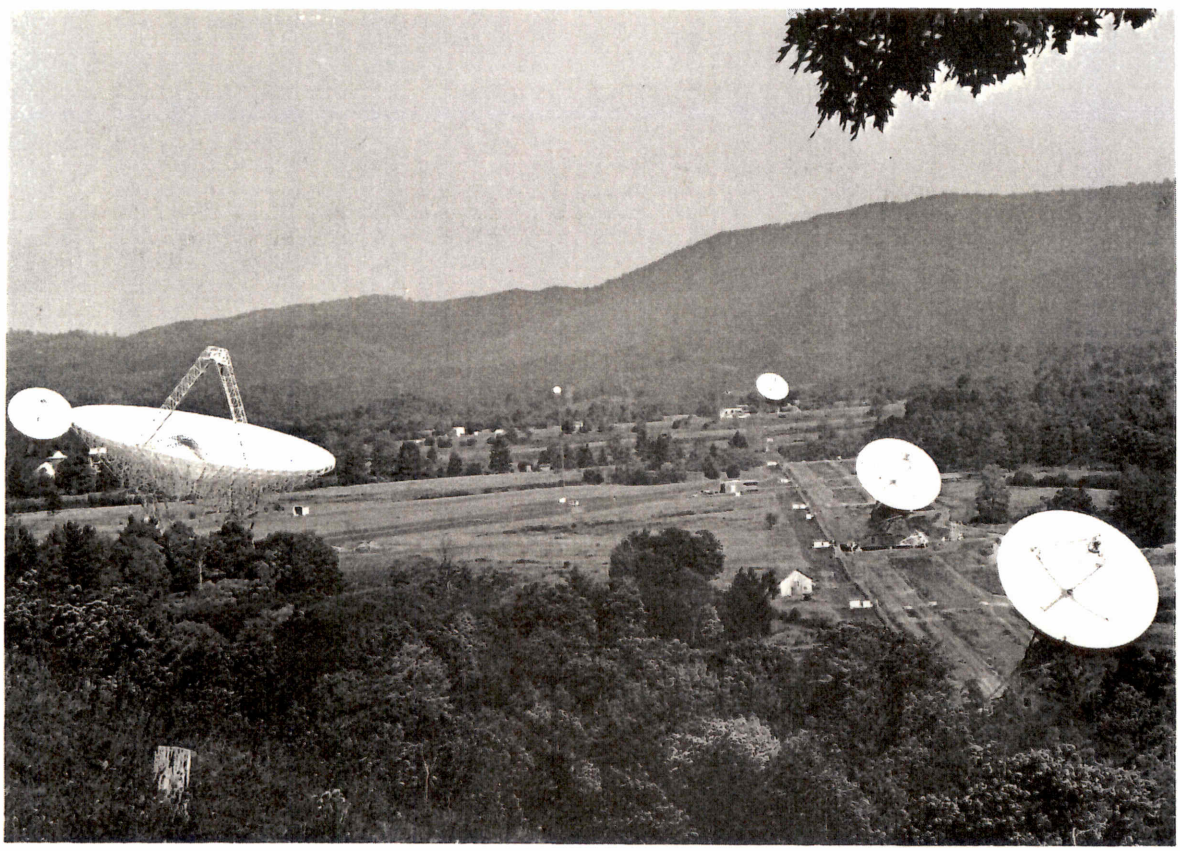
NATIONAL RADIO ASTRONOMY OBSERVATORY



PROGRAM PLAN

1974

NATIONAL RADIO ASTRONOMY OBSERVATORY

CALENDAR YEAR 1974 PROGRAM PLAN

Table of Contents

NATIONAL RADIO ASTRONOMY OBSERVATORY

CY 1974 PROGRAM PLAN

INTRODUCTION

The National Radio Astronomy Observatory is funded by the National Science Foundation under a management contract with Associated Universities, Inc. The NRAO facilities are available to any qualified scientist or graduate student without regard to institutional affiliation, and non-NRAO scientists utilize more than 60% of the observing time on the telescopes.

The major Observatory telescopes include a 300-ft meridian telescope, a 140-ft fully steerable telescope, a three-element interferometer consisting of 85-ft telescopes that can operate in conjunction with a remote portable 45-ft antenna, and a 36-ft millimeter-wave telescope. Receivers are available for observing programs that cover the wavelength range from 1 mm to 3 m. Autocorrelation and multichannel receivers are available for studies that require frequency discrimination. Each telescope is equipped with on-line computers that provide telescope control and real-time data analysis. Data are recorded on magnetic tape for further processing by general-purpose computers located in Charlottesville or in Tucson.

