</u> , May 1967