

## XIV. RADIO ASTRONOMY

### Academic and Research Staff

Prof. Alan H. Barrett	Prof. David H. Staelin	Dr. Michael Shao
Prof. Bernard F. Burke	Prof. Edward L. Wright	John W. Barrett
Prof. James R. Melcher	Dr. Alan Parrish	John D. Kierstead
Prof. Philip C. Myers	Dr. David H. Roberts	D. Cosmo Papa
	Dr. Philip W. Rosenkranz	

### Graduate Students

Ali D. Ali	Rowley L. Cheng	William H. Ledsham
Barry R. Allen	John J. Daly	Stephen Leibovic
Yaneer Bar-Yam	Emilio E. Falco	Terence H. Marshall
William T. Baumann	J. Antonio Garcia-Baretto	David F. McDonough
Charles L. Bennett	John R. Gersh	Bruce R. Rosen
Priscilla J. Benson	Perry E. Greenfield	Matthew H. Schneps
Timothy S. Bigelow	Aubrey D. Haschick	Diane C. Simmons
Richard L. Buxton	Steven T. Kirsch	Daniel D. Stancil
Alan L. Cassel	Jeffrey H. Lang	Paul Toldalagi
	Charles R. Lawrence	

### 1. LONG-BASELINE ASTROMETRIC INTERFEROMETER

National Science Foundation (Grant AST77-06052)

Michael Shao, David H. Staelin

This year the one-inch interferometer facility was completed and transported to the Mt. Wilson Observatory in California, where initial experiments were performed. This system has a baseline of  $\sim 2$  meters and tracks Polaris. The purpose of the system is to demonstrate the basic concept of two-color fringe tracking, which should eventually enable relative stellar positions to be measured with  $\sim 10^{-4}$  arc-sec accuracy. Such accuracy is sufficient to detect any Jovian planets orbiting nearby stars.<sup>1</sup>

These initial experiments have been successful. Using one-half inch apertures Polaris was tracked continuously with 2 arc-sec seeing, and intermittently with 3.5 arc-sec seeing.

Future work will include two-color tracking experiments with a 10-meter baseline, and use of siderostats so that stars other than Polaris can be observed. Such experiments would be a prelude to establishment of a permanent four-inch observatory capable of measuring positions of  $10^{\text{th}}$ -magnitude stars.

### References

1. M. Shao and D. H. Staelin, "Long-Baseline Optical Interferometer for Astrometry," *J. Opt. Soc. Am.* 67, 81-86 (1977).

## (XIV. RADIO ASTRONOMY)

### 2. CONTROLLED THIN-FILM ANTENNA

Joint Services Electronics Program (Contract DAAG29-78-C-0020)

David H. Staelin, James R. Melcher

The use of a scanning electron beam for rapidly manipulating the charge distribution on a thin membrane is being studied as a method for precisely controlling the shape of very large (30- to 1000-m) reflector antennas in space.<sup>1</sup>

The work progressed on three fronts in 1978. First, the theoretical effort has focused on the issues of electrostatic instabilities and algorithms for control. Second, to test these theories a 1-meter square membrane has been stretched on a frame between plates, the potentials of which are controlled at nine points independently. To date the basic modes have been observed, together with their stability and cross coupling. Also, the 1, 1 mode has been biased to instability and then controlled. Third, an apparatus is nearly constructed which will enable the front and back-side secondary-emission characteristics of various metals and insulators to be studied as a function of beam energy and surface contaminants.

#### References

1. J. Lang, J. Gersh, and D.H. Staelin, "Electrostatically Controlled Wire-Mesh Antenna," *Electronics Letters* 14, 665-666 (1978).

### 3. SCANNING MICROWAVE SPECTROMETER EXPERIMENT

National Aeronautics and Space Administration (Contract NAS5-21980)

David H. Staelin, Philip W. Rosenkranz

The five-channel Scanning Microwave Spectrometer (SCAMS) yielded 10 months of almost continuous data from the Nimbus-6 satellite, launched in June, 1975.<sup>1</sup>

Analysis of Typhoon June (1975) has shown that passive microwave soundings can yield wind information in two ways, by virtue of the enhanced surface emissivity due to foam and rough seas, and by means of the observed horizontal temperature gradients which are related to winds by the thermal wind equation.<sup>2</sup> These studies also demonstrated that such soundings can yield reasonable water vapor and liquid water estimates in these intense storms.<sup>2</sup>

Kalman filtering was applied successfully to the problem of temperature profile retrievals; the rms errors were reduced by as much as ~50 percent, with moderate improvements being more typical.<sup>3</sup>

Snow and ice observations have been analyzed at some length, and three manuscripts

are now in preparation.

#### References

1. D.H. Staelin, P.W. Rosenkranz, F.T. Barath, E.J. Johnston, and J.W. Waters, "Microwave Spectroscopic Imagery of the Earth," *Science* 197, 991-993 (1977).
2. P.W. Rosenkranz, D.H. Staelin, and N.C. Grody, "Typhoon June (1975) Viewed by a Scanning Microwave Spectrometer," *J. Geophys. Res.* 83, 1857-1868 (1978).
3. W.H. Ledsham and D.H. Staelin, "An Extended Kalman-Bucy Filter for Atmospheric Temperature Profile Retrieval with a Passive Microwave Sounder," *J. Appl. Meteorol.* 17, 1023-1033 (1978).

#### 4. TIROS-N SATELLITE MICROWAVE SOUNDER

U.S. Department of Commerce – National Oceanic and Atmospheric Administration  
(Grant 04-8-M01-1)

David H. Staelin, Philip W. Rosenkranz

The first Tiros-N Satellite was launched October 13, 1978, and the second unit is scheduled for launch in 1979; these operational weather satellites each incorporate four-channel passive microwave spectrometers operating in the 50-58 GHz band. The resulting microwave maps of atmospheric temperature profiles complement the maps by the other spacecraft sensors. This research program focuses on development of an improved understanding of the limits to performance of these microwave sensors and the development of high-performance estimation procedures appropriate for handling the effects of precipitation, clouds, and the surface, as well as the nonlinear, non-Gaussian, and nonstationary character of the statistics.

Initial analysis of the data has revealed that the instrument performance is excellent. Software to analyze the scientific results is now being prepared.

#### 5. SCANNING MULTICHANNEL MICROWAVE RADIOMETER (SMMR) EXPERIMENT

National Aeronautics and Space Administration (Contract NAS5-22929)

David H. Staelin, Philip W. Rosenkranz

The two SMMR passive microwave instruments were launched June 26, 1978 on the Seasat satellite, and October 24, 1978 on the Nimbus-7 satellite. The Nimbus-7 SMMR scans the earth over a ~780-km swath with resolutions of ~20-150 km, depending on frequency. The instruments view the earth at a constant incidence angle of 50 degrees, at two orthogonal linear polarizations and five frequencies: 6.6, 10.7, 18, 21, and 37 GHz.

#### (XIV. RADIO ASTRONOMY)

Parameters that can be mapped for the first time by this instrument include sea surface temperature and roughness, and certain snow, rain, ice, and humidity parameters. The effort to develop improved geophysical analysis techniques centers on the development of improved physical models for the phenomena and improved estimation techniques that appropriately reflect the nonlinear and nonstationary character of the problem.

One of the critical issues in the data interpretation process arises from the frequency-dependent angular resolution of the sensors. An approach to this problem has been developed and described.<sup>1</sup> This procedure takes proper account, in a least-squares sense, of the three-dimensional statistical behavior of the physical phenomenon and of the frequency-dependent character of the sensor.

#### References

1. P. W. Rosenkranz, "Inversion of Data from Diffraction-Limited Multiwavelength Remote Sensors. I. Linear Case," *Radio Sci.* 13, 1003-1010 (1978).

#### 6. METEOROLOGICAL REMOTE SENSING NEAR 2-mm WAVELENGTH

National Aeronautics and Space Administration (Contract NAS5-23677)

David H. Staelin, Philip W. Rosenkranz

The 118-GHz radiometer system was operated aboard the CV-990 aircraft for the Summer Microwave Hurricane Program (SMHP) during the summer and fall of 1978. Brightness temperatures were measured looking downward at clear atmosphere and rain cells and also upward at rain cells.

The clear air data were inverted using a linear statistical method of multidimensional regression. The inferred temperature profile was compared with the profile measured by a dropsonde released from the aircraft. Agreement between the two profiles was within the expected error in the retrieval procedure, ~1 K. This is the first temperature profile retrieval to be obtained using the 118-GHz oxygen line.

#### 7. MICROWAVE SPECTROSCOPY OF THE INTERSTELLAR MEDIUM

National Science Foundation (Grant AST77-12960)

Alan H. Barrett, Philip C. Myers

During the past year our studies of atomic and molecular interstellar gas clouds have continued, with observations of microwave transitions of HI, CO, CS, NH<sub>3</sub>, H<sub>2</sub>CO, and HC<sub>5</sub>N, toward Bok globules, dark clouds, molecular clouds associated with HII

regions, and globular clusters. We have used radio telescopes of the National Radio Astronomy Observatory in Green Bank, West Virginia, and at Kitt Peak, Arizona; National Astronomy and Ionosphere Center in Arecibo, Puerto Rico; Millimeter Wave Observatory, Fort Davis, Texas; and of M. I. T. Haystack Observatory.

Observations have been made of  $\text{HC}_5\text{N}$ ,  $\text{NH}_3$ , and CO emission from a number of small dense clouds in Taurus which form a streamer. The  $\text{NH}_3$  emission was found to exhibit a wide range of intensity variation from cloud to cloud, by a factor of  $\sim 10$ . The velocity width is very small, typically  $\sim 0.5 \text{ km s}^{-1}$ . The  $\text{HC}_5\text{N}$  emission was detected only in one cloud, TMC-2, where the width is extremely narrow,  $\sim 0.2 \text{ km s}^{-1}$ . The CO observations indicate that the dense clouds have temperature 10-15 K. In TMC-2, the small size ( $\sim 0.1 \text{ pc}$ ) and linewidth of the  $\text{HC}_5\text{N}$  region suggest that this dense clump may be a nearly stable prestellar condensation.

#### 8. RADIO ASTRONOMY STUDIES OF INTERSTELLAR MASERS, THE INTERGALACTIC MEDIUM, AND EXTRAGALACTIC SOURCES

National Science Foundation (Grant AST77-26896)

Bernard F. Burke, Robert C. Walker, Aubrey D. Haschick, Thomas S. Giuffrida,  
J. Antonio Garcia-Barreto

The principal aims of this research have centered on the properties of the interstellar medium. In our own galaxy, the emphasis was on the properties of interstellar masers, which are closely related to stars in their earliest stages of formation. The extragalactic studies concentrated on the properties of the interstellar gas in Seyfert galaxies and in the intracluster medium in clusters of galaxies.

The maser work emphasized the use of VLBI methods to map the maser complexes, which consist of clusters of individual spot sources, each at its own velocity. As part of his Ph. D. thesis, Robert C. Walker showed that the apparent size of a given spot is a strongly varying function of the observing frequency within the line. Near the line center, the apparent size is smaller than in the wings of the line, and no model is in full agreement with the data. A saturated maser model is closer to the data, however, than an unsaturated model. A study of the OH maser in W3OH, the observations having been taken two years previously in a 7-station VLBI experiment, finally neared completion. Aubrey D. Haschick, working with M. Reid of the NRAO, produced a detailed map of the region that strongly suggests multiple Zeeman pairs. Some work remains to be done on the enormous quantity of data that had to be reduced, but the principal task is now complete.

A discovery was made in the W3OH water maser of a strongly time-varying line that was followed through its entire development, and three VLBI experiments were

#### (XIV. RADIO ASTRONOMY)

performed to clarify the results. The  $\text{H}_2\text{O}$  complex is in the form of a well-defined arc, plus a few outlying sources. One of the sources in the arc came up from a low intensity over a one-week period, and then declined over the following month. The light curve appears to be fitted accurately by a simple phenomenological theory, but the implication is that a large amount of pump energy,  $10^{40}$  ergs or more, had to be released within one or two days. Star-formation processes may well involve such unexpected irregularities, but the current state of cosmogonic models lacks predictive power for such irregular phenomena, which may be caused by magnetic-field merging.

The study of the intracluster medium resulted in stringent upper limits to the quantity of neutral hydrogen inside clusters of galaxies. A total of 15 nearby clusters were studied by looking for hydrogen absorption lines against background radio sources. The observed upper limits on the density are several orders of magnitude below the density needed to bind the clusters or close the universe.

Work with the Very Large Array (VLA) of the NRAO in Socorro, New Mexico has begun, and several programs have been carried out that were designed, in part, to help with development of the equipment. The x-ray source associated with the galaxy NGC 2110 was identified quickly, and the coincidence of the radio source with the nucleus of the galaxy was established. The source has a 3 arc-second size and a normal radio spectrum.

The extensive program on hydrogen absorption lines in galaxies was completed by Aubrey D. Haschick in his Ph.D. thesis. Several examples of absorption lines in quasar/galaxy pairs were studied, absorption lines in Seyfert galaxies were discovered, and an unusual example of an absorption line in the radio source 2C178 was also discovered. Absorption lines in Seyfert galaxies appear to be a moderately common phenomenon.

The microwave aperture-synthesis interferometer was completed during the report year. The "debugging" operations are proceeding, and useful observations will be expected after approximately one year of engineering studies. At the same time, we are developing a cooled 7-mm mixer that should be useful for interferometric observations.