

29.0 Radio Astronomy

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29.1 Galactic and Extragalactic Research

National Science Foundation (Grant AST 86-17172)

John H. Dreher, Bernard F. Burke, Christopher Carilli, Jacqueline Hewitt, Glen Langston, Michael Heflin, Samuel Connor, Vivek Dhawan

A striking new gravitational lens candidate, MG1131+0456, was discovered in the course of the gravitational lens search project being carried out jointly with Princeton and California Technical State University. The radio source has the appearance of a nearly perfect, slightly elliptical ring, with two compact sources superimposed, one slightly outside the ring, the other slightly inside the ring but diametrically opposed. There is an additional, much fainter, source farther out on one side. The structure is consistent with the lens being a massive elliptical galaxy, the object being a multiple radio source. One of the components is almost perfectly aligned with the galaxy and is imaged into an "Einstein Ring," an idealized structure predicted by Einstein long ago. An ideal point mass, acting as a lens, imaging a compact distant object, deflects the light around all sides, the result being a ring-like image. If the lens has a gravitational quadrupole moment, as an elliptical galaxy would have, the ring would take the observed elliptical form. The compact sources, just inside and just outside the ring, are also consistent with the lensing hypothesis. If the object, in addition to having a component lined up with the lens to give the ring, also has a slightly off-axis component, its principal image would lie on the inside of the ring and its secondary image would fall diametrically opposite, but inside the ring and this is what is observed. The faint outer image would be from a third component, and it might well lie in the single-

image domain, but its secondary image in any event would be faint and could easily go undetected. A report with J.N. Hewitt as first author has been submitted to *Nature*.

An extension of the MG survey has been completed with the 300-ft transit telescope of the NRAO at Green Bank, West Virginia, and served as the thesis for G. Langston. This covers the declination range 4.25 - 20.25 hours, covering 1.464 steradians and containing 5354 sources brighter than 41 mJy. Completeness and reliability were investigated closely, and above 80 mJy it was established that a single scan gives $95 \pm 3\%$ completeness, a performance that has seldom been achieved in other surveys. Related work by Langston revealed several individual sources with unusual structure, and these are being investigated further. A deep survey of the region 1146+111 was carried out with the VLA. There are two quasars in this region that have apparently equal redshifts, whose wide separation (2.6 arc-min) raised the possibility that a gravitational lens of extraordinary character - perhaps a cosmic string - was involved. The deep radio map, however, lends no support to that hypothesis.

29.2 Millimeter-Wave VLBI

Bernard F. Burke, Vivek Dhawan

The 7 mm VLBI project, to establish that VLBI at that wavelength was reducible to standard engineering practice, reached completion with the Ph.D. dissertation of V. Dhawan. In that work, carried out jointly with colleagues around the world, he showed that mapping of radio sources was feasible, but that a sufficiently large network of large radio telescopes, all having reasonable efficiency, must be employed. The atmospheric phase shifts do not present a fundamental barrier, but high standards of accurate calibration must be achieved at all stations. Precision of frequency standards and phase-stability of the local oscillator chain are prerequisites. In addition to mapping the active galaxy 3C84 with 90 microarc-sec resolution, a selection of 16 compact sources were observed, with 15 successful detections on transatlantic baselines. The extension of these observations should provide a network of calibrators for the VLB array now being constructed by the NRAO.

29.3 Orbiting VLBI

National Aeronautics and Space Administration (Contract NAS7-918)
Jet Propulsion Laboratory (Contract 958048)

Bernard F. Burke, Samuel Connor, Michael Heflin, John W. Barrett

The QUASAT project is a study of the feasibility of extending the baselines of VLB interferometers into space. The work is in the Phase A study process within the European Space Agency, and is receiving support by NASA for the data acquisition, missions operations, orbital prediction and analysis, scientific studies, and data reduction phases. Professor Burke is chairman of the United States Science Working Group, coordinating with Doctor J.F. Jordan of the Jet Propulsion Laboratory, who is the study manager.

