

28.0 Radio Astronomy

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28.1 Galactic and Extragalactic Research

National Science Foundation (Grant AST 86-17172)

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We have discovered a “counter-jet” in the radio galaxy Cygnus A. This follows the earlier achievement, with Perley of the National Radio Astronomy Observatory (NRAO), of the discovery of the relativistic jet that emanates from the active galactic nucleus (a discovery that was made through their new methods of image processing at the the Very Large Array (VLA) at NRAO). A related project, a detailed polarization map of the radio galaxy, has also been completed. A new observing project, one of the largest programs ever undertaken at the VLA, has been begun to extend these methods to a larger selection of radio galaxies.

We have also been searching for new gravitationally-lensed quasars in collaboration with colleagues at Princeton and CalTech. One prime example, Q0023+171, has been discovered and six promising new candidate objects are being studied in greater detail. About 4000 radio maps, taken with the VLA, are being processed as part of their program. A successful series of VLBI experiments has been conducted at 7 mm wavelength, with the intention of establishing that band for standard VLBI operations. A synthesized map at 7 mm of the active galaxy 3C84 (Perseus A) has been prepared and represents the most highly detailed map ever made of that unusual object, with a resolution of 140 micro-arc-seconds. Prof. Burke is also continuing as U.S. principal investigator for the QUASAT satellite, a joint U.S.-European project to establish a VLBI station in space to get higher angular resolution than can be achieved with earth-based VLBI stations alone.

28.2 Long-Baseline Astrometric Interferometers

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

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During 1986 construction of the Mark III optical astrometric interferometer continued at the Mount Wilson Observatory. Initial measurements were made of stellar positions using the inner pair of pedestals in the North-South direction; these are separated by 12 meters. These initial crude measurements, performed without the benefit of laser measurements of pedestal position, yielded relative stellar positions over wide angles with sub-arcsecond accuracy. These have further demonstrated the ability of the two-color technique to yield instantaneous stellar positions with a precision more than five times superior to that of the single-color technique.

Three significant subsystems were developed for the Mark III interferometer: an optical delay line, a siderostat control system, and a photon camera star tracker. To adjust the path length of the delay to provide coherence between the two beams, a movable retroreflector was mounted on rails inside a vacuum chamber. Three actuators are used to control the optical path length: a stepper motor, a voice coil, and a piezoelectric transducer. A heterodyne laser interferometer with a resolution of 5 nanometers and a maximum slew rate of 0.6 meters per second monitors the optical path length through the delay line. The rms servo tracking error was approximately 8, 11, and 18 nanometers for delay line velocities of 0, 63, and 790 microns per second, respectively.¹

The Mark III siderostat subsystems employed open-loop pointing, for which the accuracy was ~ 4 arc minutes. For automatic operation of the Mark III interferometer pointing accuracies of ~ 5 -10 arc seconds were sought. An 8-parameter geometric model was developed to describe the siderostat. A single siderostat was tested at Mount Wilson Observatory, and yielded accuracies better than 10 arc seconds with some restrictions.² A multi-beam laser assembly to monitor the position of each siderostat mirror relative to a local invar plate was designed. Work on this system is continuing.

A photon camera star tracker was designed, analyzed and tested. Laboratory testing of the tracker indicated that the rms tracking error in one axis was about 0.1 arc second with a detected photon rate of 13,500 photons per second, and about 0.2 arc seconds for 2500 photons per second.³

References

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- ² M.J. Kelly, "A Siderostat Control System," S.M. Thesis, Dept. of Electr. Eng. and Comp. Sci., M.I.T., Cambridge, Mass., 1986.
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28.3 Tiros-N Satellite Microwave Sounder

*National Oceanic and Atmospheric Administration (Contract NA84AA-D-00001)
SM Systems and Research, Inc.*

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The National Oceanic and Atmospheric Administration (NOAA) operates polar-orbiting weather satellites which now carry four-channel passive microwave spectrometers (MSU) that map the three-dimensional temperature field of the atmosphere at 6- or 12-hour intervals. This instrument will be superseded at the end of this decade 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.

A study of multi-dimensional temperature profile retrieval techniques for use with MSU and AMSU was completed.¹ Both adaptive and non-adaptive retrieval techniques were studied, and under certain circumstances useful improvements could be obtained.

Additional studies of methods for estimating surface emissivity and for theoretically predicting atmospheric transmittances were continued.

References

- ¹ A.C. Braincon, "Estimation and Modeling of Multidimensional Non-Stationary Stochastic Processes: Application to the Remote Sensing of Atmospheric Temperature Fields," Ph.D. Diss., Dept. of Electr. Eng. and Comp. Sci., M.I.T., Cambridge, Mass., 1986.

28.4 High-Resolution Passive Microwave Imaging of Atmospheric Structure

National Aeronautics and Space Administration/Goddard Space Flight Center (Grant NAG 5-10)

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During 1986 a new imaging Millimeter-wave Temperature Sounder (MTS) was flown for the first time from the NASA ER-2 aircraft near 65,000 feet. The MTS includes a double-sideband receiver with eight channels, each ~ 200 MHz wide, covering the spectral region from 118.75 ± 0.45 to 118.75 ± 2.1 GHz. These channels sampled atmospheric temperature throughout the atmosphere beneath the aircraft. The cross-track scan sampled the atmosphere at 14 spots covering the region $\pm 45^\circ$ from nadir with a 7.5° spot beamwidth. An integration time of ~ 0.1 sec per spot yielded ~ 0.5 K brightness temperature resolution. The MTS also carried a nadir-looking 53.6-GHz radiometer and a wide-angle television camera. The MTS was successfully flown during the experiments GALE (February 1986) and COHMEX (June-July 1986). Strip map images of atmospheric millimeter-wave radiance revealed the zone of precipitation,

the altitudes of the cell tops, the concentration of frozen precipitation aloft, and the temperature structure around the cell. Those data reveal what may be the first direct observation of small thermal waves (less than $\sim 1\text{K}$) in the vicinity of fronts. A data reduction and display system was developed and has yielded excellent images (1024 X 1024 pels, 8-bit color) of these data.

A statistical model for error growth in numerical weather prediction models was developed and found to yield results similar to those of Lorenz and Leith, but with the added advantages that 10σ levels and the primitive equations were employed. The results predict, for example, that AMSU (50-km resolution) should significantly improve mesoscale forecasts relative to other systems with resolution of a few hundred kilometers. A simple equation predicts limits to the predictability of atmospheric dynamics as a function of the spectral regions of interest and for which data is available.

28.5 Video Image Processing

Center for Advanced Television Studies

Brazil, Conselho Nacional de Desenvolvimento Científico e Tecnológico

David H. Staelin, Gerhard de Jager, Henrique S. Malvar, Gregory J. Bartlett, Jerome S. Shapiro, Bernard I. Szabo,

Optimal pre- and post-filtering in noisy sampled-data systems was studied in the context of video and audio communications for storage systems, with optimality considered in a weighted mean-square error sense. The system model included additive noise in the input signal and in the channel. Optimal pre- and post-filters were derived for three basic classes of systems, characterized by Infinite Impulse Response (IIR), Finite Impulse Response (FIR), and block filters. Also studied were filters with nearly optimal performance that can be implemented using various fast transforms. An analytic form and a fast version were derived for a previously introduced class of pre- and post-filters for block processing with overlapping basic functions, namely, "Lapped Orthogonal Transforms (LOT's)." In all of these classes, for typical image processes and coding applications, improvements over traditional systems were obtained in the weighted error spectrum on the order of 1-6 dB.¹

Experiments were performed to characterize the spatial and temporal response of human color vision. It was found that peak luminance sensitivity occurred for test gratings at a spatial frequency near 2 cycles per degree, and for temporal variations near 4 Hz. The corresponding peak sensitivities for chrominance signals were near 1 cycle per degree and 2 Hz for I, and 0.6 cycles per degree and 7 Hz for Q. The surprising result was that the temporal sensitivity for the I component of chrominance is sufficiently low that this fact could be used to reduce the bandwidth required for communicating color television signals.²

A quantitative measure that performs well at predicting the absolute and comparative subjective picture quality of two-dimensional decimated and interpolated still images was studied. Subjective testing of 24 subjects determined viewers' preferences for degraded images. The error measure which performed best as a predictor of subject preferences suggested that these images were judged on the basis of mean-square error in the worst portion or portions of the image, using an area which is approximately 0.5%

of the whole; an exception was blur, for which subjects tended to evaluate the entire image.³

By exploiting the relationship between the Discrete Cosine Transform (DCT) and the Discrete Hartley Transform (DHT), a new fast and numerically stable algorithm for computing the DCT was developed.⁴ This technique is notable for its utilization of a minimum number of multiplications, although somewhat more additions are required.

References

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28.6 Nonthermal Radio Emission from the Jovian Planets

National Aeronautics and Space Administration/Goddard Space Flight Center (Grant NAG 5-537)

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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 1986 we continued to study the Jovian modulated spectral activity in the band below ~ 1.3 MHz. Efforts to explain these data theoretically have been unsuccessful to date. However, the characteristics of this emission have been studied quantitatively.¹

During 1986 Voyager 2 encountered Uranus, disclosing the existence of high magnetic fields and strong emissions radiated principally away from the sun. These observations also yielded the most accurate rotation period yet obtained for the planet, $17.24 \pm .01$ hours.²

Theoretical studies of the Io-generated Alfvén waves were initiated. Preliminary results suggest that the currents observed by the Voyager magnetometer experiment can be explained, and also perhaps the observed ~ 3 -keV particle energies deduced earlier.³

References

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28.7 Video Bandwidth Compression Techniques

U.S. Army (Contract MDA 903-84-K-0297)

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Successful coding of full-motion video sequences characteristic of videoconferencing can be performed at data rates of 56 kbps and lower only when adaptive coding techniques are employed. Adaptive block transform coding, with and without motion compensation, has been studied using both the Discrete Cosine Transform (DCT) and 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. These two techniques were compared using interframe-coded full-motion head-and-shoulders sequences at 28 and 56 kbps. Subjective quality assessment experiments revealed the superiority of LOT over the DCT with low data rates when no motion compensation was used. The improvement was no longer significant at 56 kbps with full motion compensation.¹

Reference

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