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(NASA-CR-174343) RESIDENT RESEARCH  
ASSOCIATESHIPS. POSTDOCTORAL AND SENIOR  
RESEARCH AWARDS: OPPORTUNITIES FOR RESEARCH  
AT THE JET PROPULSION LABORATORY Annual  
Report (Jet Propulsion Lab.) 61 p

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National Aeronautics and  
Space Administration

# Resident

# Research

# Associateships

## Postdoctoral and Senior Research Awards

1984

tenable at the  
JET PROPULSION LABORATORY  
California Institute of Technology  
Pasadena, California

administered by the  
NATIONAL RESEARCH COUNCIL  
National Academy of Sciences  
National Academy of Engineering  
Institute of Medicine

# **Resident Research Associateships**

## **Postdoctoral and Senior Research Awards**

1984

OPPORTUNITIES FOR RESEARCH  
at the  
JET PROPULSION LABORATORY  
California Institute of Technology  
Pasadena, California 91109

in association with the  
NATIONAL RESEARCH COUNCIL  
National Academy of Sciences  
National Academy of Engineering  
Institute of Medicine  
2101 Constitution Avenue  
Washington, D.C. 20418

## Foreword

The Jet Propulsion Laboratory is a division of the California Institute of Technology, operated by Caltech under contract to the National Aeronautics and Space Administration. Laboratory endeavors are devoted primarily to the programs and projects of NASA; it is within the NASA-sponsored research program that these National Research Council Research Associateships are offered at JPL.

Since the beginning of its association with NASA in 1958, JPL has been the leading center in the United States for unmanned lunar and planetary exploration. Spaceflight missions for which the Laboratory has been responsible include the Ranger series of hard-landed lunar spacecraft, the Surveyor soft-landed lunar series, the Mariner series of planetary flybys and orbiters, and the Viking Orbiter and Lander missions to Mars. Among projects now under way are the Voyager Uranus Interstellar Mission flyby and the Galileo Jupiter orbiter-probe mission. In addition, JPL conducted the Seasat project for ocean observations.

The content of the JPL research program generally reflects this long-standing interest in earth and planetary sciences, along with an involvement in the study of solar irradiance, fields and particles of interplanetary space, and observations beyond the solar system. During the past few years, the Earth sciences program has expanded into the areas of physical and biological oceanography, weather, climate, and upper-atmospheric chemistry, as well as research associated with applications to problems of national interest such as Earth resources and energy systems. Fields of active research include planetary atmospheres, planetology, comets, asteroids, interplanetary fields and particles, optical and radio astronomy, high-energy astrophysics and solar physics, and studies in atmospheric and ocean processes. The range of activity in these fields covers theoretical study, laboratory experiments, ground-based observations, instrument development, flight (aircraft, balloon, and spacecraft) experiments, and analysis of experimental data. Activities that are not totally space oriented include automation, fuel processing and combustion, systems analysis, photovoltaics, image and information processing, biomedical instrumentation, and materials research.

In addition to its flight-project responsibilities and research and development programs, JPL also operates the NASA Deep Space Network for communicating with and controlling spacecraft from earth. Antennas, 85 and 210 ft in diameter, are located at stations around the earth and connected by ground communications to the JPL Space Flight Operations Facility. All planetary

and interplanetary spaceflight missions conducted by NASA utilize this system.

The Laboratory also conducts programs in Energy and Technology Applications. These include (1) dispersed solar-energy-conversion systems, using photovoltaics and solar-thermal technology and considering many aspects of applications and utility system interactions; (2) coal mining, processing, and conversion; and (3) the development of electric and hybrid vehicle systems. A variety of other problems in transportation systems, energy conversion and utilization technology, environmental technology, and medical technology are being addressed in conjunction with various agencies.

The Laboratory is located seven miles north of the Caltech campus in the foothills above Pasadena, California. It employs approximately 4,000 people; of these, some 1,200 are professional scientists and engineers. Close relationships are maintained in many areas of research with faculty and staff at nearby universities, in addition to Caltech itself. These institutions include the University of Southern California, University of California at Los Angeles, California State University at Los Angeles, and University of California at San Diego, among others.

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# Introduction

## General Information

The National Research Council (NRC) conducts the Resident Research Associateship Programs in cooperation with a number of sponsoring Federal laboratories and research organizations approved by the NRC for participation. In the programs, a national competition is conducted by the NRC to recommend and make awards to outstanding scientists and engineers at the recent postdoctoral and experienced senior levels for tenure as guest investigators at the participating laboratories. These programs have been conducted with a number of Federal agencies since 1954.

The objectives of the program are

- to provide postdoctoral scientists and engineers of unusual promise and ability opportunities for research on problems, largely of their own choice, that are compatible with the research interests of the sponsoring laboratories and
- to contribute thereby to the overall research effort of the Federal laboratories.

These programs are intended to be analogous to fellowships, associateships, and similar temporary programs at the doctoral level in universities and other organizations. They are neither intended to be, nor to compete with, permanent professional career positions.

- An NRC Resident Research Associate is a guest investigator, not an employee of the National Research Council or of the laboratory, and there is no obligation to either organization during or after completion of tenure.

For recent doctoral graduates, the program provides an opportunity for concentrated research in association with selected members of the permanent professional laboratory staff, often as a climax to formal career preparation. For established scientists and engineers, the program affords an opportunity for research without the interruptions and distracting assignments of permanent career positions. The participating laboratories and centers receive a stimulus to their research programs by the presence of bright, highly motivated recent doctoral graduates and senior investigators with established records of research productivity. New ideas, techniques, and approaches to problems contribute to the overall research climate of the laboratories. Indirectly, the program also makes available to the broader scientific and engineering communities

the excellent and often unique research facilities that exist in the government's laboratories.

Applications for awards will be received by the Associateship Programs office of the NRC and will be evaluated on a competitive basis by special NRC panels of scientists and engineers. For the 1984 program year, it is anticipated that approximately 1,000 applications will be received for the nearly 250 new awards to be made in the NRC Research Associateship Programs.

Described in this booklet are areas of research in which Research Associateships may be awarded at the Jet Propulsion Laboratory (JPL). Each applicant is responsible for formulating a specific research plan on a problem that is related to the current research interests of the laboratory in which the applicant wishes to do research.

Applicants whose research interests appear to be related to one or more of the opportunities described in this booklet are advised to communicate directly with the research advisers who are designated for those areas of research. Research advisers can provide more specific information on current research programs and available technical facilities. Further inquiries concerning research opportunities and advisers may be directed to the NRC-NASA Laboratory Program Representative:

Dr. Harry Ashkenas  
Jet Propulsion Laboratory - 183-601  
4800 Oak Grove Drive  
Pasadena, California 91109  
Telephone: (213) 354-2140

Each applicant's proposed plan of research must be approved by one of the research advisers listed herein and endorsed by the program committee of the JPL to be eligible for an award. The endorsement affirms that the proposed research problem is compatible with the laboratory's interest and that adequate programmatic support will be available if an award is offered. A written response regarding each applicant's proposed research problem must be received from the laboratory by the Associateship Programs office before an applicant will be reviewed by the NRC evaluation panels. The Center's action on the research proposal, together with a copy of the adviser's comments, will be provided directly to the applicant by the NRC Program Representative at the JPL. It must also be determined that the applicant is acceptable for resident status at a NASA Center.

- All applicants should note that endorsement by a research adviser and/or laboratory, while an essential component of the application process, must not be assumed to imply or guarantee an award by the NRC. Applicants are formally recommended for awards only after open, national competition, in which special NRC-appointed panels rank candidates on the basis of quality alone. Final ranking in order of quality and the recommendation of applicants for awards are the exclusive prerogatives of these panels, and notification only by the NRC of an applicant's status in the competition is authoritative.



## Eligibility of Applicants

### Citizenship

Research opportunities in basic science and applied science and technology described in this booklet are open to all citizens of the United States.

- Non-U.S. citizens may submit research proposals in basic science areas only and must have full command of the English language. Non-U.S. nationals who become Associates must have valid visas throughout tenure. Only Exchange Visitor and Immigrant Visas are acceptable to the NRC. If an awardee chooses to apply for an Exchange Visitor Visa, the sponsorship must be under the NRC. If one chooses to apply for a U.S. Immigrant Visa, the NRC will not be involved in the matter.