This Program Plan presents a summary of the scientific programs of NRAO visitors and permanent staff, plans for research, test and observing equipment, a summary of items needed in the NRAO equipment account, and details of expenditures planned for operation and maintenance of the Observatory. The financial plan summary gives a cost breakdown for the estimated expenditures and commitments during 1974 for scientific research (operations and equipment) and for construction.

For a detailed description of the VLA program for 1974, please refer to the VLA Project Plan as submitted on December 19, 1973.

In the appendix accompanying this Program Plan is a summary of the scientific program of the NRAO permanent staff and a current NRAO organizational chart.

SCIENTIFIC PROGRAM

The scientific program for 1974 will be centered around observations on the four major telescope systems. These telescopes will be used for a very wide variety of investigations, covering most areas of radio astronomy research. Among the subjects of investigation are the following: solar physics; the structure and dynamics of our own and other galaxies; the interstellar medium; galactic radio sources, including supernova remnants, HII regions, pulsars, X-ray sources, IR sources, and radio "stars"; extragalactic radio sources, including quasars and galaxies; cosmology.

Observations will be undertaken at wavelengths ranging from 2 mm to 3 m in the continuum and in various molecular and atomic lines. There will be continued major emphasis on molecular spectroscopy, and on very long baseline interferometry (VLBI). The 45-ft telescope, which was put into operation late in 1973, will be used increasingly as the fourth element of the interferometer system to provide resolutions intermediate between those obtained with the 3-element system and the VLBI for studies of radio source structure.

This scientific program will be conducted by approximately 25 members of the NRAO staff, and by more than 200 guest scientists and students from more than 50 other institutions in the U.S., and by a smaller number of scientists from other countries. More than 60% of the observing time on the NRAO telescopes will be used by these guest investigators. All proposals for telescope observing time, whether by visitor or staff, are sent for appraisal to anonymous referees who are not employed by the NRAO. The programs that are run at the telescopes represent the best of those proposed, as judged by four referees. Approximately 250 separate observing programs will be undertaken on the NRAO's four telescope systems in 1974.

The program of the NRAO staff, which comprises approximately 30% of the total program, is described in somewhat greater detail in Appendix A.

RESEARCH INSTRUMENTS

The primary research instruments at the National Radio Astronomy Observatory consist of : (1) a 140-ft telescope (2) a 300-ft telescope; (3) an interferometer, consisting of three 85-ft telescopes and a 45-ft transportable telescope; and (4) a 36-ft telescope. With the exception of the 36-ft telescope, all NRAO research instruments are located at Green Bank, West Virginia. The 36-ft telescope is located on Kitt Peak, near Tucson, Arizona. The following two tables summarize the funds needed to equip NRAO research instruments.

Item 1.	Other Observing Equipment.....	$ 615.0
Item 2.	Electronic Research Equipment.....	181.0
Item 3.	Electronic Test Equipment.....	40.0
	Total.....	$ 836.0

The estimated funds for research instruments will provide auxiliary instrumentation and equipment to maintain and improve the capabilities of the telescopes, including new systems development and modifications and upgrading of existing systems. The ability of the NRAO to maintain an active research and development program in electronic hardware is essential if the Observatory is to continue in its role as the nation's principal center for research in radio astronomy. Because of rapid and unpredictable changes in "state-of-the-art" electronics hardware and unforeseen short notice requirements of the scientific community, it is desirable that flexibility within the general area of the program be maintained. The following table shows the planned distribution of funds for the "Other Observing Equipment" account. The NRAO continually updates this table as scientific priorities change. These estimates provide funds for the completion of already started projects, new development, and funds for items of continuing and general development.

ITEM 1. OTHER OBSERVING EQUIPMENT

(See attached table, page 12.)

A. Other Observing Equipment: Items to complete.

The items expected to be completed in 1974 include:

1. The 140-ft Cassegrain system.

This project was started about one year ago to provide the 140-ft telescope with lower noise feed systems. It also increases the efficiency

1. Other Observing Equipment (in thousands)

System	Estimate to Complete	Estimate for New Development	Estimate for Continued Development	General Development	Total
140-ft Telescope					
Cassegrain system	120.0				120.0
300-ft Telescope					
a) 1000-1350 MHz receiver		85.0			85.0
b) 11-cm Rx	70.0				70.0
36-ft Telescope					
a) 6-mm cooled paramp Rx	25.0				25.0
b) Cooled mixer Rx	40.0				40.0
c) Diode development			44.0		44.0
d) Josephson Junction			15.0		15.0
e) mmλ receivers				56.0	56.0
Other					
a) VLB processor		25.0			25.0
b) General Rx development				25.0	25.0
c) General computer development				110.0	110.0
Totals	255.0	110.0	59.0	191.0	615.0

and flexibility of the telescope by allowing several radiometer systems to remain operational on the telescope simultaneously. A nutating subreflector allows beam-switching operation, which stabilizes against atmospheric fluctuations. The various steps in the Cassegrain conversion projects are:

(a) The development of a four-frequency front end similar to the VLA system.

(b) The design and construction of a large vertex room.

(c) The development of a feed system similar to that of the VLA.

(d) The design and construction of a subreflector with a nutating mechanism.

(e) The replacement of the prime focus focussing and polarization rotating equipment.

Step (e) is the remaining step to be accomplished during 1974. The installation of the total system is scheduled for July 1974.

2. An 11-cm receiver for the 300-ft telescope.

This receiver provides increased sensitivity by a factor of four over the present single-channel system, which has been in use since 1965. The new system uses a cooled, dual-channel parametric amplifier. The receiver will be completed during 1974.

3. A 6-mm cooled paramp receiver front end for the 36-ft telescope.

This cooled parametric amplifier receiver will provide a new frequency band for the 36-ft telescope. The parametric amplifier will operate at a higher frequency than previously possible. It has been developed under a contract with the University of Denver for about 1-1/2 years. It will be completed in early 1974.

4. A cooled mixer receiver for the 36-ft telescope.

The NRAO has been developing cooled mixer-parametric IF amplifier receivers for the millimeter wavelength range for the past two years. The first operational model will work in the 80-120 GHz range and will be installed on the 36-ft telescope early 1974. Cooled mixer assemblies covering 33-50 GHz and 140-150 GHz will also be developed during 1974 and incorporated in the same front-end system as the 80-120 GHz receiver.

Although these items are expected to be completed during 1974, upgrading and modification will continue in future years as required.

B. Other Observing Equipment: New Development Items

Two new items are planned for 1974.

1. 1000-1350 MHz receiver.

Recent discoveries of galaxies with very large redshifts of the hydrogen line has made improvements of receivers in the range below 1350 MHz vitally important. The existing NRAO receiver in the 1000-1350 MHz range has a noise temperature of 270 K while the new receiver will have a noise temperature of 50 K, which is comparable to the best NRAO hydrogen-line system (1350-1420 MHz).

2. VLB processor and computer.

This item will expand the VLA processing system to include a three-station processor which will provide higher efficiency by a factor of three in processing multiple station VLB experiments and spectral-line VLB observations. The VLB processing is presently a limitation on the amount of VLB work that can be done. NRAO's processor is the only processor in the world at the present time.

C. Other Observing Equipment: Continuing Development Items

Items of continuing development are for millimeter wavelength work at the 36-ft telescope. The further development of Schottky diodes and Josephson junctions as devices for obtaining greater receiver sensitivity in the millimeter wavelength range is planned. Work in these areas to date has provided improved sensitivities by a factor of four over conventional systems.

All NRAO receivers used on the 36-ft telescope uses diodes developed and fabricated by the University of Virginia under a continuing contract. These diodes have lower series resistance and lower noise properties than commercially available diodes. Further decrease in mixer diode noise temperatures by a factor of two to three may be possible through new fabrication and diode coupling techniques.

University research work on Josephson junctions has shown feasibility of very low noise, very high frequency receivers using Josephson effect devices. NRAO plans to develop practical radiometer systems utilizing these devices.

D. Other Observing Equipment: General Development Items

Items included herein provide for general improvements, major modifications, additions and updating of the Observatory's existing receiver

systems and also provide for expansion of the on-line computers at the telescopes by adding on-line terminals, displays and additional core. Other typical improvements are: replacement of receiver front-end components with improved components as they become available, adaptation of receivers to do specialized experiments, such as polarization measurements, comet observations, etc.

ITEM 2. ELECTRONIC RESEARCH EQUIPMENT

Items funded under this part of the program are the numerous smaller experiments and development projects--usually costing less than $10k each. These funds are made available in response to visitor and staff requests for minor modifications to existing observing equipment and relatively inexpensive "off-the-shelf" new items.

ITEM 3. ELECTRONIC TEST EQUIPMENT

These funds are used to add to and update the Observatory's general bank of test equipment for use in the laboratories and also for monitoring and testing the extremely complex observing systems on the telescope.

