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NATIONAL RADIO ASTRONOMY OBSERVATORY
Charlottesville, Virginia

Quarterly Report

October 1, 1971 - December 31, 1971

RESEARCH PROGRAMS

<u>140-foot Telescope</u>	<u>Hours</u>
Scheduled observing	1971.00
Scheduled maintenance and equipment changes	181.00
Time lost due to: equipment failure	47.00
power	0.00
weather	4.25
interference	4.75

The following line observations were conducted.

<u>Observer</u>	<u>Program</u>
C. Heiles (Berkeley) and M. Gordon	Measurements of OH in dust clouds at 1667 MHz.
D. Cesarsky (Caltech) and E. Chaisson (Harvard)	Study of 1683-MHz recombination-line emission originating in neutral hydrogen regions.
T. Wilson (Max-Planck-Institut für Radioastronomie, Bonn, W. Germany)	Observations of OH from supernova remnants at 1667 and 1720 MHz.
J. Ball (Harvard) and E. Chaisson (Harvard)	Study of an anomalous recombination line near 1683 MHz in the direction of W3 and DR 21.
J. Taylor (Massachusetts) and J. Lockman (Massachusetts)	Observations of a region near the galactic center to map the 18-cm H158 α recombination line.
D. Dickinson (Smithsonian Astrophysical Observatory) and B. Turner	Polarization studies of the main 1667-MHz OH lines in ten weak sources.
S. Gottesman (Caltech) and M. Gordon	Observations of 18-cm recombination lines from distributed ionized hydrogen.
G. Verschuur and M. Gordon	Search for 18-cm recombination lines in high-velocity clouds.

<u>Observer</u>	<u>Program</u>
B. Turner	Observations of the galactic distribution of OH in the range $337^{\circ} \leq \ell \leq 75^{\circ}$ at 1667 MHz.
C. Heiles (Berkeley) and B. Turner	Continued measurements of the four 18-cm OH lines in dust clouds.
A. Barrett (MIT) and P. Myers (MIT)	Map at the 1667-MHz OH line three galactic dark clouds known to contain OH and H ₂ CO molecules.
J. Ball (Harvard), K. Bechis (MIT), W. Wilson (Aerospace Corp.), and P. Schwartz (NRL)	Monitor of 18-cm OH emission from 36 infrared stars.
J. Ball (Harvard), C. Gottlieb (Harvard), H. Radford (Smithsonian Astrophysical Observatory), and B. Zuckerman (Maryland)	Search for the O ¹⁷ H molecule at 1624 and 1625 MHz, the O ¹⁸ H molecule at 1639 MHz, and the O ¹⁶ H molecule at 1667 MHz in the external galaxy M82.
G. Verschuur	Observations at 1667 MHz to study OH emission in H I regions, to study distributed OH, and to investigate OH emission in cold clouds.
E. Chaisson (Harvard) and A. Dupree (Harvard)	Observations at 18 cm of the carbon α and β recombination lines in NGC 2024, W3 and K3-50.
C. Gottlieb (Harvard), P. Palmer (Chicago), L. Rickard (Chicago), and B. Zuckerman (Maryland)	Continued observations of NH ₂ CHO (formaldehyde) at 1540 MHz.
B. Zuckerman (Maryland) and B. Turner	Search for the CH molecule at 3374 ± 36 MHz.
R. Whitehurst (Alabama) and M. Roberts	Investigation of the rotation curve and sheets of 21-cm neutral hydrogen in M31.
J. Gallagher (Wisconsin)	Search for 21-cm neutral hydrogen in elliptical galaxies.
G. Knapp (Maryland) and G. Verschuur	Mapping of cold, high latitude 21-cm neutral hydrogen clouds to determine their velocity structure.
A. Milman (Maryland)	Detailed mapping and high-velocity resolution studies of 21-cm neutral hydrogen in L134 and L1547/L1552.

<u>Observer</u>	<u>Program</u>
F. Kerr (Maryland) and G. Kaplan (Maryland)	Observations at the 21-cm line of neutral hydrogen to study an unusual feature found in one of the high-velocity clouds in Hulsbosch's Complex A.
G. Knapp (Maryland)	High-frequency resolution mapping of 21-cm neutral hydrogen in dust clouds.
G. Assousa (Carnegie Institution of Washington) and J. Erkes (SUNY, Albany)	Studies of 21-cm neutral hydrogen around the supernova remnant HB21.
F. Kerr (Maryland) and J. Carlson (Maryland)	Observations of the 1421-MHz neutral hydrogen line and the 1424.7 MHz H167 α recombination line in the direction of the galactic center to search for a "black hole".
F. Kerr (Maryland), G. Knapp (Maryland), and P. Bowers (Maryland)	Investigation at the 21-cm neutral hydrogen line of a peculiar feature near M92.
F. Kerr (Maryland) and G. Knapp (Maryland)	High-sensitivity search for 21-cm neutral hydrogen in globular clusters.
E. Grayzeck (Maryland)	Observations at the 21-cm line of neutral hydrogen of positions of hot luminous stars and X-ray sources.

The following very long baseline observations were conducted.

J. Moran (Smithsonian Astrophysical Observatory), W. Wilson (Aerospace Corp.), E. Hardebeck (Caltech), P. Schwartz (NRL), J. Ball (Harvard), and O. Rydbeck (Chalmers Univ., Onsala, Sweden)	Observations at the 18-cm OH-line of strong OH-emission sources associated with IR stars in order to determine their angular size, their relative and absolute positions--using the Chalmers University's 84-foot telescope, the Haystack 120-foot telescope, and the NRAO 140-foot telescope.
M. Cohen (Caltech), B. Clark, and K. Kellermann	Observations at 10.7 GHz to measure the fine structure of 10 sources, using the Caltech 130-foot telescope at Owens Valley and the NRAO 140-foot telescope.

The following continuum observations were conducted.

E. Seaquist (David Dunlap Observatory, Canada) and F. Biraud (Meudon, France)	Investigation of the spectrum of circular polarization of 3 or 4 sources at 1666 MHz.
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<u>Observer</u>	<u>Program</u>
R. Lovelace (Cornell), G. Zeissig (U. of Puerto Rico), and D. Backer	Observations at 1666 MHz to study the scintillation parameters of 3C 273 and 3C 279.

36-foot Telescope

	<u>Hours</u>
Scheduled observing	1948.75
Scheduled maintenance and equipment changes	206.75
Scheduled tests and calibration	121.25
Time lost due to: telescope and receiver failure	215.75
digital system failure	21.50
power	2.75
weather	219.00
interference	0.0

During this quarter a new type of cryogenic superheterodyne bolometer receiver was tested on the telescope. Major modifications were made to both on-line computer programs and intensive documentation was started.

<u>Observer</u>	<u>Program</u>
B. Turner, P. Palmer (Chicago), and B. Zuckerman (Maryland)	Search for HC ₃ HO, C ₂ O and other molecules at 85-95 GHz.
W. Howard and H. Hvatum	Search for strong spectral lines at 85-95 GHz.
R. Hobbs (NASA-Goddard), S. Maran (NASA-Goddard), E. Conklin, and H. Y. Chin (NASA-Goddard)	Search for pulsar radiation from CP 0328, NP 0532, and JP 2022 at 31 GHz.
E. Conklin	Observations of Ohio State sources with flat spectra at 31 GHz.
K. Johnson (Arizona)	Observations of 3C 120 for variability at 31 and 85 GHz.
C. Gottlieb (Harvard), J. A. Ball (Harvard), A. E. Lilley (Harvard), H. Penfield (Harvard), and H. Radford (Harvard)	Observations of methyl alcohol at 96 GHz.
W. Wilson (Aerospace Corp.) and P. Schwartz (NRL)	Observations of HCN, CO, CN, and X-ogen in late-type stars.
W. M. Goss (Max-Planck-Institut für Radioastronomie, Bonn, W. Germany)	Mapping of 3C 391 at 31 GHz.

<u>Observer</u>	<u>Program</u>
E. Mayfield (Aerospace Corp.), F. Shimabukuro (Aerospace Corp.) and S. Edelson (NASA-Ames)	Investigation of non-thermal processes in solar active regions at 31 GHz.
J. Rather	Tests and observations of planets and extragalactic sources at 260 GHz.
P. Solomon (Minnesota), K. Jefferts (Bell Labs), A. Penzias (Bell Labs), and R. Wilson (Bell Labs)	Observations of CS in the galactic center, H II regions and IR objects.
E. Epstein (Aerospace Corp.), W. Fogarty (Aerospace Corp.) and J. Montgomery (Aerospace Corp.)	Search for short-term time variations in QSO's at 85 GHz.
A. Penzias (Bell Labs), R. Wilson (Bell Labs), K. Jefferts (Bell Labs), P. Solomon (Minnesota), and H. Liszt (Princeton)	Further observations of CO, CN, and other molecules at 101-115 GHz.
P. Thaddeus (NASA-Goddard), M. Kutner (Columbia), A. Penzias (Bell Labs), R. Wilson (Bell Labs), and K. Jefferts (Bell Labs)	Search for HCO, HCN, and other molecules at 168-178 GHz.
K. Jefferts (Bell Labs) and T. Phillips (Bell Labs)	Observations of CN and search for DCN at 115 and 140 GHz.
L. Snyder (Virginia) and D. Buhl	Search for new HCN, HNC, and X-ogen isotopes and transitions; search for new molecules at 70-95 GHz.
M. Simon (SUNY, Stony Brook) and P. Berger (SUNY, Stony Brook)	Search for solar recombination lines at 85-95 GHz.

Interferometer

	<u>Hours</u>
Scheduled observing	2007.00
Scheduled maintenance and equipment changes	145.00
Time lost due to: equipment failure	66.00
power	0.00
weather	18.25
interference	0.50

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

<u>Observer</u>	<u>Program</u>
C. Heiles (Berkeley), K. Riegel (UCLA), D. Elliott (UCLA), S. Gottesman (Caltech), W. B. Burton, M. Roberts, and M. Wright	Observations of six galaxies in a two-dimensional synthesis, 18 galaxies in a fan-beam synthesis, and absorption in selected galactic and extragalactic radio sources in both two-dimensional and fan-beam synthesis.

The following continuum observations were conducted simultaneously at 2695 and 8085 MHz, except as noted.

<u>Observer</u>	<u>Program</u>
E. Fomalont and R. Sramek	Observations to test the general relativity theory by the measurement of deflection of emission from 3C 279 in the solar gravitational field.
B. Burke (MIT), J. Spencer (MIT), and P. Crane (MIT)	Observations of the continuum emission from H II regions in M31 and M33.
K. Johnson (Arizona) and K. Kellermann	Monitoring 30 sources for flux density variability.
J. Wardle	Monitoring of variable sources for changes in polarization and flux density.
J. Broderick (NAIC) and E. Fomalont	Observations in an attempt to detect emission from the globular clusters M3, M13 and M15.
C. Wade and R. Hjellming	Measurements of the decline of emission of Nova Delphini 1967, Nova Serpentis 1970, and Nova Scuti 1970, a search for radio emission from new novae, and observations of binary stars.
C. Wade and R. Hjellming	Observations at 8085 MHz to improve the measured radio position of Cyg X-1.
H. Bradt (MIT), G. Spada (MIT), G. Murthy (MIT), S. Rappaport (MIT), W. Zaumen (MIT), C. Wade, and R. Hjellming	Observations of the positions and variations of X-ray sources.
D. De Young and D. Hogg	Measurements of the time variations in the complex sources Vir A, Cyg A, and Cas A.

<u>Observer</u>	<u>Program</u>
J. Cahn (Illinois) and R. Rubin (Illinois)	Flux density measurements of planetary nebulae.
E. Seaquist (David Dunlap Observatory, Canada) and F. Biraud (Meudon, France)	Investigation of the spectrum of circular polarization of several sources.
F. Biraud (Meudon, France)	Observations to measure accurate radio positions of Zwicky Compact Galaxies that are likely radio sources.
P. Kronberg (Toronto, Canada)	Measurements of the polarization structure of extragalactic radio sources.
P. Kronberg (Toronto, Canada) and J. Wardle	Polarization measurements of approximately 100 quasistellar sources.
E. Fomalont and K. Kellermann	Further observations to study the confusion level of faint sources at 2695 MHz.
J. Wardle	High-resolution observations of the polarization of sources.
R. Sramek	Study of the structure of radio cores in normal elliptical galaxies.
R. Hjellming and C. Wade	Observations to study possible X-ray sources for intensity and polarization changes.

The following very-long baseline observations were conducted.

W. Cannon (Caltech), D. Muhleman (Caltech), A. Moffet (Caltech), M. Cohen (Caltech), P. Hemenway (Virginia), K. Kellermann and R. Sramek	Four-station experiment using two NRAO 85-foot telescopes and two Owens Valley Observatory 90-foot telescopes to collect astrometric and geodetic data and to measure the general relativity theory light-bending effect.
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300-foot Telescope

	<u>Hours</u>
Scheduled observing	1914.75
Scheduled maintenance and equipment changes	237.25
Time lost due to: equipment failure	63.25
power	0.25
weather	5.00
interference	1.25

The following continuum observations were conducted.

<u>Observer</u>	<u>Program</u>
M. Davis	Observations at 2695 MHz to measure the flux densities of sources selected from the 1400-MHz 300-foot survey.
M. Kundu (Maryland) and T. Velusamy (Maryland)	Observations at 2695 MHz to complete an intensity and polarization survey of supernova remnants.
H. Arp (Hale Observatory) and M. Roberts	Studies of the association of radio sources with normal spiral galaxies at 2695 MHz.
J. Dickel (Illinois) and A. Willis (Illinois)	Polarization measurements of supernova remnants at 2695 MHz.
J. Wardle and M. Wright	Search for 2695-MHz radio emission from peculiar galaxies.
G. Westerhout (Maryland)	Observations at 20-cm wavelength to measure the polarization of the galactic background.

The following line observations were conducted.

<u>Observer</u>	<u>Program</u>
G. Verschuur	High-resolution, 21-cm line observations of neutral hydrogen to obtain data at high galactic latitudes, to obtain four constant latitude scans at $b = 0^\circ, 5^\circ, 10^\circ$, and 15° across the entire sky in order to measure variations in cloud structure and to study large Z extensions of some spiral arms.
M. Wright and S. Gottesman (Caltech)	Search for 21-cm neutral hydrogen in the region of quasistellar objects near spiral galaxies.
W. Burton and G. Verschuur	Studies of the detailed structure of 21-cm neutral hydrogen that is associated with a very distant spiral arm extending to high Z distances.
G. Knapp (Maryland) and C. Heiles (Berkeley)	Observations of dust clouds and a measurement of the 300-foot beam efficiency at the 21-cm line of neutral hydrogen.

<u>Observer</u>	<u>Program</u>
M. Goss (Max-Planck-Institut für Radioastronomie, Bonn, W. Germany) and A. Winnberg (Max-Planck-Institut für Radioastronomie, Bonn, W. Germany)	Observations of the 21-cm neutral hydrogen profiles of 66 extragalactic sources.
M. Roberts	Observations of 21-cm neutral hydrogen in galaxies.

The following very-long baseline observations were conducted.

<u>Observer</u>	<u>Program</u>
W. Erickson (Maryland), N. Vandenberg (Maryland), J. Broderick (NAIC), T. Clark (NASA-Goddard), and S. Knowles (NRL)	Very-long baseline observations at 111.5 and 196.5 MHz using the NAIC 1000-foot telescope at Arecibo and the NRAO 300-foot telescope to monitor the apparent angular size and the pulse shape of the Crab pulsar. In addition to these telescopes, the NRL 150-foot telescope at Sugar Grove was added to the configuration to observe meter wavelength spectra of compact sources.

ELECTRONICS DIVISION--EQUIPMENT DEVELOPMENT

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

Interferometer Development	8%
Interference Protection	2%
Very Long Baseline Interferometer	18%
50-Channel Receiver	3%
6-cm Receiver	3%
384-Channel Autocorrelation Receiver	3%
Visitor Support and Routine Maintenance	30%
21-cm Cooled Paramp	9%
Millimeter-Wave Development	8%
IF Processor Construction	5%
140-foot Computer Addition	3%
Antenna Measuring Instrument	5%
Antenna Pattern Range	3%

During this quarter construction of the 21-cm cooled paramp system, 140-foot computer control system, and 50-channel filter receiver have proceeded on a normal basis. These projects should be completed in early 1972. The development of a laser instrument for accurate measurement of reflector surfaces has been initiated. An antenna feed pattern measurement range has been installed in Green Bank.

Development of cryogenically-cooled crystal mixers for use in millimeter-wave receivers has been started. Initial theoretical and experimental results have shown that an order-of-magnitude improvement in receiver sensitivity is feasible.

ENGINEERING DIVISION

In addition to the performance of recurring alignment and inspection tasks in support of the operating divisions, the Engineering Division was involved in a number of special projects.

A contract was let for the fabrication and supply of a 45-foot diameter transportable antenna. This antenna is to be an altitude-over-azimuth antenna with a reflector RMS of 0.030 inches and a non-repeatable pointing error of 30 seconds of arc. Delivery is scheduled for early July. The Engineering Division is presently designing a focusing feed mount for this antenna. This antenna will be designed for use both as a prime focus instrument and as a Cassegrain instrument.

Work is progressing both at NRAO and by subcontract on the design of a surface panel system for the 65-meter millimeter-wave telescope as well as preparation of estimates of cost for fabrication of the structure and estimates of erection costs.

Design of a vertex feed mount for conversion of the 36-foot telescope to a Cassegrain antenna is nearing completion.

Design and fabrication of an altitude-azimuth mount for a 5-foot millimeter-wave dish for Tucson was completed.

COMPUTER DIVISION

Hardware

For the IBM 360/50 computer, Electronics Division construction of special circuit cards for the IBM 2701 Data Adapter enabled high-speed operation on the three channels which drive the three experimental CRT's, allowing us to make use of the inherent speed capabilities of the CRT.

For the on-line DDP 116 computers, line printers (Potter Model LI-3000) were ordered and received. Evaluation tests were completed by the Electronics Division, who are in the process of constructing the interfaces. These printers are more than ten times faster than teletypes and allow 132-column printout. They are intended to speed up the process of making on-line system program changes.

Software

The systems programming group on the IBM 360/50 has installed a Plotter Spooling, where the pen-plotter's outputs are now handled in as fully automatic a way as were the printouts. The remote job-entry program, accessible

through two (text-only) CRT's, has had its source-deck editing features considerably improved, and considerable programming is now being done through CRT's

The applications programming group brought several projects near completion: The (graphics) CRT handling of spectral-line interferometer data is now in production use, and data presentation in a strict contour-plot sense has been found less desirable than presentation of a 2-D projection of a 3-D solid plot. The programs for Total Power and Switched Power have been further improved, through incorporation of schemes that enable the observer to judge the quality of his data.

The on-line systems programming group has concentrated on the new 140-foot telescope pointing programs for the forthcoming DDP 116 - H316 multi-processor, the revised inductosyn shaft encoder hardware and the new control panel.

GREEN BANK OPERATIONS

The addition to the 300-foot control building was completed in early November, and the operations console and receivers were moved into the new control room on November 15. The new control room has an area of 1000 square feet, approximately twice that of the old room. The extra space available not only relieves the overcrowding, which had been a serious problem, but also permits more rapid change of radiometer systems since the back-end racks can be moved in and out more easily. The building has been shielded by steel mesh in order to provide protection from interference for the many low-frequency programs run on the telescope. The new heating-cooling system maintains the temperature in the control building to within 2° F, enabling an improvement in the stability of the back-end electronics.

The old control room has been converted into office space, to be used both by the observers and by the operations staff.

SYMPOSIUM ON INTERSTELLAR MOLECULES

On October 4-6, 1971, the National Radio Astronomy Observatory and the University of Virginia were joint hosts for a Symposium on Interstellar Molecules attended by 110 scientists. The program consisted of a number of invited papers that provided the astronomical background on stellar evolution, cosmic abundances, structure of the interstellar medium, interstellar grains, dust clouds and globules and molecules in stellar atmospheres. Then, the symposium participants, whose principal research interests ranged through astronomy, physics, chemistry and biology, heard invited and contributed papers on observations of interstellar molecules, the techniques of frequency calculations and laboratory measurements, molecular excitation models, the chemistry of molecules in the interstellar environment and the biological implications of the recent molecular discoveries. Discussions following each paper were both lively and informative.

JANSKY LECTURE

The sixth annual Karl G. Jansky Lecture was delivered on October 4, 1971 by Dr. Charles H. Townes of the University of California, Berkeley, on the topic "Exploring for the Creation". Dr. Townes, who delivered the evening talk at the time of the Symposium on Interstellar Molecules, is a Nobel laureate, internationally known for his research on the interaction of electromagnetic waves and matter. In 1968 he and his collaborators discovered radiation from interstellar molecules of water vapor and ammonia, an event that heralded a marked increase in the rate of molecular-line detections during the past four years. His lecture was well attended.

PERSONNEL

Appointments

Paul L. Baker	Research Associate	October 1, 1971
Duane D. Madron	Head, Plant Maintenance	October 1, 1971
Peter Brosche	Visiting Assistant Scientist	October 29, 1971
Nidumolu V.G. Sarma	Visiting Electronic Engineer	November 8, 1971
Richard H. Gammon	Research Associate	December 15, 1971

Terminations

Jochen Edrich	Electronic Engineer	December 13, 1971
*Thomas Williams	Head, Plant Maintenance	December 31, 1971

*Retirement