The experimental aspect of the study has used the TDRSS Satellite, a data relay satellite in geosynchronous orbit over the Atlantic Ocean, in conjunction with ground stations in Japan and Australia, to perform a successful experiment at 2.3 GHz, with baselines over two earth diameters in length. The work has been carried out jointly with the Jet Propulsion Laboratory and Haystack Radio Observatory. The next step will be to extend operations to 15 GHz. The short wavelength (2 cm) will give angular resolution of the order of 60 microarc-seconds. The ground receivers, which are cooled HEMT amplifiers, are being built by RLE, following NRAO design, and are expected to have exceptionally good low-noise performance.

29.4 Studies of Planetary Systems of Other Stars

Bernard F. Burke

A preliminary study of the feasibility of directly imaging planets in other solar systems has been carried out by Professor Burke, and a preliminary report was given at the 1987 International Astronautics Federation Congress at Brighton, England. The conclusion is positive: with sufficient care, the direct detection of an earth-like planet is feasible if it is orbiting a star within ten parsecs from the sun. The critical elements are: 1) the construction of an orbiting optical interferometer of the order of 20-30 meters maximum baseline; 2) the provision of phase-stable optics and correlators; 3) the development of low-sidelobe optics; and 4) the adaptation of radio VLBI methods to the optical domain.

In the above list, item (3), low-sidelobe optics, is the most challenging. Tapering the aperture illumination is essential, but the "noise sidelobes" generated by optical imperfection must be rigorously controlled. The conclusion was reached that the rms deviation of the wavefront imposed by optical imperfections should not exceed $\lambda/80$ over spatial frequencies extending from 1 cm to the full aperture of the optics. The main elements would be off-axis paraboloidal mirrors in the 1.5 - 2 cm range, and would thus have to be different from ordinary optical practice. There seem to be no fundamental technological barriers, however. The radio experience is directly applicable to the optical case, except for the limitation that amplification on heterodyne missions is infeasible because of quantum noise. Optical techniques exist, however, to provide the necessary cross-correlation capability.

29.5 Long-Baseline Astrometric Interferometer

*U.S. Navy - Office of Naval Research (Contracts N00014-84-C-2082
and N00014-86-C-2114)*

David H. Staelin, Michael Shao, John W. Barrett, Braden E. Hines, Edward J. Kim

During 1987 development of the Mark III optical astrometric interferometer continued at the Mount Wilson Observatory, and initial scientific results were obtained. Several manuscripts were prepared for publication.

Work began on the electronics for the laser siderostat subsystem. This system measures the positions of the siderostat mirrors relative to their associated concrete

pedestals. Four laser interferometers measure the distances between a large hemispherical mirror bonded to the siderostat mirror and four reference points tied to an invar assembly, which is attached to one of the steel reinforced concrete pedestals located at the ends of the various baselines. The hemispherical mirror, 6.8 inches in diameter, is mounted on the back of each main movable siderostat mirror such that the center of curvature of the mirrors is located within several microns of the surface of the main mirror and close to the intersection of its azimuth and elevation axes. The four measurements are redundant so that the existence of fringe counting errors can be detected. Initial observations reveal that errors occur under rapid slewing at intervals of several minutes. Because that is too frequent to be useful, additional changes in operational procedures and system design are contemplated.

Operation of the interferometer in a photon-starved non-tracking mode appears to be feasible, and the necessary polychromatic fringe measurement system is being developed. It uses a dispersive prism which projects the spectrum across the face of the same photon camera used for star-tracking. Measurements of the relative flicker rates of different optical spectral bands permits the fringe visibility and fringe centers to be estimated. Special high-speed electronics which operate on photon addresses and arrival times are being developed for this purpose.

Papers were prepared describing the initial scientific results regarding stellar diameter measurements,¹ measured star positions,² the two-color method for astrometry,³ a description of the Mark III interferometer,⁴ atmospheric phase measurements,⁵ and the earlier Mark II results.⁶

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29.6 Tiros-N Satellite Microwave Sounder

SM Systems and Research, Inc.

Phillip W. Rosenkranz, David H. Staelin, Charlene C. Kuo

Four-channel passive microwave spectrometers (MSU) have been used operationally on the National Oceanic and Atmospheric Administration (NOAA) polar orbiting weather satellites since 1977. They will be superseded in the early 1990's by the Advanced Microwave Sounding Unit (AMSU) which has 15 channels that image the earth with 50-km resolution every 12 hours at frequencies distributed from 23 to 90 GHz, and an additional five channels that simultaneously image the earth with 15-km resolution at frequencies distributed from 90 to 183 GHz. This effort involves scientific support of the AMSU program, with emphasis on physics and retrieval methods.

A new approach to estimating the interference coefficients between the separate 5-mm wavelength oxygen lines has been developed and used to improve expressions for the absorption coefficient of oxygen in air.¹ Additional studies of the transmittance of atmospheric oxygen in the stratosphere and mesosphere have also led to definition of an extension to AMSU that could usefully sound temperature profiles up to 70 km altitude.²

Earlier work on methods for sounding water vapor using the 183-GHz resonance foundered when temperature inversions or quasi-isothermal regions existed in the troposphere. A new approach to this problem has been developed. It involves an iterative combination of nonlinear physics with *a priori* statistics. This new method is much more robust in the presence of the intrinsic singularities associated with these retrievals. Improved theoretical expressions for pressure broadening of the rotational bands of water vapor from 300 to 1100 cm^{-1} were also developed.³

A conference was organized and held June 1-3, 1987, at Williamsburg, Virginia, to discuss AMSU and the extension of this technology to operational systems in geosynchronous orbit. Study of such geosynchronous systems was begun and was documented for the proceedings of this NOAA-sponsored conference, to be published in 1988.

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29.7 High Resolution Passive Microwave Imaging of Atmospheric Structure

National Aeronautics and Space Administration/Goddard Space Flight Center (Grant NAG5-10)

David H. Staelir, Philip W. Rosenkranz, John W. Barrett, Pierino G. Bonanni, Albin J. Gasiewski, Gregory J. Zanciewicz

Considerable progress was made in reducing and analyzing the data obtained during 1986 using the new imaging millimeter-wavelength temperature sounder (MTS). The eight-channel MTS operates near the 118-GHz resonance of oxygen. The cross-track scan sampled the atmosphere at 14 spots converging the region $\pm 45^\circ$ from nadir with a 7.5° spot beamwidth. The MTS was flown on the NASA ER-2 aircraft near 65,000 ft for 14 missions during the experiments GALE (February 1986) and for 21 missions for the experiments COHMEX (June-July 1986). Research efforts have involved development of microwave scattering models for use in interpreting this data, a study of the apparent degrees of freedom in the radiance spectrum of clouds, the relative sensitivity of 53.6- and 118-GHz soundings to clouds and precipitation, and the accuracy of temperature profile retrievals obtained using the eight-channel MTS data.

29.8 Video Image Processing

*Center for Advanced Television Studies
Brazil, Conselho Nacional de Desenvolvimento Cientifico e Tecnologico
(Grant 300.832-82)*

David H. Staelin, Henrique S. Malvar, Sergio Brofferio, James C. Preisig, Jerome S. Shapiro, Bernard I. Szabo, Gregory W. Wornell, Shiufun Cheung, William I. Irving, Gordon M. Lum, Muriel Medard

This effort has involved the publication of prior research results, and continued work with motion estimation and coding techniques. A new method for fast computation of the discrete cosine transform and the discrete Hartley transform¹ was published, as was some of the work on the optimal FIR pre- and postfilters for decimation and interpolation of random signals,² which is particularly relevant to filter design for high-definition television systems.

The work on motion estimation has involved a comparative analysis of present methods for estimating local motion, and a more general method for optimally combining such local motion estimates to yield more accurate estimates of regional motion. Video coding work has involved a study of transform image coding with composite block source models, a method of coding where each type of block has its own optimal transform. Research continued on the use of pseudorandom noise in the quantization of random variables with nonuniform probability distributions. Small efforts were begun in character recognition of arbitrary fonts,^{3,4} and the efficient recognition of the occurrence of widely separated scene repetitions in noisy television sequences.

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29.9 Nonthermal Radio Emission from the Jovian Planets

National Aeronautics and Space Administration/Goddard Space Flight Center (Grant NAG5-537)

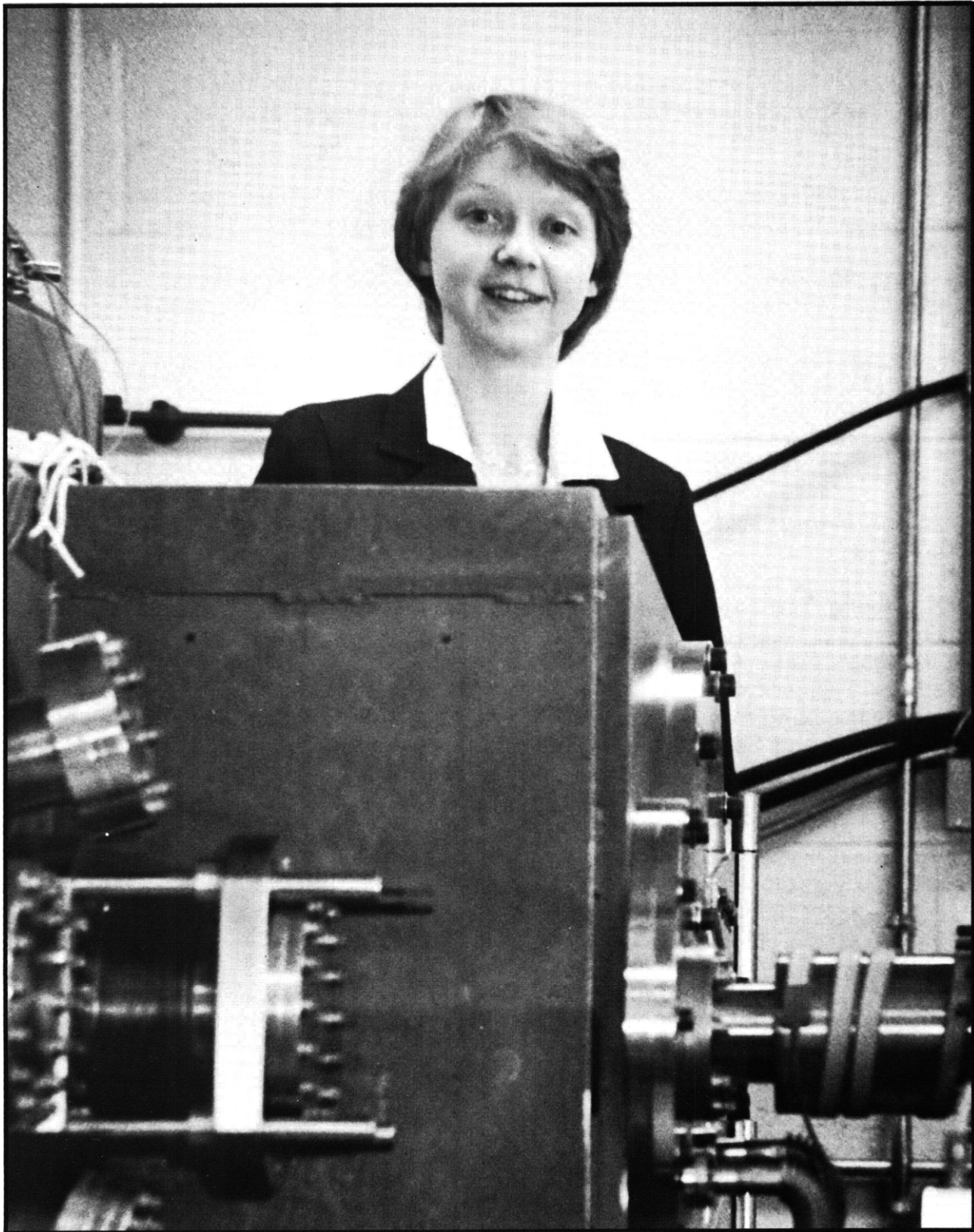
David H. Staelin, Tomas A. Arias, Roeland V. Hammerschlag, Stephen S. Eikenberry

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. Study of the striated spectral activity (SSA) in Jovian and Saturnian radio emission has continued and has been submitted for publication.¹

Theoretical studies of the Io-generated Alfvén waves were continued. Obtaining a complete self-consistent wave/particle beam solution compatible with the launch geometry has proved elusive.

Reference

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