EQUIPMENT

No major equipment acquisitions are planned for 1974. However, a brief summary and description of the equipment account follows:

Item 1.	Maintenance, Shop and Repair Equipment.....	$ 59.5
Item 2.	Office and Library Furnishings & Equipment.....	15.0
Item 3.	Living Quarters Furniture.....	5.0
Item 4.	Building Equipment.....	18.0
Item 5.	Scientific Services & Engineering Equipment.....	2.5
	Total.....	$100.0

Item

1. Maintenance Shop and Repair Equipment

Funds planned in this account provide for the replacement and/or acquisition of new equipment for the Green Bank maintenance division and several items for the shops at Green Bank, Charlottesville and Tucson. Items included in this account are: a backhoe, cinder spreader, tractors and mowers, replacement trucks and other vehicles, milling machines, lathes, engravers, plus several auxiliary items and adapters to be used with existing equipment.

2. Office and Library Furnishings and Equipment

These funds provide for replacement, updating and acquisition of typewriters, adding machines, desk calculators, desks, chairs and other office furnishings for the Green Bank, Charlottesville and Tucson sites.

3. Living Quarters Furnishings

These funds provide for replacement of household appliances and furnishings, such as beds, chairs, tables, lamps, draperies, carpets, etc., used in the residence hall and furnished houses in Green Bank.

4. Building Equipment

These funds provide for items that are generally attached to and become a part of the buildings. Included are such things as small air conditioners, small heating units, water heaters, etc.

5. Scientific Services and Engineering Equipment

These funds provide for small equipment additions in the darkroom, public education, and engineering divisions. Items such as cameras, film processing units, projectors, measuring equipment, etc., are included in this amount.

OPERATIONS AND MAINTENANCE

A. Personnel Services and Benefits (Level = Full-Time at December 31, 1973)

Category	1973			1974		
	Level	Salaries	Benefits	Level		Benefits
Scientific and Engineering	54	961,800	173,700	65	1,168,000	230,000
Technical	79	890,500	160,300	80	908,000	176,200
Administrative and Clerical	58	762,600	137,300	58	824,000	159,900
Operations and Maintenance	57	512,500	92,200	57	550,000	106,500
Total - Operations and Maintenance	248	3,127,400	563,500	260	3,450,000	672,600
VLA Construction	32	403,100	72,200	46	646,000	125,300
Total Personnel	280	3,530,500	635,700	306	4,096,000	797,900

OPERATIONS AND MAINTENANCE

B. All Other Materials, Supplies and Services

1.	Directors Office	$ 3.5
2.	Research Group	2.5
3.	Scientific Services Includes planned expenditures for library books, periodicals and other supplies for the Green Bank and Charlottesville libraries and also includes cost of preprints and reprints, darkroom and scientific drafting materials and supplies.	74.0
4.	Electronics Division Includes expenditures for general electronics and laboratory supplies at Green Bank, Charlottesville and Tucson, including receivers and electronics equipment maintenance, material and supplies, e.g., helium, wire, tubes, resistors, small tools, special parts, etc., and radio noise control and suppression costs.	340.0
5.	Computer Division Includes cost of tapes, cards, paper, maintenance agreement, outside programming assistance for the computer division.	50.0
6.	Engineering Division Includes cost of engineering and drafting supplies, small A/E studies.	70.0
7.	Tucson Operations Division Includes reimbursement to KPNO for services, general maintenance of telescope, office upkeep, vehicle rental and supplies, postage, telephone, etc.	141.0
8.	Fiscal Division Includes cost of audit service, tax assistance, general office supplies, e.g., blank checks, records, cards, tapes, paper, etc.	21.0
9.	Business Management Division (CV) All Charlottesville general office supplies, freight (in and out), Xerox rental, office machine service agreements, GSA auto rental, legal services, outside printing, personnel recruitment, etc.	103.0
10.	Telescope Operations Division (GB) Includes costs of maintaining the telescopes, e.g., painting, cryogenics, oil, grease, spare parts, special cabling and wiring, etc.	87.0

11. Plant Maintenance (GB).....$150.0
    Includes costs of maintaining the Green Bank physical plant, e.g., electrical, water and sewer systems, material and supplies for the auto shop, paint shop and carpentry shop and general equipment maintenance. Costs of maintaining the buildings, houses, control buildings, grounds, roads and airstrip. Also includes cost of materials and supplies for safety and security and cost of upkeep of the ambulance and fire-fighting equipment.
12. Central Shops..... 26.0
    Includes costs of general machine shop supplies, metals, welding materials, etc.
13. Administrative Services (GB)..... 105.0
    Includes costs of operating the cafeteria and residence hall, e.g., food for resale and other cafeteria supplies, linen and laundry service, freight and express (in and out), office machine service agreements, Xerox rental, GSA vehicle rental, purchasing office supplies, warehouse supplies (not stock items), darkroom and printing supplies, office supplies, etc., all for Green Bank.

FINANCIAL PLAN

1974

	(a) Actual Expenditures 1973	(b) Commitments Carried Over to 1974	(c) Uncommitted Carry Over to 1974	(d) New Funds 1974	(e) Expenditure & Commitment (b,c,d) 1974
I. Scientific Research					
A. Operations					
Personnel Compensation	3,127.4			3,450.0	3,450.0
Personnel Benefits	563.5			672.6	672.6
Travel-Domestic	200.1			214.0	214.0
Travel-Foreign	17.0			15.0	15.0
Communications & Utilities	185.6			200.0	200.0
Computer Rental	406.6			455.0	455.0
Building Rent & Maintenance	126.3	28.2	30.0	115.0	173.2
Management Fees	125.0			125.0	125.0
Other Material, Supplies & Services	1,045.2	162.4	170.6	1,002.4	1,335.4
Miscellaneous Revenue	(85.9)			(85.0)	(85.0)
Subtotal	5,710.8	190.6	200.6	6,164.0	6,555.2
B. Equipment					
Research Instruments	1,346.6	243.5		836.0	1,079.5
Operating Equipment	115.1	46.9		100.0	146.9
Subtotal	1,461.7	290.4		936.0	1,226.4
II. Construction					
Very Large Array	1,533.2	770.0	531.8	5,000.0	6,301.8
Other	62.3	0.3	12.3		12.6
Subtotal	1,595.5	770.3	544.1	5,000.0	6,314.4
TOTAL	8,768.0	1,251.3	744.7	12,100.0	14,096.0

APPENDIX

NRAO SCIENTIFIC STAFF PROGRAMS

The following scientific program description is a summary of the research program of the NRAO staff for 1974. Some of this work will be done in collaboration with visiting scientists.

A. Comet Kohoutek

Observations of Comet Kohoutek at several molecular line frequencies are being planned using the 36-ft and 140-ft telescopes. These observations include the following molecules which could be important constituents of cometary nuclei, particularly if comets are formed from the primordial material in a molecular cloud: OH, X-ogen, HNC, HCN, HNCO and CH_3CCH. Studies of the presence and distribution of these molecules in this important comet will fill in another link in the evolution of the solar system.

B. Galactic Studies

1. Hydrogen line.

An investigation will be made of the observable consequences of the sun being situated in a flow pattern of the sort predicted by the density-wave theory. In particular, the kinematics of the local hydrogen and of the Gould Belt stars, which are generally thought to represent a special subsystem within the Galaxy, will be considered in these terms.

Searches will be made for very narrow spectral features in emission profiles observed in the galactic plane and for high-velocity hydrogen clouds in the strip of sky seen by the calibration horn antenna.

2. OH studies.

A 140-ft survey of the galactic distribution of OH which began in 1969 will be completed. Selected areas of this survey, comprising unusually massive clouds, will be observed in more detail in order to study their interactions with surrounding interstellar material. The results of the survey will be analyzed in terms of galactic structure, the classification scheme for anomalous OH emission sources, and the relation of OH to other molecules, IR sources, HII regions, and other types of galactic objects. A high-sensitivity observational program of dust clouds will continue in order to derive the physical conditions in those clouds more accurately and to determine whether the chemistry in those objects differ from that of the higher density clouds near HII regions.

3. Supernova remnants and stellar astronomy.

In the latter stages of the development of the supernova remnants where late isothermal expansion is taking place, dense, high-velocity clouds will be formed. A search for various high-velocity molecular-line components

in several old supernova remnants is planned which will yield useful data on physical conditions prevailing inside the expanding supernova shell as well as the time scales for molecular formation.

A search for newly appearing radio counterparts of X-ray sources and the study of those caught with transient events, together with an observational study and search of radio-emitting binary stars, will be continued. Data have now accumulated over a period of years on the triple radio source Sco X-1. These data will be evaluated to determine proper motions of the companion sources. A multi-frequency investigation of radio emission from Cyg X-3 will be carried out, usually as part of international campaigns to gather simultaneous radio, infrared and X-ray data. An analysis will be made of the complete radio evolution of Novae HR Delphini and FH Serpentii over the time period 1970-1973.

4. HII regions and dust clouds.

An analysis of aperture synthesized maps of selected HII regions will be made, with particular emphasis placed on the relationship of continuum features with sources of IR, ionized carbon, and the molecules OH, CS, HCN and CO. Work will continue on a model for the Orion Nebula. Studies of the shapes of low-frequency recombination lines will be continued in an effort to establish the large-scale spectrum of turbulence in HII regions. An interferometer search for compact "knots" in HII regions identified as sources of far infrared emission will be concluded, and the relationship of the IR peak to the radio continuum peaks and molecule line hot-spots will be investigated.

An analysis of high-resolution studies of H, OH, and H_2CO and of the extinction in large, tenuous clouds in Taurus will be completed. Relationships will be derived between chemical abundances and extinction in this cloud that promise to distinguish between competing theories of interstellar molecule formation. Studies will be made of the evolution of dense interstellar clouds after they have collapsed from the ambient gas and have initiated the star formation process. To aid this study, a search will be made with the NRAO interferometer for compact continuum sources in dark clouds similar to those already detected that are believed to be associated with the early stages of stellar evolution. In a parallel study, those dark clouds found to contain a large number of compact radio sources will be searched for recombination lines of either hydrogen or carbon and an attempt will be made to map the spatial distribution of these lines. The resultant line and continuum data will be compared with infrared and molecular line data in these same clouds and an attempt will be made to see if there exists a generic relation among any of these features.

5. Carbon monoxide.

Galactic structure will be investigated using the carbon monoxide lines near 2.6 mm. A number of aspects of galactic structure will be studied, including questions of the degree of line saturation, line intensity as a function of position in the sky, and the extent of correlation with other spiral arm tracers. Currently, there are conflicting views as to whether CO, like hydrogen, is primarily a tracer of locations where the overall distributions of stars is producing a gravitational sink, or whether, unlike hydrogen, CO is better considered as a tracer of regions where the gas has been compressed, perhaps by the shock front predicted by the density-wave theory.

6. CH.

The recent radio detection of interstellar CH will be pursued in order to compare its distribution with that of other molecules seen both optically and in the radio region. Searches will be made to find all three hyperfine components of the ground-state multiplet, since these are necessary to establish the validity of quantum mechanical studies of the structure of simple diatomic hydrides. Theoretical studies of its anomalous excitation will be made.

7. Other molecular lines.

Observations of a large number of transitions in the millimeter-wave region have been made of SiO, CS, CH_3CN, and OCS. These results will be analyzed to determine the excitation of these molecules and to derive temperatures and densities in these interstellar clouds. Information about the fundamental nature of the interaction of H_2 molecules with these molecules will be sought.

Mapping of HCN at millimeter wavelengths will be continued in order to study the relationship between these clouds and IR sources in compact HII regions. These studies promise to yield information on the evolution of dense interstellar clouds as they collapse to form stars. Further observations of a new, highly excited line of H_2CO and of recently discovered anomalies of the eight hyperfine lines of CN at λ2.6 mm are planned. These studies indicate the possibility of regions of unprecedented high density in certain interstellar clouds.

A study of several molecular clouds in the galactic center is being carried out using the lines of HI, OH, CO, HCN, HNC, HNCO and CH_3CCH. The galactic center is a very complex region and to understand the chemical and physical processes taking place there, the study of a number of molecular lines will be required.

An effort is being made to identify the X-ogen line at 89.189 GHz. Its possible identification of HCO^+ is very important in considering ion-molecule reactions as a major formation mechanism in interstellar chemistry. Searches for other components and isotope shifts are continuing. Another interesting molecule being worked on is HNC at 90.665 GHz. This molecule has no terrestrial analog and would also be important in interstellar chemical reactions.

8. Molecular line searches.

In addition to searches that will take place for molecules containing atoms already found by radio astronomers, searches will continue for molecules containing the atoms P, Mg, Cℓ, and Fe which have not yet been detected by radio means but which have significant cosmic abundances.

C. Discrete Sources

1. Polarization and source spectra.

The study of radio source spectra will be extended to shorter wavelengths with observations at 2 cm on the 140-ft telescope and at millimeter wavelengths at the 36 ft. This work will be confined to the transparent sources, where the radio spectra reflects particle energy distribution and where the interpretation is not confused by time variations. The long series of observations of the flux density of Cas A will be continued at frequencies near 1400 MHz. Further studies will be made of its variability, and a similar set of measurements will be started at frequencies near 820 MHz. Linearly polarized structure of extragalactic sources will undergo further analysis.

2. Radio source surveys.

A 6-cm source survey will be completed during the coming year, using the new 6-cm Cassegrain facility on the 140-ft telescope. Source flux densities at 2.8, 6, and 11 cm measured at Bonn will be used to determine the spectra of the sources and accurate positions will be obtained from the NRAO interferometer. The sources are being investigated for identification, spectra, number-counts, and isotropy and these observed quantities will be compared with the predictions of various cosmological models. These data will be compared with similar material for the southern sky which has been collected by the Parkes observers. In the region of overlap, the agreement is very good, but taken as a whole there appear to be striking departures from isotropy in the number-counts, spectral-index distribution and identification content, suggesting a radical departure from currently accepted models.

In an effort to investigate the spatial distribution of sources in greater detail than has been previously possible, a study of the angular size distribution of extended double sources and its dependence on flux density will be started. The purpose of this study is to take advantage of the fact that the extragalactic sources appear to be better "standard rods" than "standard candles". Other surveys will be made at 21 cm to extend existing source catalogues and absolute measurements of the brightness of the strip of the galaxy and of an area of sky away from the galactic plane will be made at a frequency near 820 MHz.

3. Galactic center.

A determination of the variation of the velocity dispersion of the neutral hydrogen gas will be made as a function of distance from the galactic center within $R \lesssim 4$ kpc. Knowledge of the function $\sigma(R)$ is crucial to an understanding of the forces maintaining the layer in the nuclear region, and also to an understanding of the mechanism producing the observed radial motions. A separate investigation will search for velocity structure in the nuclear disk using observations of high-frequency resolution.

Detailed observations in both line and continuum will be carried out to look for individual components in the nuclear disk, to derive the random velocity distribution as a function of distance from the galactic center, to map high-velocity features outside the galactic plane which may have been expelled by super explosions at the center, and to determine high-velocity structure very near the galactic center.

Theoretical calculations of the effects of super explosions near the center will be carried out with the hope of obtaining the observed asymmetry in the neutral hydrogen and molecular cloud distribution in the inner 300 pc of the galaxy. Theoretical calculations of the evolution of gas in dense stellar systems are planned in order to determine the time scale for the possible build up of massive stars of objects in galactic nuclei.

4. Very long baseline (VLB) surveys.

Observations of the variable compact radio sources using up to five simultaneous stations, including NRAO, Caltech, Fort Davis, Bonn, Sweden, and the USSR, are being continued and extended. A primary aim is to study the variations in the size and shape of the emitting regions in an effort to better understand the early history of the discrete sources. In particular, the previously observed changes will be concentrated upon to see if they are due to the physical motion of one or more components or to properly phased variations in the intensity of one or more fixed components. The previous observations are ambiguous on this point, and simultaneous observations are necessary to uniquely distinguish between the two general classes of models. At least two wavelengths will be used in order to determine the

spectrum and its variation of the variable components. In particular, it is desirable tc know whether a particular variable component is opaque or transparent, since this significantly restricts the range of applicable models.

A second part of the VLB program will be to make use of the very high sensitivity systems at 3.8 cm available at NRAO, Goldstone and Haystack to explore the weak, compact nuclear components which appear to lie at the nucleus of many or even most extragalactic radio sources. A preliminary survey to isolate these "core" sources has already been made with the new radio-link interferometer.

These investigations will be done with the conventional MKII VLB record system. In addition, possibilities of doing real time correlation using either NASA satellites or TV microwave facilities are being explored.

The feasibility of constructing a specially dedicated VLB array using seven to ten antennas having continental or intercontinental dimensions is being studied. In particular the (u,v) coverage obtained from practically feasible telescope locations is being examined, with attention to the fact that on the longer baselines the hour angle track is limited if the latitude of the array is not sufficiently high. Methods of inverting limited (u,v) data with poor phase stability are also being studied.

The very small components within larger radio sources will be investigated by both VLB techniques and through the use of the Green Bank radio-link interferometer.

5. Radio astrometry.

Absolute position measurements will be made with the 35-km radio-link interferometer in order to achieve an accuracy of 0".01 arc or better for approximately 25 radio sources. A bi-product of this method will be the detailed assessment of the errors, principally of atmospheric origin, which limit the accuracy of such measurements.

The 35-km interferometer will be used to measure the motion of the earth's pole and the short-term variations of UT1-UTC. This program, meant to demonstrate feasibility of the method, promises to measure the relative position of the pole with an accuracy of a few hundredths of an arc second over a time resolution of the order of one week.

Absolute positions of 200-300 radio sources will be measured with the 3-element interferometer to a typical accuracy of 0".05 arc and will provide an improved calibration net for the University of Texas source survey.

6. Theory.

The problem of the radiation transfer of radio recombination lines through a cold, largely neutral gas will be investigated theoretically. Such a medium may markedly affect the intensity and shape of radio-recombination lines emitted by HII regions and such effects will be quantitatively evaluated. Observational tests of the theoretical predictions will be initiated.

The intensity and spectrum of the inverse Compton radiation arising from the interaction of low-energy cosmic ray electrons with stellar photons very near ordinary stars such as the sun will be calculated. An estimate will be made of the influence of the resultant radiation on the ionization of the interstellar medium.

Theoretical investigations of the behavior of galactic nuclei are planned using an existing N-body computer code. The primary interest is to determine under what conditions such star systems can undergo "violent relaxation" to form in short times the extremely dense, active galactic nuclei which are observed.

The effect of ablation on massive objects and normal stars moving supersonically through dense gas clouds may have a significant effect on the evolution of galactic nuclei. A computation of this complex phenomenon is planned.

It is now clear that extended extragalactic radio sources must have relativistic particles generated in their interiors after they are ejected from the parent object. The mechanism for such particle generation is one of the most outstanding problems regarding such sources. Sufficient data are now available that detailed theoretical models may be definitively tested, and it is planned to calculate a series of such models to determine if the energy source resides in massive condensed objects, intense low-frequency radiation, or plasma turbulence. The different brightness distributions, polarization properties, and spectral index behavior of such models will hopefully allow the selection of the most likely process to be made.

Two-dimensional hydrodynamical calculations of the effects of explosions in thin disks are planned. The purpose of these calculations will be to study the effects of focussing and explosion in directions perpendicular to the disk with possible relevance to formation of double radio sources.

Observations now suggest that most of the compact extragalactic radio sources cannot be explained by simple expanding clouds of particles and

magnetic fields. A theoretical investigation is planned to determine if a continuous but nonuniform energy input resulting from stellar encounters and supernovae in dense stellar systems can account for the observed behavior of many of these sources.

D. Galaxies

1. Continuum studies.

Observations of compact extragalactic sources are planned to determine the presence or absence of coherent plasma radiation processes.

Observations have been completed of a 6-cm survey of 1135 galaxies in the Bright Galaxy Catalogue, and of 507 Markarian galaxies. The survey results are now being analyzed. These surveys will be used to discuss the radio luminosity function of normal galaxies. Aperture synthesis maps of Markarian galaxies and interferometer observations of 19 spiral galaxies with Byurakan classifications have been completed and source structure models are being determined based on the observations.

2. Hydrogen-line studies.

Three samples of galaxies are under consideration for which some of the data has already been obtained. These are the cataloged, nearer and brighter systems. Most spirals and irregular-type and some elliptical galaxies north of $\delta = -20$ (the 300-ft declination limit) as listed in the Reference Catalog of Bright Galaxies are included here. Although the sample suffers from the usual problems of selection on apparent magnitude, its value lies in the fact that many of these galaxies have been studied optically. These data will allow a study of the HI optical depth, HI content, and the total mass of a statistically meaningful sample. Galaxies of the same absolute magnitude and out to a specific distance are also under study. This sample is made up exclusively of ScI galaxies to a limiting apparent magnitude of 15 (pg). Although Malmquist effects are present, the results will yield properties of these systems per unit volume of space--a rarely achieved datum in extragalactic work. Finally, a sample of galaxies from the list of Markarian, Haro, and Zwicky will be studied to see how these special-type systems fit into the continuum of properties of normal-type galaxies.

The high gain aspect of the 300-ft telescope, together with the low-noise 21-cm receiver, makes the system ideally suited for the study of low-surface brightness hydrogen in the outer regions of spiral galaxies. Such studies will yield information on the extent of such hydrogen and the kinematics of these outer regions. Optical techniques fail in such important

kinematic studies because of the lack of significant amounts of luminous material. Radio synthesis techniques are also severely handicapped because of the low surface brightness involved. Previous studies of this sort on M31 have been particularly fruitful.

3. Absorption lines.

A search for absorption by redshifted neutral hydrogen in the direction of quasars and radio galaxies will be continued. Absorption features detected in the radio galaxy Perseus A and the quasar 3C 286 have been valuable stimuli for continuing this experiment. The statistics of such a study will yield important conclusions on the spatial density of galaxies, because of the statistical nature of the line-of-sight coincidence of hydrogen clouds (presumably in the galaxies) and quasars.

4. Theory.

The possibility of binding clusters of galaxies with M dwarf stars, and the resulting implications with regard to star formation, primordial turbulence and cosmological models, will be investigated.

A method is being developed for deriving the dynamical age of a cluster of galaxies from its observed properties, mainly the density distribution. The method uses numerical N-body calculations and may help clarify the missing mass problem.

E. General Relativity Test

The program of conducting radio measurements to determine relativistic bending of light in the presence of a strong gravitational field in order to check predictions made by various general relativity theories will be continued.

F. Telescope Measurements

The surface of the 36-ft telescope will be measured in an attempt to improve its performance. Various tasks in the computation and measurement of the deflections of telescopes will be undertaken to improve our knowledge of the design of large millimeter-wave antennas.

NATIONAL RADIO ASTRONOMY OBSERVATORY
ORGANIZATION CHART
February 15, 1974