

NATIONAL RADIO ASTRONOMY OBSERVATORY
Charlottesville, Virginia

Quarterly Report

July 1, 1971 - September 30, 1971

RESEARCH PROGRAMS

	<u>Hours</u>
<u>Interferometer</u>	
Scheduled observing	2056.75
Scheduled maintenance and equipment changes	151.25
Time lost due to: equipment failure	54.00
power	0.00
weather	33.75
interference	4.25

During this quarter the following continuum observations at 2695 and 8085 MHz were conducted simultaneously, except as noted.

<u>Observer</u>	<u>Program</u>
R. Sramek	Observations of the structure of radio cores in normal elliptical galaxies.
R. Sramek and J. Wardle	Linear polarization measurements of elliptical galaxies.
R. Hjellming and C. Wade	Observations to study possible X-ray sources for intensity and structural changes.
B. Dennison (Louisville) and E. Fomalont	Observations at 8085 MHz to determine the confusion level of faint sources.
K. Johnson (Arizona) and K. Kellermann	Observations of the flux densities of variable sources.
J. Wardle	Observations to monitor variable sources for polarization and intensity changes.
F. Drake (Cornell) and F. Briggs (Cornell)	Observations at 1420 MHz to study Mars, Jupiter, Saturn and Mercury, and brief observations of Neptune and Uranus.

The following 21-cm neutral hydrogen-line observations were conducted.

<u>Observer</u>	<u>Program</u>
C. Heiles (Berkeley), S. Gottesman, M. Roberts, M. Wright and W. B. Burton	Fan beam synthesis of 18 galaxies, a two-dimensional synthesis of 6 galaxies, and both a fan beam and a two-dimensional synthesis of absorption of selected galactic and extragalactic radio sources.
F. Kerr (Maryland), G. Knapp (Maryland), and D. Ball (Maryland)	Observations of continuum sources in the directions of high-velocity clouds searching for hydrogen-line absorption.
L. Welachew (Caltech), S. Gottesman, and M. Wright	Observations to measure hydrogen in absorption in front of NGC 253 and M82.

The following very long baseline experiments were conducted.

<u>Observer</u>	<u>Program</u>
M. Cohen (Caltech), P. Hemenway (Virginia), B. Clark, K. Kellermann, R. Sramek, and J. Broderick	Two separate experiments, at 1420 MHz and 8085 MHz, were conducted to collect astrometric and geodetic data in a four-antenna configuration utilizing two NRAO 85-foot telescopes and two Owens Valley Radio Observatory 90-foot telescopes.

140-foot Telescope

	<u>Hours</u>
Scheduled observing	2017.25
Scheduled maintenance and equipment changes	174.25
Time lost due to: equipment failure	105.25
power	2.25
weather	3.00
interference	1.75

The following line observations were conducted.

<u>Observer</u>	<u>Program</u>
W. Flygare (Illinois), R. Rubin (Illinois), R. Benson (Illinois), and H. Tigelaar (Illinois)	Observations to search for the following molecules: (1) CH_3COOH (acetic acid) at 6.015 GHz, (2) CH_2CHCHO (acrolein) at 8.902 GHz, (3) SiH_3CN (silyl cyanide) at 9.946 GHz, (4) CH_2CHCN (vinyl cyanide) at 9.485 GHz and 6.732 GHz, (5) HCN (hydrogen cyanide) at 9.423 GHz, (6) CH_3NO (nitrosomethane) at 3.638 GHz, and (7) CH_2NOH (formaldoxime) at 1.779 GHz.
B. Zuckerman (Maryland) and P. Palmer (Chicago)	Observations to search for the following molecules: CH_3NH_2 (methyl amine) at