### Education and Experience

Awardees must hold the Ph.D., Sc.D., or other earned research doctoral degree recognized in U.S. academic circles as equivalent to the Ph.D. or must present acceptable evidence of having completed all the formal academic requirements for one of these degrees before tenure may be initiated. Applicants must have demonstrated superior ability for creative research. An applicant's training and research experience may be in any appropriate discipline or combination of disciplines required for the proposed research.

### Prior Affiliation with the Laboratory

A primary objective of the Associateship Programs is to provide a mechanism for new ideas and new sources of stimulation to be brought to the sponsoring laboratory. Thus, persons with substantial recent prior affiliation with a specific laboratory may not be eligible to apply for an Associateship at that laboratory.

Substantial recent prior affiliation includes direct employment relationships either with the laboratory or with a contractor whose work is performed at the laboratory. A long-term consulting relationship with the laboratory usually makes the applicant ineligible. Research contracts with universities that provide support for graduate students and faculty performing research on the campus are not ordinarily considered disqualifying.

### Reapplication

Persons who have previously held an NRC Research Associateship may apply for another award only if a period of at least two years will have

elapsed between termination of the first award and the proposed tenure of a second award. Persons who have previously applied for an NRC Associateship, but who were not recommended for an award by the NRC panels, may reapply after one year. Candidates who were recommended for an award by the NRC panels, but who were not offered an award because of funding or other limitations, may reapply at any time without a mandatory waiting period.

### Consideration

Qualified applicants will receive consideration without regard to race, creed, color, age, sex, or national origin.

### Conditions of the Award

Regular Research Associateships will be awarded to persons who have held the doctorate less than five years at the time of application and will be made initially for one year.

Senior Research Associateships are awarded only to investigators who have held the doctorate five years or more at the time of application. Senior applicants should have research experience that has resulted in significant contributions and recognition as established investigators in their specialized fields. Awards to senior Associates will generally be for one year; however, awards for shorter periods will be considered.

Under certain conditions, extensions will be granted to allow Associates to bring their research programs to a reasonable stage of completion. An extension must not be assumed.

- No commitment on the part of an Associate, the sponsoring laboratory, or the NRC with regard to later employment is implied or should be inferred by the offer or acceptance of an award.

These Research Associateships are tenable only at the approved, participating laboratories listed in this booklet. No period of the Associateship tenure may be spent in residence at another laboratory or institution. Associates will have the status of visiting scientists or engineers in the laboratory but will be subject to the general working conditions at the laboratory. The Jet Propulsion Laboratory, which provides the funds to support this program, will furnish all necessary support services, facilities, and equipment for the approved research program of each Associate.

- Although applications for NRC-NASA Research Associateships will be accepted throughout the year, they will be evaluated in competition only during certain periods. Three competitive reviews will be held in 1984. Completed applications that are postmarked not later than January 15, April

15, and August 15, and received by the NRC not later than January 25, April 25, and August 25, will be reviewed for announcement of awards in March, July, and November, respectively. The NRC must be advised by the JPL that the proposed research has been approved; otherwise, the NRC will assume that the proposed research is not of sufficient current interest to NASA or that support facilities cannot be made available.

Associateship awards will be made by the NRC. The date on which tenure of an Associateship award may begin is negotiated on an individual basis. Tenure should normally begin within six months of the award; however, the starting date may be delayed by mutual agreement of JPL, the Associate, and the NRC. Sufficient time must be allowed between the offer of an award and the beginning of tenure to enable the NRC and JPL to complete all necessary administrative procedures. The starting date cannot be later than 12 months from the date of the original award. If this condition cannot be met, a new application, including a newly approved plan of research, must be submitted to the NRC and will be judged without prejudice in the next competition.

- While every effort has been made by the participating Center or laboratory to provide Research Opportunities of ample scope and relevance, the appearance of any Research Opportunity in this booklet does not guarantee that it will be available at the time Associateship awards are offered. Changes and/or deletions may occur following the publication of this booklet, and all opportunities are subject to final review and approval by the laboratory and the NRC prior to the awarding of tenure.

### Stipend

A Research Associate will receive a stipend from the NRC while carrying out the research proposed as part of the application procedure. The current stipend for a regular Research Associate is at the annual rate of \$24,500. The base is subject to adjustments from time to time in accordance with general national guidelines pertaining to scientists and engineers. An appropriately higher stipend will be offered to senior Associates.

Following current salary practices in certain professional fields that are experiencing a short supply of new doctoral graduates, a stipend supplement may be allotted by the NRC to awardees in those disciplines. For the 1984 program year, stipend supplements of up to \$5,000 may be added to the basic stipend for regular awardees holding recognized doctoral degrees in engineering, computer science, and clinical space-biomedical science.

- Applicants are cautioned against entering into any agreement or understanding with individual Research Advisers or other laboratory personnel concerning additional funding or other remuneration for work as an Associate. Stipends for Research Associates are limited to the amounts and by the

conditions set forth above, and any other arrangement, formal or informal, between an applicant and laboratory personnel for additional monies or other considerations is strictly prohibited by the NRC.

### **Commitment**

Associates must devote their full-time effort to the approved research program and must be in residence at the sponsoring laboratory during the entire period of the Associateship. No additional monetary aid or other remuneration may be accepted from another appointment, fellowship, or similar grant, except for sabbatical leave, during the period of the Associateship.

### **Taxes and Insurance**

All Associates are, in effect, self-employed. All arrangements for payment of income taxes are the responsibility of the individual Associate. An appropriate amount, estimated to approximate the tax liability of foreign nationals, will be withheld by the NRC from stipends of non-U.S. Associates on Exchange Visitor Visas. Details will be provided at the time of the award. Job-related injury or death will be covered by insurance (workmen's-compensation type). A group health insurance program is required for Associates and optional for dependents.

### **Relocation and Travel**

A suitable relocation reimbursement will be determined for each awardee. Details will be provided at the time of the award. Funds will also be made available for limited professional travel during tenure, provided such travel is recommended in advance by an Associate's research adviser at JPL and approved by the NRC.

### **Publication**

Since an Associate's later scientific and technical career will be judged by others, publication in the accepted open technical literature is highly encouraged. Publications should include a statement indicating that the research was conducted while the author held an NRC Research Associateship.

### **Summary of the Application Procedure**

For further details on the application procedure, refer to the Instructions that accompany the application packet.

- The Associateship Programs office of the NRC will receive all applications and supporting documents and conduct the competitive evaluation of applications.

- Detailed information on application procedures, all necessary forms, and a list of the supporting documents required are available on request from the

Associateship Programs (JH 608)  
National Research Council  
2101 Constitution Avenue, N.W.  
Washington, D.C. 20418

- Application materials from previous competitions must not be used.
- Submit the following to the Associateship Programs office.

Signed Application form  
Office Card  
Research Proposal (one copy with original signature on each page)  
Approval of Research Form (one set)  
Previous and Current Research form

- The above application materials must be postmarked no later than January 15, 1984, April 15, 1984, and August 15, 1984, and must be received in the Associateship Programs office no later than January 25, April 25, and August 25, respectively.

- Have the following sent directly to the Associateship Programs office:

Official transcripts of all graduate and undergraduate credits (not required for senior applicants)

Four Reference Reports from the respondents listed on the Application. Only official Reference Report forms may be used by regular applicants. Letters of reference will be accepted for senior applicants. Senior applicants should endeavor to include some references from individuals who are not co-employees

- The above supporting documents must be received by the NRC by February 15, June 1, and October 1, respectively.

- The NRC will forward the Research Proposal to the NASA Center Program Representative, who will direct it to the appropriate research adviser indicated on the form. The research adviser will review the Research Proposal and forward it to the Center's program committee for endorsement.

- No applicant will be eligible for an award without the research adviser's approval of the Research Proposal and its endorsement by the program committee at the laboratory.

- Completed applications that have been postmarked January 15, April 15, and August 15 and endorsed by the NASA Center will be reviewed by the NRC panels in February, June, and October, respectively.

- The Associateship Programs office will notify applicants of the disposition of their applications in March, July, and November, respectively.
- Awards will be offered by the NRC to the extent of available spaces and funding, and acceptances or declinations must be made to the NRC.

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The National Research Council administers NRC-NASA Research Associateships at the following NASA Centers: Ames Research Center, Moffett Field, California; Dryden Flight Research Facility, Edwards Air Force Base, California; Goddard Space Flight Center, Greenbelt, Maryland; Jet Propulsion Laboratory, Pasadena, California; Johnson Space Center, Houston, Texas; Langley Research Center, Hampton, Virginia; Lewis Research Center, Cleveland, Ohio; and Marshall Space Flight Center, Huntsville, Alabama.

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# Opportunities For Research

## Earth and Space Sciences Division

### Remote Sounding of Planetary Atmospheres

D.J. McCleese

44.40.16.01

Spectral measurements of the infrared radiation leaving a planetary atmosphere contain information on the composition, vertical temperature structure, and cloud morphology within. This principle has been highly refined and successfully applied to the study of Earth's atmosphere from satellites. At JPL, we are developing new infrared remote sensing instruments for the detailed study of the atmospheres of other planets from spacecraft. This is accomplished by a program of theoretical modeling of radiative transfer in planetary atmospheres and by the development and testing of instrumentation in the laboratory. The current focal point is the design and implementation of an instrument for a future mission to Mars. This instrument is intended to map the abundance and spatial distribution of the water vapor in the Martian atmosphere, to determine the thermal structure of the atmosphere globally, and to map the airborne dust and condensates. The measurement techniques employed include gas correlation spectroradiometry and filter radiometry.

#### References

- J.T. Houghton & F.W. Taylor, Rep. Prog. Phys. 36, 827 (1973).  
J.T. Houghton & F.W. Taylor, J. Atmos. Sci. 32, 620 (1975).

### Detailed Analysis of Planetary Atmospheric Structures

G.S. Orton

44.40.16.02

Detailed models are being developed for atmospheric structures (including temperature, composition, and cloud properties) as a function of location on the planet and as a function of time. Emphasis is placed on radiative transfer, both as a tool for determining atmospheric structure by passive remote sensing and as an agent in the establishment of energetic (radiative-convective) equilibrium. A continuous updating process revises and improves existing models as Earth-based and spacecraft data become available. Infrared observations of planetary thermal and reflected solar radiation are made on a regular basis using advanced imaging and spectroscopic facilities. As a complementary effort, the program develops advanced concepts for atmospheric experiments on spacecraft. The work has a strong interaction with

other efforts at JPL such as supporting laboratory spectroscopy, determining optical properties of candidate atmospheric constituents, and developing remote retrieval algorithms. The program has emphasized analysis of the structures of thick planetary atmospheres, especially those of the outer planets and atmospheres with obscuring cloud and aerosol layers. Recent emphasis is on analysis of Voyager reflected solar radiation and planetary thermal emission data to explore the atmospheres of Jupiter and Saturn. Results of this work will be used in support of Galileo mission science and experiment planning for other, future planetary missions.

#### References

- G.S. Orton *et al.*, *Icarus* 47, 145 (1981).  
G.S. Orton *et al.*, *Icarus* 52, 94 (1982).

### Thermal-Infrared Spectroscopy

G.S. Orton

44.40.16.03

This program involves laboratory and theoretical spectroscopy of planetary gases in the spectral region of approximately  $10\text{--}10,000\text{ cm}^{-1}$  (1 to 1000  $\mu\text{m}$ ). Current emphasis is on pressure-induced spectra of  $\text{H}_2$ , He,  $\text{CH}_4$  and  $\text{N}_2$ ; on the synthesis of detailed line parameters (such as frequency, strength, width, and ground-state energy) for  $\text{CH}_4$ ,  $\text{NH}_3$ ,  $\text{C}_2\text{H}_6$ ,  $\text{PH}_3$ , and their corresponding isotopes; and on the infrared and visible properties of cloud constituents (such as  $\text{NH}_3$ ,  $\text{CH}_4$ , and  $\text{H}_2\text{SO}_4$ ), which are thought to form in planetary atmospheres.

#### Reference

- G.S. Orton & A.G. Robiette, *J. Quant. Spectrosc. Rad. Transfer* 24, 81 (1980).  
N. Husson *et al.*, *J. Quant. Spectrosc. Rad. Transfer* 27, 505 (1981).

### Remote Sensing of the Atmosphere, Ocean, and Earth's Surface with UV-Visible Excimer Lasers

J.B. Laudenslager

44.40.16.04

Basic research is conducted in areas of excimer laser development and laser spectroscopy of atmospheric gases, minerals, and small, chlorophyll-containing biological organisms (phytoplanktons) in the ocean. Excimer lasers such as  $\text{XeCl}$ ,  $\text{XeBr}$ ,  $\text{KrCl}$ , and  $\text{ArF}$  are being developed along with various wavelength-shifting methods for use in remote-sensing applications.

Current research is concerned primarily with the development of these laser systems to meet the requirements of wavelength, pulse energy, and bandwidth for remote-sensing applications. Laboratory experiments are carried out using several computerized commercial high-resolution tunable-dye lasers as well as prototype excimer lasers to obtain basic spectroscopic data for the above-mentioned applications.

#### References

- T.J. Pacala *et al.*, *Appl. Phys. Lett.* 40, 1 (1982).  
I.S. McDermid & J.B. Laudenslager, *J. Chem. Phys.* 76, 1824 (1982).



**Development of an *In Situ* Measurement Method for Tropospheric Trace Gases Using Two-Color Resonant Ionization Laser Spectroscopy**

J.B. Laudenslager

44.40.15.05

A highly sensitive and selective laser analytical method, Resonant Ionization Spectroscopy, is being developed to measure trace tropospheric gases. Tunable dye lasers with doubling crystals for operation in the ultraviolet are being used initially to identify an appropriate two-color ionization method for NO and NO<sub>2</sub> under simulated tropospheric conditions. High-energy excimer lasers in the ultraviolet are also being developed for eventual field measurements of NO<sub>x</sub>. Two scanning high-resolution commercial dye laser systems, several prototype tunable excimer lasers, and a TOF mass spectrometer will be available for this research. Extension of this ionization detection method to molecules other than NO and NO<sub>2</sub> is also planned.

*Reference*

T.J. Pacala *et al.*, Appl. Phys. Lett. 40, 1 (1982).

**Chemistry of Planetary Atmospheres, Comets, and Interstellar Clouds**

W.T. Huntress, Jr.

44.40.16.06

Research is being conducted on the chemistry of planetary atmospheres, comets, and interstellar clouds. Laboratory work is concentrated in two areas. In the first area, an ion-cyclotron resonance mass spectrometer is used to examine ion-molecule reactions occurring in the atmospheres of the planets, comets, and interstellar clouds with particular emphasis on Titan. In the second area, laboratory studies are conducted in an effort to simulate the clouds in Jupiter's atmosphere and identify the coloring agents and chemical composition of the cloud aerosols. Theoretical work is also being done. Comprehensive chemical models are made of chemical evolution in interstellar clouds and of chemistry in cometary comae.

*References*

W.T. Huntress, Jr. & G.F. Mitchell, Astrophys. J., 231, 456 (1979).

W.T. Huntress, Jr. *et al.*, Astrophys. J. Suppl. Ser. 44, 481 (1980).

**Electron-Photon-Atom Interactions**

S. Trajmar

44.40.16.07

Electron collisions with laser-excited atoms (or molecules) and with atoms in high-intensity laser fields are studied in crossed electron-photon-atom beam experiments. A scanning, single-frequency, cw-dye laser is used for generating excited species for electron scattering measurements. From these measurements, cross sections and orientation and alignment parameters are deduced. A 1500-W cw-CO<sub>2</sub> laser and high-power pulsed lasers are available for electron-scattering studies in intense laser fields. These experiments are concerned with stimulated bremsstrahlung and inverse bremsstrahlung.

*References*

S. Trajmar, Science 208, 247 (1980).

D.F. Register *et al.*, Phys. Rev. Lett. 41, 749 (1978).

### Electron Impact Spectroscopy and Collision Studies

S. Trajmar

44.40.16.08

Electron-atom (molecule) collisions are studied in a beam-beam configuration. The energy and angular distribution of scattered electrons is measured individually or in coincidence with other electrons, photons, or ions. From these measurements spectroscopic information, cross sections for various collision processes related to atmospheric reactions, and insight into the basic nature of electron-atom (molecule) interactions is gained.

#### References

S. Trajmar, *Proc. Chem. Res.* **13**, 14 (1980).

D.C. Cartwright *et al.*, *Phys. Rev. A*, **16**, 1013, 1041, & 1052 (1977).

### Electron-Atom Collision Physics in the Intermediate Energy Region

S.K. Srivastava

44.40.16.09

Experimental apparatus and facilities exist for the cross-beam study of electron-atom collision processes. The interest is in the measurement of electron collision cross sections for the excitation of valence and autoionizing states, attachment, and inner-shell excitation of metal atoms. Utilizing the technique of high-energy electron scattering spectroscopy, where electrons are treated as pseudophotons, the photoabsorption spectra of various metal atoms are also being obtained.

#### References

S. Trajmar *et al.*, *J. Phys. B*, **10**, 3323 (1977).

S.K. Srivastava *et al.*, *J. Chem. Phys.* **65**, 208 (1976).

### Dissociative Electron Attachment and Ionization Studies

S.K. Srivastava

44.40.16.10

Two spectrometers are in use for the study of dissociative electron attachment and ionization for the various molecules of interest in the planetary and stellar atmospheres and lasers. Experimental results for dissociative electron attachment to O<sub>2</sub>, CO<sub>2</sub>, and SO<sub>2</sub> have been completed. A new technique has been developed to measure dissociative-attachment cross section from the vibrationally excited molecules. Opportunities exist to do basic research in these fields with the aim of their application to planetary or stellar atmospheres.

### Ultraviolet Emission Cross Sections of Gases of Astrophysical Interest by Electron Impact

J.M. Ajello S.K. Srivastava

44.40.16.11

An electron-impact excitation chamber has been fabricated for the study of emission cross sections from metal atoms and molecules of astrophysical interest over the wavelength range extending from the EUV to the visible. Studies have begun of S, SO<sub>2</sub>, and other Jovian planetary-system gases in order to emphasize the transfer of electron impact energy into excited states of the neutral and ionized atom by both direct excitation and dissociative excitation. For example, for the case of direct excitation, reactions of the type  $e + A \rightarrow A^{*+} \rightarrow A^+ + h$ , where A is an atom and A<sup>+</sup> is its ion in the

excited state, will be examined by this apparatus consisting of an electron-scattering spectrometer in tandem with a vacuum UV spectrometer. Additional facilities, including fast-coincidence circuits, exist for the measurements of life times of the excited states.

#### Physics of Electron-Ion Interactions

A. Chutjian

44.40.16.12

Experimental facilities exist for the study of the scattering of low-energy electrons from singly charged positive and negative ions. A crossed-beam geometry is currently being used. Quantities measured are inelastic differential and integral cross sections and cross sections for dielectronic recombination. Projectile ions are generated that are of planetary (OII, SII), cometary ( $N_2^+$ ,  $CO^+$ ), and stellar (MgII, AlII, CaII) interest.

Capability also exists for the study of ion scattering (in the energy range 0.3-8 keV) from neutral atomic and molecular targets of stellar and interstellar interest including charge exchange of singly and multiply charged ions. Cross sections are also measured for the energy and angular distributions of ejected, autoionized electrons following ion-neutral collisions.

#### Reference

A. Chutjian, *J. Phys. B* 14, L57 (1981)

A. Chutjian *et al.*, *Phys. Rev. Lett.* 50 1357 (1983).

#### Laboratory Interstellar Submillimeter and Microwave Spectroscopy Program

R. L. Poynter E.A. Cohen H.M. Pickett

44.40.16.13

Submillimeter and microwave spectra of both stable and transient atomic and molecular species are investigated in this laboratory research program. The program's objective is to determine the spectroscopic parameters of such species with accuracies sufficient to predict their spectral lines from the microwave through the submillimeter region. The spectral lines are employed by radio astronomers for the identification and interpretation of their observational data. Both known and likely interstellar molecules are investigated.

Computer-controlled submillimeter and microwave spectrometers are available for this research. Special absorption cells are used for the generation and study of transient atomic and molecular species. Stark, Zeeman, or source-modulation methods are employed as needed.

This program provides direct support to the galactic and extragalactic radio astronomy program and maintains a close contact with the Theoretical Astrophysics, Interstellar Chemistry, Planetary Radio Astronomy, and Thermal Infrared Spectroscopy programs.

#### Reference

H. Pickett, E. Cohen, & T. Phillips, *Ap. J. Letters* 236, L43 (1980).

#### Observations of Physical Processes in the Atmospheres of Comets

R.L. Newburn, Jr.

44.40.16.14

Comets are among the most poorly understood members of the solar system, but there is growing evidence that they originated in the outermost parts of

the solar nebula and may be composed of the most primitive material man can study. Such observations as exist are already sufficient to show considerable variation among comets in gas composition and gas-to-solids ratio and to suggest structural and age variations as well.

Since it will be impractical to launch space missions to a large variety of different comets, a program of ground-based astrophysical observations and modeling is receiving increasing emphasis at JPL. Spectrophotometry of comae and tails to give quantitative information on dust and gas production and distribution is under way, and other spectroscopic and photometric programs are contemplated. Work is carried out at JPL's Table Mountain and other observatories.

#### **High-Energy Astrophysics: X-Ray and Gamma-Ray Astronomy**

A.S. Jacobson G.R. Riegler

44.40.16.15

Research in the fields of X-ray and gamma-ray astronomy is being conducted from stratospheric balloons and satellites. Prime emphasis is on high-resolution spectroscopy in the region of 30 keV to 10 MeV using actively shielded germanium crystals. Activities encompass many areas of instrument development, observation, and data analysis connected with an observational nuclear astrophysics program involving balloon flights and a gamma-ray spectrometer in the HEAO program. Studies in EUV and X-Ray Astronomy include detector development and analysis of data from the HEAO-1 and -2 experiments. Research opportunities for theoretical studies in gamma-ray astronomy and data analysis in high-energy astrophysics are available.

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G.R. Riegler *et al.*, Astrophys. J. 225, L71 (1980).

#### **Ultraviolet Studies of Solar System Objects**

R.M. Nelson

44.40.16.16

In four years of research, the International Ultraviolet Explorer spacecraft has returned many valuable spectra of solar-system objects. The opportunity is available to reduce and analyze some of these data, particularly those of solid-surface bodies such as planetary satellites and asteroids. This opportunity will include observing with the IUE spacecraft and maintenance of the JPL IUE PDP-11 data-processing system. Opportunities also exist for laboratory spectral-reflectance measurements of possible solid-state surface components of the planetary satellites and asteroids.

#### **Solar-System Photometry and Imaging**

T.V. Johnson D.L. Matson G.J. Veeder, Jr.

44.40.16.17

This program consists of studies of the planets and the satellites through photometric observations and imaging over a wide spectral range of 0.3  $\mu\text{m}$  to 3  $\mu\text{m}$ . Equipment includes a Cassegrain scanner, a standard filter photometer, a special two-channel photometer allowing simultaneous visual and near infrared observations to be made, and the Silicon Imaging Photometer

System (SIPS), a silicon vidicon camera system which is capable of photometric imaging in a variety of modes over the spectral range 0.3  $\mu\text{m}$  to 1.1  $\mu\text{m}$ . Observations can be made at JPL's Table Mountain Observatory; in addition, facilities at other observatories are available for observers with appropriate programs.

*Reference*

T.V. Johnson *et al.*, *Proceedings of the Eighth Lunar Scientific Conference* (Pergamon, New York, 1977), p. 1029.

**Sodium D-Line Emission from Io**

D.L. Matson R.W. Carlson G.J. Veeder, Jr. 44.40.16.18  
T.V. Johnson D.B. Nash

Io, the innermost of the Galilean satellites of Jupiter, exhibits remarkable properties. Active volcanoes are continually renewing its surface. Io's morphology clearly shows that it has had a history of quite a different nature from those of other solar-system bodies. Geologically it is at present the most active "planet." Io has the highest reflectivity of any object in the solar system, yet it shows none of the prominent absorption bands of frosts or hydrated minerals. Furthermore, this satellite is surrounded by an extensive cloud of neutral sodium and other atoms, which emit at their characteristic atomic wavelengths. Opportunities exist for collaborative work on (1) the origin of sodium and the mechanism(s) of its removal from Io's surface; (2) the role played by Io's volcanoes, atmosphere, and ionosphere; (3) observation of atomic species about Io; and (4) the interactions between Io, the atomic clouds, and the Jovian magnetosphere. Our future investigations are expected to involve theoretical calculations, telescopic observations, and laboratory studies of candidate Io-surface materials.

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D.L. Matson *et al.*, *Science* 199, 531 (1978).  
R.W. Carlson *et al.*, *Astrophys. J.* 223, 1082 (1978).

**Experimental Studies on Meteorites and Sputtering**

S.R. Rajan D.L. Matson T.V. Johnson 44.40.16.19  
G.J. Veeder, Jr. D.B. Nash

Experimental studies on meteorites relating to the regolithic processes on meteorite parent bodies, radiation history in the early solar system, and the origin of meteorites are being conducted. Emphasis is given to understanding the meteorological evidence bearing on the interrelationships between asteroids, meteorites, and comets. Opportunities exist in (1) nuclear track studies for determining preatmospheric sizes, spectra, and composition of heavy nuclei in ancient solar flares; (2) formation, compaction, and brecciation ages of carbonaceous and gas-rich meteorites; (3) characterization and comparison of the regoliths on various meteorite parent bodies and relevance to theoretical modeling; (4) measurement of isotopic ratios using nuclear reactions to determine the origin and diffusion effects in refractory inclusions from carbonaceous chondrites; and (5) theoretical and laboratory studies of

sputtering in order to evaluate its role throughout the solar system — Moon, meteorites, atmospheres of Mercury and Mars, the surface of Io, rings of Saturn, etc.

#### **Geologic Mapping of Solar-System Bodies by Remote Sensing**

D.L. Matson    T.V. Johnson    44.40.16.20  
R.S. Saunders    A.E. Metzger

This opportunity involves theoretical, observational, and data-analysis investigations of the geological units on planetary surfaces. Data-analysis studies involve use of telescope and spacecraft data and require the techniques of image processing and data-base management. The theoretical investigations are largely limited to the study of the relationships of the various remotely sensed quantities to the physics and chemistry of minerals and rocks. We have applied these methods of investigation to the Moon, Mars, the Galilean satellites of Jupiter, and the satellites of Saturn. Work will be extended to other bodies as soon as the appropriate data become available.

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B.A. Smith *et al.*, *Science* 215, 504 (1982).  
A.E. Metzger *et al.*, *Proceedings of the Tenth Lunar and Planetary Scientific Conference* (Pergamon, New York, 1979), p. 1719.

#### **Radio Astronomy - Planetary**

S. Gulkis    M.A. Janssen    M.J. Klein    44.40.16.21

The planetary radio astronomy group is actively pursuing a variety of theoretical and observational research programs whereby radio astronomical techniques are applied to current problems in solar-system physics and astronomy. Opportunities exist for participation in several ongoing programs that include spectroscopic and continuum studies of (1) the atmospheres and surfaces of solar-system planets and their satellites, (2) the radiation belts and magnetospheric environment of Jupiter, and (3) the chemical composition and temperatures of comet nuclei. Observational facilities include the 26-m, 34-m, and 64-m antennas of the NASA Deep Space Network. Guest observations are also conducted with facilities at the Caltech Owens Valley Radio Observatory and national observatories including the NRAO. The emphasis for future programs is focused on the development of a comprehensive observational capability for planetary studies at short-millimeter and submillimeter wavelengths from ground-based and airborne observations using receiving systems developed at JPL.

#### **Radio Astronomy - Galactic and Extragalactic**

S. Gulkis    T.B.H. Kuiper    44.40.16.22

This research focuses on spectroscopic and/or continuum studies of (1) stellar and galactic evolution including the chemistry and evolution of dense clouds, star formation, pre-main-sequence, and post-main-sequence mass loss; and (2) precision measurements of the positions of galactic and extragalactic radio sources. In the stellar evolution program, emphasis is placed on

observations of galaxies and interstellar and circumstellar clouds from ground-based and airborne platforms using JPL equipment. Facilities of the NASA Deep Space Network are used for continuum and spectral-line observations. A two-element interferometer, which consists of a 26-m and 64-m antenna, is operating at 13-cm wavelength at the DSN tracking station in Australia. Various millimeter and submillimeter receivers capable of airborne astronomy exist or are under development. The Galactic and Extragalactic radio astronomy program maintains close contact with the Laboratory Interstellar Spectroscopy program, the Theoretical Astrophysics program, and the Interstellar Chemistry program. Proposals combining one or two of these areas with observations are also welcome.

#### **Asteroid Studies**

D.L. Matson T.V. Johnson

44.40.16.23

A.W. Harris G.J. Veeder, Jr.

A wealth of information about the composition of asteroid surfaces has become available as a result of recent observational theoretical work. We are interested in the outstanding cosmochemical problems posed by the different types of asteroidal surface compositions and the resulting implications for the evolution of other solar-system objects. Opportunities exist in (1) participation in ongoing programs of asteroid photometry and spectrophotometry using ground-based astronomical telescopes and Earth-orbiting spacecraft; (2) laboratory-simulation studies; and (3) theoretical study of composition and process models using published optical data on asteroids, meteorites, and other laboratory samples.

#### *References*

G.J. Veeder *et al.*, *Astron. J.* **83**, 651 (1978).

D.L. Matson *et al.*, *Proceedings of the Seventh Lunar Scientific Conference* (Pergamon, New York, 1976), p. 3603

#### **Outer Planets Spectroscopy**

J.T. Bergstralh T.V. Johnson

44.40.16.24

Spatially resolved spectroscopic and photometric measurements of sunlight reflected from the outer planets provide information on the chemical composition and vertical stratification of clouds and the properties of aerosol hazes within the upper tropospheres of these planets. Observations in the spectral region dominated by reflected sunlight (about 3000 Å to 3 μm) complement the technique of thermal-IR sounding, since the shorter wavelengths are more sensitive to the scattering characteristics of aerosol particles. We are conducting theoretical modeling studies of radiative transfer in the atmospheres of the outer planets, as well as observation studies of limb darkening and spatial variations of molecular absorption features in their spectra.

#### **Planetary Geology and Geomorphology**

R.S. Saunders

44.40.16.25

Studies of the Earth and planetary surfaces will be performed with emphasis on comparative analysis to understand physical processes shaping these

surfaces. The approach should stress synthesis and may include field studies and the use of images (visible, infrared, radar), spectral properties, geochemical data, gravity and magnetic field data, and topography. Ongoing research includes field studies of eolian and fluvial processes and the evolution of volcanic landforms, theoretical geomorphology analysis of radar images of terrestrial and Venusian scenes; studies of Martian channels using Mariner and Viking data, studies of erosional processes operating early in Martian history, and glacial studies of the geomorphology of the Galilean satellites using Voyager data.

#### **Theoretical Studies of Solar-System Origin and Evolution**

W.R. Ward A.W. Harris

44.40.16.26

A fundamental shortcoming of present scenarios of solar-system origin is the inability to match expected outcomes of star formation with the initial state of the solar nebula as inferred by "dismantling" the present bodies of the solar system into a protoplanetary cloud. The gap in understanding is further obscured by our limited knowledge of the long-term evolution of the planetary system — that is, variations in the orbital and rotational characteristics of the planets that may have occurred in 4.5 b.y., thus confusing our ideas of the primordial state of the solar system. Opportunities exist for theoretical studies of hydrodynamics, collision dynamics, and orbital and rotational dynamics aimed at closing this gap in our understanding of planetary information.

#### **Physical and Dynamical Evolution of Comets**

P.R. Weissman

44.40.16.27

Comets are probably the best obtainable source of original material from the primordial solar nebula. Understanding the physical nature of the cometary nucleus and the dynamical evolution of cometary orbits can thus be of significant value in learning about the origin of the planetary system. Also, studies of cometary impacts have interesting implications for surface morphology, planetary-volatiles inventories, and the possible role of impacts with regard to biological extinctions. The emphasis in this program is on theoretical studies through computer modeling of the dynamical evolution of long- and short-period comets, using both integrated and Monte Carlo techniques, and computer modeling of the sublimation of volatiles on the surfaces of cometary nuclei. Current areas of study include the origin and evolution of the Oort cometary cloud; the role of planetary, stellar, and nongravitational perturbations in the evolution of cometary orbits; the flux and mass distribution of comets passing through the planetary region; and volatile and nonvolatile production rates for both known and hypothetical cometary nuclei.

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P.R. Weissman & H.H. Kieffer, *Icarus* 47, 302 (1981).



### **Lunar and Planetary Gamma-Ray Spectroscopy**

A.E. Metzger

44.40.16.28

Gamma-ray measurements are capable of identifying the composition of rocks and soils, particularly when these have been exposed to cosmic-ray bombardment. The technique was utilized in the Apollo program to map 20% of the Moon's surface from orbit. Some half-dozen elements have been isolated, and the results have contributed to the current understanding of the nature and evolution of the lunar crust and maria. A computer technique has been developed to improve spatial resolution. At the same time, studies and experimental programs are under way to support the development of an advanced instrument for future space flights to Mars, the Moon, comets, and asteroids. Opportunities exist for (1) analysis of lunar gamma-ray data and the implications for lunar origin and evolution, (2) conduct and analysis of accelerator experiments designed to simulate cosmic-ray induced gamma-ray emission, (3) incorporation and utilization of a supplemental neutron mode through laboratory and theoretical studies, and (4) climatological effects on Mars in terms of their modulation of the emitted gamma-ray flux.

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E.L. Haines & A.E. Metzger, *Proc. Eleventh Lunar and Planetary Sci. Conf.* (Pergamon, New York, 1980), p. 689.

### **Planetary X-Ray Spectroscopy**

A.E. Metzger

44.40.16.29

Planetary objects may emit X-rays by secondary solar excitation or through plasma interactions if the object possesses an inherent magnetic field. Observations and X-rays from planetary magnetospheres and surfaces relate to the location, nature, and degree of these processes. Characteristic X-ray emission lines carry information on the composition of a planetary surface, atmosphere, or plasma. The first detection of such a flux from Jupiter has recently taken place. A continuing observational program is anticipated.

#### *Reference*

- A.E. Metzger *et al.*, *J. Geophys. Res.*, to be published (1983).

### **Gravity-Wave Detection by Spacecraft Tracking**

H.D. Wahlquist F.B. Estabrook

44.40.16.30

The detection of VLF gravitational radiation by precision Doppler tracking of interplanetary spacecraft is being pursued. The effect of gravity waves on the Doppler signal is known, and possible astrophysical sources for VLF gravitational radiation have been suggested. Proposals have been accepted by NASA to conduct searches for gravity waves on interplanetary missions to be launched in the early 1980's. Studies are now under way to determine the instrumental accuracy and frequency stability requirements, the noise interference problems resulting from propagation of the Doppler signal through various media (interplanetary plasma, ionosphere, troposphere, etc.) and the data analysis and reduction algorithms to optimize detection based on the characteristic signature of the Doppler response to gravity waves.

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#### Applied Mathematics

F.B. Estabrook H.D. Wahlquist

44.40.16.31

New methods are being developed for analytical solution of sets of nonlinear partial differential equations — in particular for understanding the nonlinear waves and solitons that occur in plasmas, superconducting transmission lines, "freak" ocean waves, and solid-state lattices. These methods use modern differential geometry, Lie-group theory, and the Cartan calculus of differential forms to derive prolongation structures and inverse scattering equations, and to discover invariance properties and Backlund transformations.

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#### Space-Plasma Physics

M.M. Neugebauer B.E. Goldstein

44.40.16.32

Research in the area of space plasmas centers on the physics of the solar wind and on the interactions of the solar wind with the planets and comets. Collaborative design work on a high-energy ion mass spectrometer for the Giotto mission to Halley's comet is under way. A mission involving a close approach to the sun is part of JPL's future plans. Studies related to turbulence and waves in the solar wind, or cometary plasma interactions, are of particular interest.

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M.M. Neugebauer *et al.*, *Rev. Sci. Instrum.* 53, 277 (1982).

#### Interplanetary and Planetary Magnetic Fields

E.J. Smith B.T. Tsurutani

44.40.16.33

Magnetic field measurements are available in interplanetary space from 1 to beyond 10 AU (ISEE-3, Pioneer 10, Pioneer 11). Studies are being carried out to determine the average properties, large-scale structure, and dynamics of the magnetized solar wind in the outer solar system and their dependences on the solar cycle. Magnetic-field data acquired near Jupiter and Saturn are being used to study the planetary fields, the magnetospheres of the planets, and their interaction with the solar wind.

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E.J. Smith *et al.*, *J. Geophys. Res.* 85, 5655 (1980).

#### Magnetospheric and Interplanetary Plasma Waves

B.T. Tsurutani E.J. Smith

44.40.16.34

Plasma waves are being studied in the Earth's magnetosphere and magnetotail and in interplanetary space using measurements of fluctuating magnetic and

electric fields. Data are available from ISEE-1, -2, and -3 in the frequency range from 5—10,000 Hz (magnetic fields) and from 5 Hz to 310 kHz (electric fields). Magnetic field measurements (1—1000 Hz) are also available from OGO-6 in a low-altitude polar orbit. The data are used to study the origin and modes of propagation of the plasma waves and their interaction with charged particles.

#### References

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B.T. Tsurutani & E.J. Smith, *J. Geophys. Res.* 82, 5112 (1977).

### Stratospheric Chemistry

W.B. DeMore

44.40.16.35

The principle thrust of this research is study of chemical kinetics and photochemistry as related to the Earth's atmosphere. Particular emphasis is placed on the influence of man-made pollutants on the stability of the ozone layer. A considerable array of experimental apparatus is being used for direct measurements of chemical rate constants, including flow-discharge systems coupled to mass-spectrometric and resonance-fluorescence/absorption-monitoring devices. Studies of fundamental photochemical processes relevant to the stratosphere are also conducted, as well as photoequilibrium measurements of simulated stratospheric systems.

### Atmospheric Kinetics and Photochemistry

R.T. Watson

44.40.16.36

Several advanced kinetic techniques are utilized to investigate the homogeneous kinetic behavior of atoms and free radicals that control the chemistry of the troposphere, stratosphere, and mesosphere. Low-pressure discharge-flow and high-pressure flash-photolysis systems are interfaced to a variety of detection techniques that include molecular beam mass spectrometry, resonance fluorescence, resonance absorption, and UV-VIS spectrophotometry. Atoms and radicals of particular interest are H, OH(<sup>2</sup>K), HO<sub>2</sub>, Cl, ClO(<sup>2</sup>II), Br, BrO(<sup>2</sup>II), F, FO, O(<sup>1</sup>P), CH<sub>3</sub>OO, NO<sub>3</sub>, and HOSO<sub>2</sub>. In addition, the techniques of laser-induced fluorescence and laser flash photolysis are used for kinetic and spectroscopic experiments.

### Atmospheric Sensing with Infrared Laser Techniques

R.T. Menzies

44.40.16.37

The development of tunable laser techniques for spectroscopy and remote measurement of atmospheric gases is a continuing interest. Laboratory spectral studies are conducted to supply data for use in various remote-sensing applications. Various laser spectroscopy techniques are used including heterodyne, aptogalvanic, and optoacoustic processes. The current atmospheric measurement program includes the use of tunable lead-salt diode lasers for the measurement of stratospheric species that play important roles in stratospheric photochemistry. Studies of vertical profiling techniques using

radiative transfer and differential absorption calculations are also being conducted. The program also includes the development of laser radar techniques for use in differential absorption or Doppler modes and for the measurements of gases, aerosols, and winds in the lower atmosphere.

#### **Infrared Atmospheric Remote Sensing/Laboratory Spectroscopy**

J.S. Margolis R.A. Toth L.R. Brown 44.40.16.38

Determination of the concentrations of minor gases at various altitudes in the Earth's atmosphere is of considerable importance in meteorology, pollution, and photochemistry. For such determinations,  $0.01\text{-cm}^{-1}$  resolution interferometers are flown in balloons and the Space Shuttle to record the atmospheric spectrum in the 2-to-16  $\mu\text{m}$  region. These data are analyzed at the ATMOS (Atmospheric Trace Molecule) computing facility using a Prime minicomputer.

Interpretation of such data requires accurate knowledge of line positions, line strengths, and line widths of different vibration-rotation bands of atmospheric molecules. For this purpose, laboratory spectra are recorded with the  $0.005\text{-to-}0.01\text{ cm}^{-1}$  resolution interferometer at Kitt Peak National Observatory, with a  $0.004\text{-cm}^{-1}$  resolution Bohem interferometer at JPL, and a tunable diode laser facility at JPL. Recent studies include analyses of  $\text{N}_2\text{O}$ ,  $\text{NO}_2$ ,  $\text{CH}_4$ , and  $\text{HDO}$ .

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R.A. Toth & J.W. Brault, Appl. Opt. 22, 908 (1983).

#### **Microwave Remote Sensing of Earth's Upper-Atmospheric Phenomena**

J.W. Waters 44.40.16.39

Microwave techniques at millimeter wavelengths are presently being used for ground-, aircraft-, and balloon-based measurements to improve our understanding of Earth's upper atmosphere. Programs planned for the future include spacecraft-based measurements. The spectral range of the measurements will also be extended to submillimeter wavelengths. Research opportunities are available in measurement and data-interpretation programs, instrument development, and atmospheric physics.

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J.W. Waters *et al.*, Science 214, 61 (1981).

#### **Millimeter and Submillimeter Spectroscopy of Stratospheric Molecules**

E.A. Cohen H.M. Pickett 44.40.16.40

This laboratory program provides basic millimeter and submillimeter spectroscopic data of molecules of stratospheric interest. It directly supports a field-measurement program that detects stratospheric constituents by their millimeter and submillimeter thermal radiation. Parameters to be measured are line frequencies, line widths, and dipole moments. Molecular parameters must be determined with sufficient accuracy for prediction of spectra throughout the submillimeter region.

Obtaining and analyzing spectra of transient species and free radicals of importance in stratospheric chemistry is another important objective of this program. Two computer-controlled spectrometers are available for this research with coverage from the microwave to well into the submillimeter region. Plans are being made to use far-infrared laser techniques above 1000 GHz. Flow discharge, photolysis, and pyrolysis cells are being used to generate transient molecules. Techniques using eximer-laser photolysis are being developed. Research opportunities exist in submillimeter spectroscopy and transient molecule generation.

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### Theoretical Studies of the Planetary Upper Atmosphere

S.S. Prasad

44.40.16.41

The goal of this program is to understand the present state and the past evolutionary history of planetary upper atmosphere, including the stratosphere, mesosphere, and thermosphere. Present emphasis is on the atmospheric chemistry driven by energetic charged-particle precipitation and by the solar resonant excitation of metastable species. Examples of the problems currently under study are (1) synthesis of complex molecules on Titan by the absorption of cosmic rays and solar UV, (2) abiogenic formation of nitrous oxide in the Earth's atmosphere, and (3) auroral electron interaction with the atmosphere and its implication for backscattering and bremsstrahlung X-ray generation. Past atmospheric conditions on Venus and Titan are also being investigated under this program. One-dimensional and two-dimensional photochemical-dynamical models are employed, but our emphasis is not so much on model development as on studying individual atomic and molecular processes in their relation to the atmosphere. This research program maintains close contact with other JPL programs devoted to laboratory kinetics and remote sensing. Possibilities for collaborative research with interested scientists at Caltech and nearby NASA/Ames Research Center also exist.

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S.S. Prasad, *Nature* 289, 386, (1981).

### Theoretical Studies of Chemistry in Interstellar and Stellar Environments

S.S. Prasad M.M. Litvak W.T. Huntress, Jr.

44.40.16.42

With the discovery of many complex organic molecules in dense interstellar clouds, the study of molecular astrochemistry has become an important part of astrophysics and space science. The objectives of this research are (1) to understand the formation and chemistry of molecules by gas-phase ion-molecule and neutral-neutral reactions in interstellar clouds and circumstellar envelopes, (2) to study the effects of chemistry on gravitationally collapsing clouds where stars are expected to form, and (3) to predict the chemical

composition in regions behind shock fronts. Building on previous work related to simple molecules, we are extending our method to the problem of complex molecule formation, such as long-chain hydrocarbons and organic aldehydes, acids, amines, and nitriles, that have been observed in dense clouds. Spectroscopic observations have strongly suggested the presence of shock waves in a number of astrophysical environments where enhanced density and temperature will lead to a significant influence on chemistry. This program is carried on in close concert with observational molecular radio astronomy, laboratory measurements of ion-molecule reactions, and microwave spectroscopic measurements of candidate interstellar species.

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#### Infrared Emission from Comets

M.S. Hanner

44.40.16.43

Cometary infrared emission contains information on the nature of the dust grains, as well as the thermal properties of the nucleus and the rate at which material is being emitted from the nucleus. Thermal emission by solid grains is being modeled, based on measured optical constants of minerals likely to be present in cometary dust. The models are compared with infrared photometry of comets, in order to derive the composition, size distribution, and flux of emitted dust. The techniques used for analysis are similar to those applied to the study of circumstellar dust clouds. Particle dynamics and the thermal properties of the nucleus are also considered. The results of the theoretical studies will be applied to the design of instrumentation for future space observations of comets.

#### Reference

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#### Imaging-Radar Hydrology/Urban Morphology and Land Cover

M.L. Bryan

44.40.16.44

L-Band, X-Band aircraft data coupled with Landsat and Seasat remotely sensed digital data are being studied to improve the understanding and mapping of hydrologic features (drainage-basin analysis, flooding, flood-plain mapping) and of urban morphology (land-cover analysis). The approaches utilized in these efforts concern visual and machine analysis of remotely sensed data and modeling of the land scene with respect to microwave backscatter. It is proposed that Shuttle Imaging Radar data and airborne scatterometer data be collected during the next year to provide a wider base for analysis. The study area for the urban work is the Los Angeles, California, basin and environs; for the hydrologic work, the study areas are located primarily in the United States and concentrate on the use of Seasat Synthetic Aperture Radar. Opportunities exist for the development of interpretation

keys, automatic data-processing procedures, and comparative analysis of remotely sensed data in these two discipline areas.

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**Imaging-Radar Geology/Planetology**

C. Elachi

44.40.16.45

Research is ongoing in the analysis of spaceborne and airborne radar imagery of selected geologic regions in the United States and Central America. Emphasis is on the applicability of spaceborne imaging radar for geologic mapping including structural and lineaments mapping, rock-type identification, roughness-units classification, and mapping in heavily vegetated regions. Work also includes comparative analysis of Landsat, Seasat, and SIR-A data. Strong emphasis is also on the development of data-base and interpretation techniques for future planetary missions such as Venus Mapper and Earth orbiting missions such as SIR (Spaceborne Imaging Radar) and free-flying SAR.

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J. Ford, *AAPG Bulletin*, 64, 2064 (1980).

**Imaging Radar for Geologic Mapping in Continuously Vegetated Environments**

J.P. Ford

44.40.16.46

Because of the inherent inability of making direct geological observations of the surface in heavily vegetated environments, it is essential to understand the responses of different imaging remote sensors at microwave (radar), infrared, and optical wavelengths that provide the most structural and lithologic information. Primary image data sets include SIR-A, Seasat SAR, Landsat MSS, RBV, and TM. Multiple-incidence SIR-B data are scheduled for acquisition by mid-1984. Analyses are in progress using corresponding radar and optical/infrared data sets of densely vegetated localities in the Caribbean, South America, Southeast Asia, Indonesia, etc. Research includes the use of digital image-processing techniques, spatial coregistration of different data sets, and determination of their relative contribution to geologic mapping. Image analyses are corroborated through field checking.

*Reference*

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**Microwave Remote Sensing of Atmospheric Pressure**

D.A. Flower

44.40.16.47

A multifrequency, active-millimeter-wave instrument is being designed to measure atmospheric pressure at the Earth's surface from an orbiting satellite. Although atmospheric temperature, water-vapor content, and other meteorological parameters are routinely measured over the whole globe from space,

we rely on an inadequate network of ground stations for surface-pressure data. Ground stations have also historically served as the basis for synoptic weather forecasting. Active microwave instruments are just beginning to find applications in remote sensing, and this technique imposes exacting demands on established microwave technology. Research opportunities are available in both the scientific and engineering aspects of this program.

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### Microwave Remote Sensing of Meteorological Parameters

R. Kakar

44.40.16.48

Microwave remote-sensing experiments for use on the Space Shuttle and advanced Earth-observation satellites are being considered for measuring various parameters of meteorological interest. These experiments use concepts developed for previous microwave experiments but will provide much greater spatial resolution and range of wavelengths than have been available previously. Phenomena to be studied include variability in atmospheric temperature and moisture content, storm development, and boundary-layer phenomena near the ocean surface. An advanced microwave sounding experiment is currently being considered for use on future operational meteorological satellites. Challenging problems exist both in the design of the instrumentation and the scientific interpretation of the measurements. Research opportunities of either a scientific or engineering nature are available.

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### Microwave Remote Sensing of Surface Parameters

E.G. Njoku

44.40.16.49

Recent Earth-observation satellite experiments using microwave radiometry have shown the feasibility of measuring a variety of surface geophysical parameters from space. These include oceanographic parameters (sea-surface temperature, wind speed), land parameters (soil moisture, snow cover, vegetation), and polar-region parameters (sea ice, glaciers). Research is in progress to refine data-interpretation techniques for existing satellite instruments (Seasat and Nimbus-7) and to improve surface-emission models as a basis for future Shuttle or satellite experiments (e.g., DMSP microwave radiometer). Opportunities also exist for applications of satellite radiometer data to a variety of oceanographic and climate problems.

#### References

- E.G. Njoku & J.A. Kong, *J. Geophys. Res.* 82, 3108 (1977).  
E.G. Njoku *et al.*, *IEEE J. Oceanic Eng.* OE-5, 100 (1980).



### **The Geophysics of Remote Sensing**

A.B. Kahle

44.40.16.50

A program is underway to develop techniques for utilizing data acquired by remote sensing of the Earth's surface. The emphasis is on geology, including lithologic and structural mapping, mineral location, and soil moisture mapping. Rather than concentrating on a limited spectral region, the study will combine data from measurements of reflected solar radiation in the visible and near infrared with thermal infrared and active and passive microwave data. The approach includes theory, modeling, and interpretation of satellite, aircraft, field, and laboratory measurements.

Numerous geophysical problems involving reflection and emission spectroscopy of natural surfaces, atmospheric effects, meteorological effects, ground moisture, thermal and microwave properties of materials, and effects of local topography and vegetation are of interest.

### **Geologic Applications of Remote Sensing**

A.F.H. Goetz

44.40.16.51

A program is under way to apply remote-sensing techniques to problems in the earth sciences, including mineral exploration, and lithologic and structural mapping. Initial work was primarily with LANDSAT data, but multispectral data from many satellite and aircraft systems, spanning the spectrum from visible through thermal infrared to active and passive microwave, are now being utilized.

In addition to computer enhancement of the remotely sensed data, the program involves a good deal of field work with a variety of specially devised sensors, and laboratory work on samples brought back from the field.

Primary interest in these studies is in using remotely sensed data in one or more of the following areas: economic geology, structural geology, planetary evolution, mineralogy, geochemistry, and statistical techniques of data analysis.

### **Remote Sensing Applied to Economic Geology Exploration Problems**

M.J. Abrams

44.40.16.52

A program is ongoing to evaluate applications of remote-sensing technology to problems of nonrenewable-resource exploration. Current projects are concentrating on representative test sites for porphyry copper deposits, sedimentary uranium deposits, and hydrocarbon deposits. Future projects will examine porphyry molybdenum and ultramafic associated chromium deposits. The projects involve substantial field work with a variety of specially designed instruments, and examination of a wide range of remote-sensing data spanning the spectrum from visible, infrared, near-infrared, and thermal infrared, through active and passive microwave. Primary goals of these projects are to evaluate the utility of operational and experimental remote sensing data for exploration problems and to provide recommendations for future aircraft and satellite systems. Applicants should have strong back-

grounds in one or more of the following fields: economic geology, structural geology, statistical data analysis techniques, and remote sensing.

#### **Geobotanical Applications of Remote Sensing**

B.N. Rock

44.40.16.53

An ongoing research program is being conducted in geobotany, utilizing remotely sensed vegetation data for discrimination and mapping of native (nonagricultural) species and/or species associations, as well as for detection of the state of health (i.e., identification of stress symptoms) of actively growing vegetation. The multispectral data used include those acquired in the visible through the near- and short-wave infrared (0.40—2.50  $\mu\text{m}$ ) and selected regions of the thermal infrared (3.0—5.0  $\mu\text{m}$  and 8.0—14.0  $\mu\text{m}$ ). Detailed laboratory and field studies are conducted for the purpose of comparison with data acquired from aircraft and satellite. Active field sites are located in both the eastern and western portions of the United States.

Primary interest in these studies is in determining the structural (leaf anatomy and morphology), chemical (pigment systems), physiological, and geometric (canopy form and/or leaf-orientation) basis for interpretation of plant spectral data. Applicants should have a strong background in botany (such as plant anatomy and/or physiology). Some background in soil science or geology would also be valuable.

#### **The Search for Extraterrestrial Intelligence**

S. Gulkis T.B.H. Kuiper E.T. Olsen

44.40.16.54

A modest R&D effort using existing radio telescopes and prototype advanced digital systems is being pursued to develop and articulate exploratory strategies for the detection of a broad range of possible microwave signals. A significant aspect of the work is the development and evaluation of search strategies, including target selection and optimal search techniques.

Proposals are welcome including, but not necessarily limited to, search strategy, signal recognition, avoidance of radio frequency interference, and the design of hardware and software for data analysis.

#### **References**

- S. Gulkis *et al.*, *Strategies for the Search for Life in the Universe* (D. Riedel, Boston, 1980), p. 93.  
B.C. Murray *et al.*, *Science* 199, 485 (1978).

#### **Application of Remote-Sensing Methods to Exploration for Nonrenewable Resources**

J.E. Conel

44.40.16.55

Research positions are available to investigate application of remote-sensing methods to exploration for important mineral commodities along the following lines: (1) existing mineral-exploration models need to be modified and updated to include information derived from remote sensing methods, e.g., rock-type mapping, patterns of alteration, patterns of vegetation and/or vegetation stress; (2) empirical studies of the chemical composition and spectral-

reflectance properties of alteration associated with uranium, porphyry copper, molybdenum, chromite deposits, hydrocarbon seepage, and associated effects in vegetation; (3) empirical experimental and synthetic chemical studies related to spectral-reflectance effects introduced by trace quantities of elements in common alteration minerals. Many of these opportunities will involve field work.

#### **Infrared Astronomy on IRAS**

H.H. Aumann

44.40.16.56

The primary objective of the Infrared Astronomy Satellite (IRAS) is to produce a survey of the sky in four broad photometric channels between 8  $\mu\text{m}$  and 120  $\mu\text{m}$ . In addition to the "survey mode", the sensors on IRAS can be used in an "observatory mode" to study selected galactic and extragalactic sources of interest. The IRAS spacecraft was launched in January 1983 with a predicted lifetime of 10 months in orbit.

Opportunities exist for participation in the ground-based science-data analysis of survey data and the planning and analysis of additional observations taken in the survey mode or in the observatory mode.

#### **References**

J. Br. Interplanet. Soc. 36, 1 (1983). [This special issue is devoted entirely to IRAS.]

J. Duxbury & B.T. Solfer, Soc. Photo-Opt. Instrum. