

## 28. Radio Astronomy

### Academic and Research Staff

*Prof. B.F. Burke, Prof. J.W. Dreher, Prof. D.H. Staelin, Dr. G. de Jaeger, Dr. P.W. Rosenkranz, Dr. M. Shao, J.W. Barrett*

### Graduate Students

*T.A. Arias, G.J. Bartlett, P.J. Bonanni, A.C. Briançon, C. Carilli, P.M. Cassereau, L.D. Clark, M.M. Colavita, V. Dhawan, A.J. Gasiewski, M. Hellin, J.N. Hewitt, R.W. Holm, M.J. Kelly, A.M. Kirkland, G.I. Langston, J. Lehar, H.S. Malvar, J.C. Preisig, J.M. Shapiro, B.I. Szabo, A.S. Tom, G.W. Wornell*

### 28.1 Galactic and Extragalactic Research

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*Bernard F. Burke, John Dreher*

The distribution of matter in galaxies and in the universe as a whole is being investigated. The primary methods are the study of the deflection of radio and light waves by the gravitational fields associated with large-scale aggregation of matter, and by direct observations of the gravitational interactions of galactic systems.

1) The VLA is being used for a continuum study of the original twin quasar, the gravitationally lensed source 0957 + 561. The principle emphases of the observational VLA monitoring program is to measure the time delay between the arrival of wave fronts of the two lensed images. A determination of the time delay could in principle constrain estimates of cosmological parameters, and such studies of many gravitational lens systems will certainly tell us a great deal about cosmology and the distribution of matter on the largest scales.

2) VLBI observations of a sample of radio sources showing subarcsecond structure are being analyzed for evidence of gravitational lensing on a subsecond scale. Theoretical calculations indicate that lensing by single galaxies should produce many examples of multiple images with such small separations.

3) The gravitational lens search program continues, with 1000 more observations at the VLA, of sources selected from the MG survey. A total of 4000 sources have been observed, and a sample of these will be observed optically. Optical observations at Kitt Peak have yielded several candidates for gravitational lensing. the most spectacular instance so far was revealed by optical spectra of what appear to be a pair of quasars with apparently identical redshifts, notable for the

image separation of 2.6 arcminutes, 30 times larger than the previous lenses found. the nature of the lens is not known yet, but speculation yields interesting possibilities: it could be a cosmic string, a supermassive black hole, or an accumulation of matter in an unfamiliar state. Radio observations are being planned that should eliminate or confirm the possibilities.

4) Follow-up observations of VLA snaps for models of radio source evolution are complete. The data will be used to test models of radio sources powered by massive black holes.

5) The M.I.T. Greenbank radio survey of the sky at 6 cm nears completion of the first half. The survey will be complete for the brightest sources in the declination range  $17^\circ$  to  $47^\circ$ .

6) We are also conducting a study of the powerful double-lobed radio galaxy, Cygnus A. Multi-frequency, with high resolution VLA images have revealed a wealth of structures within the radio lobes, including a previously undetected Jet extending from the core source into the northern lobe, and many lower surface brightness "filaments" of emission threading the lobes. A screen of magnetized gas in front of the source has also been seen, which gives rise to extreme values of Faraday rotation ( $|RM| > 2000$  rad/m/m). We plan to extend these studies to the limits of the present VLA system, with further observations at frequencies ranging from 327MHz – 23 GHz. Using our radio data, along with previous optical and x-ray observations, we hope to investigate the conditions within the Faraday screen, as well as to verify or constrain existing theoretical models of extended extragalactic radio sources.

7) A program to observe the fine-scale structure of the HII regions associated with active sites of massive star formation is also underway. Early results using high resolution VLA images support both "implosive" star formation models and the hierarchical "ring" formation scenario. Complementary to this continuum work, millimeter wavelength observations of molecular lines are being made at Hat Creek as well as recombination line observations at the VLA

8) Work is also being performed on the analysis of a novel technique to remove the effects of "windowing" on irregularly sampled time series data. the technique is being applied to analyze the short-time scale (<1hr) variability of the B1Lac object OJ287.

## **28.2 Jovian Decametric Radiation**

*National Aeronautics and Space Administration (Grants NAGW-373 and NAG5-537)*

*David H. Staelin, Philip W. Rosenkranz, Tomás A. Arias, Roeland V. Hammerschlag*

The Planetary Radio Astronomy (PRA) experiment on the Voyager 1 and 2 spacecraft observed radio emission from Earth, Jupiter, Saturn, and Uranus in 198 channels distributed over the band from 1.2 kHz to 40.5 MHz.

During 1985 the Voyager data was examined much more carefully with 6-second resolution at frequencies below 1.2 MHz where the spectrometer has higher spectral resolution and is more insensitive to spacecraft-interference. The Jovian modulated spectral activity (MSA) which was discovered last year was studied much more intensively. These studies suggest that the polarization of this emission varies rapidly and without organization on the observed space-time scale. The occasional saw-tooth form of the emissions with respect to frequency has been studied further and theoretical work to explain this behavior was begun.

The software that displays the Voyager PRA data as a function of frequency and time has been largely transferred to the Apollo computer, which can provide color imagery for study.

### 28.3 Long-Baseline Astrometric Interferometer

*U.S. Navy – Office of Naval Research (Contract N00014-84-C-2082)*

*David H. Staelin, Michael Shao, John W. Barrett, M. Mark Colavita, Lloyd D. Clark, R. Walter Holm, Mathew J. Kelly*

During 1985 the Mark III optical astrometric interferometer entered the construction phase at the Mount Wilson Observatory with the installation of a large concrete table flanked by six reinforced concrete pedestals, each 4 ft x 4 ft at the base, 8 ft tall, and half buried. The outermost pedestals in the north-south direction are separated by 20 meters, whereas the inner pair are separated by 10 meters; the two east-west pedestals are at similar distances from the beam combiner. Two 18-ft vacuum tanks containing movable delay lines have been installed on the concrete table, which now sits inside an insulated shed approximately 12 x 6 meters in size.

An improved star-tracking mechanism based on a photon camera has been developed and will be installed when the new photon camera becomes available. Remaining to be completed are the main beam combiner and the laser systems for monitoring the positions of the siderostat mirror assemblies to the high precision required ( $\approx 1000 \text{ \AA}$ ).

This two-color astrometric instrument, operated under a joint program involving the Smithsonian Astrophysical Observatory and M.I.T., is expected to demonstrate wide angle ( $\geq 20^\circ$ ) differential astrometry with accuracies on the order of  $10^{-3}$  arc seconds. The astrometric measurements, expected to begin late in 1986 or early 1987, should illuminate the limits to astrometric accuracy posed by the atmosphere and by other effects.

Also during 1985 the initial analysis of the Mark II astrometric interferometer data was completed.<sup>1</sup> This experiment, also at Mount Wilson, demonstrated the success of the two-color method for removing much of the atmospheric error introduced by the atmosphere. The various atmospheric effects were analyzed theoretically.

## References

1. M.M. Colavita, "Atmospheric Limitations of a Two-Color Astrometric Interferometer," Ph.D. Thesis, Department of Electrical Engineering and Computer Science, M.I.T., May 1985.

## 28.4 Tiros-N Satellite Microwave Sounder

*SM Systems and Research, Inc.*

*Philip W. Rosenkranz, David H. Staelin, Alain C. Briançon*

The National Oceanic and Atmospheric Administration (NOAA) operates polar orbiting weather satellites carrying 4-channel passive microwave spectrometers (MSU) which map the three-dimensional temperature field of the atmosphere at 6- or 12-hour intervals. This research program is directed toward improved utilization of this passive microwave data on present and future NOAA satellites.

Much effort this year was directed toward the next-generation Advanced Microwave Sounding Unit (AMSU). The AMSU has 15 channels which image the Earth with 50-km resolution every 12 hours at frequencies distributed from 23 to 90 GHz; twelve of these channels sound atmospheric temperature profiles from 0 to 41-km altitude. Five additional channels between 90 and 186 GHz will sound atmospheric precipitation and humidity with 15-km resolution. Continued progress was made on definition of an optimum architecture for operational data reduction systems for AMSU. The goal is to maximize algorithmic flexibility through creative use of data arrays provided at execution, rather than by altering program code.

The utility of multi-dimensional temperature profile retrievals was studied further, and the performance of various techniques was compared. It was found that these techniques yield superior performance for MSU data, and relatively smaller improvement for AMSU. Because of the nonstationary character of atmospheric statistics, useful improvements in retrieval accuracies can also be achieved by using adaptive retrieval techniques, and study of such techniques is being continued.

## 28.5 Video Bandwidth Compression Techniques

*Defense Advanced Research Project Agency (Contract MDA903-82-K-0521)*

*David H. Staelin, Gerhard de Jaeger, Philippe M. Cassereau, Gregory W. Wornell*

This research effort focuses on techniques for coding at 9.6 – 56 kbps full-motion video sequences characteristic of videoconferencing. When block transform coding techniques are used at low data rates, unacceptable block noise can be produced at the boundaries of those rectangular image subunits over which the transforms are computed. This problem can be

mitigated by use of a new class of transforms, designated Lapped Orthogonal Transforms (LOT), which have basis functions that overlap the basis functions in adjacent blocks while retaining orthogonality. This transform was successfully used for motion-compensated video compression and exhibited reduced block noise without excessive ringing near block edges or image contours.<sup>1</sup> It is believed that improved versions of the LOT can be developed.

Cluster techniques were applied to the energy distributions within an ensemble of block transforms in order to define categories of transforms for which quantization patterns could be effectively tailored. It was found that coding performance continued to improve as the number of transform categories reached 32.<sup>2</sup> Incorporation of these adaptive transform techniques should, in principle, noticeably improve the performance of present video coding algorithms.

#### **References**

1. P.M. Cassereau, "A New Class of Optimal Unitary Transforms for Image Processing," S.M. Thesis, Department of Electrical Engineering and Computer Science, M.I.T., May 1985.
2. A.M. Kirkland, "Image Block Classification for Adaptive Transform Coding," S.M. Thesis, Department of Electrical Engineering and Computer Science, M.I.T., September 1985.