<u>Observer</u>	<u>Program</u>
B. Zuckerman <u>et al.</u> , continued	9.706 GHz and CH_2N_2 (diazomethane) at 6.942 GHz.
D. Dickinson (Smithsonian), H. Radford (Smithsonian), and A. E. Lilley (Harvard)	Search for the $3_{03}-2_{12}$ transition of CH_2O_2 (formic acid) at 3.440 GHz and HCO (formyl radical) at 2.892 GHz.
B. Zuckerman (Maryland) and B. Turner	Observations over the frequency range of 3.390-3.738 GHz to search for the interstellar CH molecule.
P. Palmer (Chicago), C. Gottlieb (Harvard), and B. Zuckerman (Maryland)	Search for the four hyperfine split lambda doublet lines of the $V = 1$ state of OH and the $1_{11}-1_{10}$ transition of HCONH_2 (formamide) over the frequency range 1.538-1.541 GHz.
C. Gottlieb (Harvard), J. Ball (Harvard), A. E. Lilley (Harvard), and H. Radford (Smithsonian)	Observations at 1.569 GHz to search for CH_3SH (methyl mercaptan), at 1.371 GHz to search for CH_2CHCN (acrylonitrile), and at 1.065 GHz to search for the lowest K-doubling transition of CH_3CHO (acetaldehyde).
P. Thaddeus (Goddard Institute for Space Studies), R. de Zafra (Goddard Institute for Space Studies), M. Kutner (Columbia), R. Zare (Columbia), and C. Heiles (Berkeley).	Observations at 1.544 GHz to search for $\text{C}_2\text{H}_5\text{N}$ (ethylenimine).
C. Heiles (Berkeley), H. Weaver (Berkeley), N. Evans III (Berkeley), and M. Werner (Berkeley)	Search for the $4_{23}-4_{22}$ transition of H_2CO (formaldehyde) at 1.066 GHz and the $1_{11}-1_{10}$ transition of H_2CS (thioformaldehyde) at 1.046 GHz in Sgr B ₂ , W43, W51, W12, and in the Taurus dust cloud and cloud L134.
D. Dickinson (Smithsonian) and H. Penfield (Harvard)	Search for the fine structure lines of atomic hydrogen at 1.369 and 1.236 GHz.
F. Kerr (Maryland) and G. Knapp (Maryland)	Additional measurements in 21-cm neutral hydrogen toward the Kapteyn Selected Areas.
E. Grayzeck (Maryland)	Observations of 21-cm neutral hydrogen at the positions of hot luminous stars.

<u>Observer</u>	<u>Program</u>
F. Kerr (Maryland), W. Sullivan (Maryland) and G. Keplan (Maryland)	Observations of high-velocity neutral hydrogen clouds at 21 cm.
F. Kerr (Maryland) and G. Knapp (Maryland)	Search for 21-cm high-velocity neutral hydrogen in the directions of six globular clusters.
W. Burton and G. Verschuur	Detailed studies of the structure of 21-cm neutral hydrogen far from the galactic plane which is associated with a distant spiral arm.
C. Heiles (Berkeley) and M. Gordon	Measurements at the 21-cm neutral hydrogen line and the 1667-MHz OH line of the parameters of dust clouds.
A. E. Lilley (Harvard), J. Ball (Harvard), D. Cesarsky (Harvard), and A. Dupree (Harvard)	Investigation at 21 cm of a narrow recombination line component in W3, W51, and NGC 2024.
W. Flygare (Illinois), R. Rubin (Illinois), R. Benson (Illinois), and H. Tigelaar (Illinois)	Observations over the frequency range of 22.9-23.5 GHz to search for the following molecules: (1) HCNO (fulminic acid), (2) CNCH ₂ CN (malononitrile), (3) CH ₂ N ₂ (diazomethane), (4) CH ₂ NOH (formoxime), and (5) HCOCH ₂ OH (glycolaldehyde). Observations over the frequency range of 19.26-21.87 GHz to either search for or make additional measurements of the following molecules: (1) NH ₂ CHO (formamide), (2) NH ₂ CN (cyanamide), (3) CH ₃ CHO (acetaldehyde), (4) CH ₃ NO (nitrosomethane), (5) CH ₂ CHNO ₂ (nitroethylene), (6) CH ₃ NC (methyl isocyanide), (7) CH ₃ CH ₂ CH ₃ (propane), (8) CH ₂ CHNO ₂ (nitroethylene).
J. Hagen (Penn State), P. Swanson (Penn State), and R. Bernheim (Penn State)	Search for interstellar CH ₂ at 20.7 GHz.
R. Rubin (Illinois) and B. Turner	Search at 1.35 cm for recombination lines in NGC 7027.
B. Turner	Observations to search for excited OH lines at 23.8 GHz in W3 OH, W49, W51N, W28N, NML Cyg, and VY CMa.

<u>Observer</u>	<u>Program</u>
B. Balick (Cornell) and Y. Terzian (Cornell)	High-resolution mapping at 23.404 GHz of H65 α in the H II regions M42, M17, W3, and W51.
P. Palmer (Chicago), B. Zuckerman (Maryland), M. Morris (Chicago), and B. Turner	Continued observations to search for NH ₃ in galactic sources at 23.7 GHz.
A. Dupree (Harvard) and E. Chaisson (Harvard)	Observations at 2704 and 2726 MHz of the α and β recombination lines of carbon in NGC 2024 and W3.
G. Assousa (Carnegie Institution of Washington) and J. Erkes (SUNY, Albany)	Study of 21-cm neutral hydrogen radiation around the supernova remnant HB21.
W. Altenhoff (Max-Planck-Institut für Radioastronomie, Bonn, W. Germany) and T. Wilson (Max-Planck-Institut für Radioastronomie, Bonn, W. Germany)	Observations of the Rosette Nebula in recombination line radiation near 1400 MHz.
M. Roberts	Observations at 1421 MHz to search for high-velocity neutral hydrogen clouds in other galaxies and to search for neutral-hydrogen emission from the galaxies Maffei 1 and Maffei 2.
G. Knapp (Maryland), F. Kerr (Maryland), and P. Bowers (Maryland)	Investigation of a peculiar 21-cm neutral hydrogen feature near Messier 92.
R. Whitehurst (Alabama) and M. Roberts	Search at 21 cm for recombination lines from fundamental particles.
D. Cesarsky (Caltech) and E. Chaisson (Harvard)	Study at 1683 MHz of recombination-line emission originating in neutral hydrogen regions.

The following continuum observations were conducted.

<u>Observer</u>	<u>Program</u>
B. Balick (Cornell) and Y. Terzian (Cornell)	High-resolution mapping of the H II regions M42, M17, W3, and W51 at 23.4 GHz.
M. Kundu (Maryland) and T. Velusamy (Maryland)	Observations at 11 cm to measure the polarized brightness distribution of known and suspected supernova remnants.

ObserverProgram

R. Lovelace (Cornell), G. Zeissig
(Puerto Rico), and D. Backer

Investigation at 20 and 40 cm of small-scale structure in 3C 273 and 3C 279 and observations at 1667 MHz to study the scintillation parameters of 3C 273 and 3C 279.

S. Goldstein (Virginia) and F. Gauss
(Virginia)

Observations of strong radio sources to obtain the position angle and amplitude of the linear polarized flux at discrete points over a 200-MHz band centered at 1350 MHz.

The following very long baseline observations were conducted:

ObserverProgram

G. Purcell (Caltech) and D. Shaffer
(Caltech)

Observations at 606 MHz to investigate the size and structure of radio sources having substantial structure between 0".1 and 0".001 arc using the Caltech Owens Valley 130-foot telescope and the NRAO 140-foot telescope.

L. Matveyenko (Cosmic Space Institute, Moscow, USSR), D. Jauncey
(Cornell), J. Broderick, B. Clark,
and K. Kellermann

Observations at 13-cm wavelength to study the structure of sources using the NASA 85-foot telescope at Barstow, California and the NRAO 140-foot telescope.

300-foot TelescopeHours

Scheduled observing	1999.50
Scheduled maintenance and equipment changes	151.25
Time lost due to: equipment changes	49.00
power	0.00
weather	12.00
interference	0.00

During this quarter the following continuum observations were conducted:

ObserverProgram

H. Murdoch (Sydney, Australia)

Observations at 1400 and 2695 MHz to obtain the spectra of sources contained in the Molonglo 408-MHz survey.

M. Kundu (Maryland) and T. Velusamy
(Maryland)

Observations at 2695 MHz to search for weak extended sources in the direction of pulsars that are known to have long

<u>Observer</u>	<u>Program</u>
M. Kundu <u>et al.</u> , continued	periods and measurements of the intensity and polarization of galactic supernova remnants.
T. Menon (Tata Institute, Bombay, India)	Measurements of the 11-cm fluxes of 350 sources for which occultation positions are available from the Indian occultation telescope.
K. Kellermann and M. Davis	Measurements of the 11-cm flux densities of sources detected in the NRAO 140-foot and 300-foot 6-cm survey.
G. Westerhout (Maryland)	Observations at 1400 and 2695 MHz to measure the polarization of the galactic background.
Y. Terzian (Cornell) and B. Balick (Cornell)	Observations at 2695 MHz to measure the brightness temperature distribution in M33 and M31.
J. Webber (Illinois)	Observations at 2695 MHz of a large sample of weak radio sources in the Vermillion River Observatory Catalog.
M. Davis	Observations at 2695 MHz to measure flux densities of sources selected from the 1400 MHz 300-foot survey.

The following line observations were conducted:

<u>Observer</u>	<u>Program</u>
R. Harten (Maryland) and G. Mader (Maryland)	Observations of 21-cm galactic neutral hydrogen to compare and aid in combining data taken in the northern and southern hemispheres.
G. Westerhout (Maryland), R. Harten (Maryland), and G. Mader (Maryland)	Observations of 21-cm neutral hydrogen at constant galactic latitude to calibrate the Maryland-Green Bank 21-cm line survey.
D. Williams (Berkeley)	Observations of 21-cm neutral hydrogen to study ionization holes around supernova remnants and the absorption spectra of the associated sources.

The following pulsar observations were conducted:

<u>Observer</u>	<u>Program</u>
R. Manchester	Observations from 200-500 MHz to continue pulsar polarization and timing measurements.
R. Manchester (Massachusetts), G. Huguenin (Massachusetts), and J. Taylor (Massachusetts)	Observations over the frequency range of 250-500 MHz to measure the polarization of single pulses and to obtain additional timing data of pulsars.

36-foot Telescope

	<u>Hours</u>
Scheduled observing	1216.0
Scheduled maintenance and equipment changes	877.5
Scheduled tests and calibration	23.5
Time lost due to: telescope and receiver failure	63.0
digital system failure	67.25
power	4.5
weather	34.0
interference	3.0

No observing was scheduled for the period July 15 - August 15 due to anticipation of adverse weather conditions. During that time, major changes were made in the telescope and control room, including: installation of azimuth legs on the focal support, eliminating four steel guy-wires; complete rewiring of the dome electrical system and reorganizing of the control room; testing and installation of a new encoder and tachometer system; overhaul of all line and continuum receivers; and installation of a new, versatile computer program for telescope tracking, scanning, and data acquisition.

During July 1-14 and August 16-September 30, the following observations were made:

<u>Observer</u>	<u>Program</u>
P. Palmer (Chicago), B. Zuckerman (Maryland), and B. Turner	Study of NH_3 and search for HNC and HNCS at 22-24 GHz.
W. Flygare (Illinois), R. Rubin (Illinois), R. Benson (Illinois), and H. Tigelaar (Illinois)	Search for HCNO and other molecules at 22-24 GHz.
Y. Terzian (Cornell) and A. Parrish (Cornell)	Observations of the Cygnus X region at 31 GHz.
K. Johnson (Arizona)	Monitoring of 3C 120 for variability at 31 and 85 GHz.

<u>Observer</u>	<u>Program</u>
F. Biraud	Search for circular polarization in compact sources at 31 GHz.
L. Matveyenko (Space Research Institute, Moscow, USSR)	Observations of linear polarization in the Crab Nebula at 85 GHz.
I. Moiseev (Crimean Astrophysical Observatory) and V. Efanov (Crimean Astrophysical Observatory)	Circular polarization of the quiet sun and active regions at 85 GHz.
E. Conklin	Observations at 85 GHz of unusual sources from the Ohio State catalog.
W. Dent (Massachusetts) and R. Hobbs (NASA-Goddard)	Measurement of flux densities of variable sources at 31 and 85 GHz.
E. Mayfield (Aerospace Corp.), F. Shimabukuro (Aerospace), and S. Edelson (NASA-Ames)	Investigation of non-thermal processes in solar active regions at 31 GHz.
J. Wardle	Measurement of linear polarization of radio sources at 31 GHz.
B. Turner, P. Palmer (Chicago), B. Zuckerman (Maryland), W. Howard, and H. Hvatum	Search for HC ₃ HO, C ₁₀ and other unidentified molecules at 85-95 GHz, and a search for strong spectral lines at 85-95 GHz.

ELECTRONICS DIVISION--EQUIPMENT DEVELOPMENT

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

Interferometer Development	11%
Interference Protection	2%
Very Long Baseline Interferometer	18%
24-GHz Receiver	6%
6-cm Receiver	3%
384-Channel Autocorrelation Receiver	9%
Visitor Support and Routine Maintenance	32%
21-cm Cooled Paramp	9%
Millimeter-Wave Development	2%
IF Processor Construction	5%
140-foot Computer Addition	3%

During this quarter several Mark II very-long-baseline interferometer terminals were completed. Others, completed earlier in the year, have been used successfully.

Work is continuing on the 21-cm cooled paramp development, and IF processor construction.

The construction of a 50-channel, 1.2 MHz filter bank was initiated this quarter. Development work on cooled crystal mixers has also been started. A contract for construction of parametric amplifiers covering 500-1000 MHz has been let, and the contract for a cooled 15-GHz paramp is proceeding on schedule.

ENGINEERING DIVISION

The efforts of the Engineering Division during this quarter were concentrated on the following projects:

1. Manufacture and installation of auxiliary feed legs to replace guy cables on the 36-foot telescope at Kitt Peak. Installation of revised encoder mounting system on azimuth and elevation axes of the 36-foot telescope.
2. Construction was completed on the oil separator at the 300-foot telescope to prevent escape of excess oil to area waterways.
3. A tower for feed testing was designed, procured and erected adjacent to the laboratory building in Green Bank.
4. Contracts for design studies for alternate surface panel systems for the 65 meter homology antenna were signed, and design studies are in progress.
5. Designs of a secondary reflector for the 36-foot telescope and equipment for handling and mounting receiver equipment at the vertex are in progress.
6. A design study of replacement feed legs for the 140-foot telescope is underway.

COMPUTER DIVISION

<u>IBM 360/50 Computer Statistics</u>		<u>Hours</u>
Shift time (operating system)		2196
Independent time (not operating system)		45
Unscheduled down-time		23
Scheduled maintenance		13
Usable time		2115
Computer actually busy		2067.999
Busy fraction of usable time	97.78%	
Number of active user codes	98	
Number of jobs run	16,113	

Hardware

1. IBM's System Management Instrument, which measures electronic coincidences of various conditions, was temporarily installed to help point out sources of

inefficiencies in the operating system software or in the hardware configuration of the IBM 360/50.

2. A magnetic tape cleaning machine (Data Devices, Mark III) was procured, and a tape-cleaning plan instituted; each of the 3000 NRAO data tapes will be cleaned about once per year in an attempt to improve their useful life.

Software

1. Experiments with the MVT operating system and three 100K-byte user partitions have started, while most production data processing continues under MFT with four 90K-byte user partitions.

2. The 36-foot telescope DDP-116 pointing and continuum-data recording program was completely rewritten in the interactive-terminal language already running there for spectral work on the H316 spectral-line processor.

3. The 140-foot and 300-foot DDP-116 programs were revised to fit "total power" and "switched power" procedures, and to produce the data format needed in new IBM 360/50 standard reduction programs. The new switched power program will replace the old standard programs AC4141 through AC4144 and will run twice as fast.

4. A macro assembler for DDP-116's, that will run directly on any DDP-116 rather than on the IBM 360/50 as previously done, was written and is undergoing checkout.

ANTENNA DESIGN

Homology Telescope

The main NRAO effort is now being directed to assembling the design information and writing the report on the work done so far.

Some months ago we agreed with the Max-Planck-Institut für Radioastronomie to work together on the design of a millimeter-wave telescope. The first step in this cooperation was taken last March when MPI started design work on an antenna of the same size and with essentially the same design goals as our own. Since then there has been an active exchange of information with Bonn. Their design is being done mainly by Krupp and MAN, but other companies may be brought in.

The results of this cooperative effort should be of considerable interest to both observatories. Although the performance goals are identical, the ways of meeting them are being thought out reasonably independently here and in West Germany. Thus the two designs may differ in several aspects and comparisons will be valuable.

SEMINAR

An international seminar on high-velocity neutral hydrogen was held at the NRAO in Green Bank from September 5-8, 1971. The meeting, which consisted largely of discussions of the problems raised by observations of hydrogen moving with anomalous velocities not explained by normal galactic rotation, was attended by some 35 astronomers from different institutions, geographically ranging from Leiden to Berkeley. The participants presented much new data and many theories at the meeting and, as a consequence, the informal discussion format proved very successful.

PERSONNEL

Appointments

Robert W. Haas	Electronics Engineer I	July 14, 1971
Donald C. Backer	Research Associate	August 17, 1971
Anthony R. Kerr	Electronics Engineer II	August 19, 1971
Bruce Balick	Research Associate	September 15, 1971

Terminations

Hugh S. Murdoch	Visiting Associate Scientist	July 21, 1971
Takenori Nakano	Visiting Associate Scientist	July 23, 1971
Francois Biraud	Visiting Assistant Scientist	July 27, 1971
John Broderick	Research Associate	August 13, 1971
Thuppalay K. Menon	Visiting Scientist	August 20, 1971
Eugene H. Tademaru	Research Associate	August 31, 1971
Richard N. Manchester	Research Associate	August 31, 1971
Stephen T. Gottesman	Research Associate	September 3, 1971
Carl E. Heiles	Visiting Scientist	September 9, 1971

Leave of Absence

David S. DeYoung (at High Altitude Observatory)	Assistant Scientist	July 1, 1971 to July 31, 1971
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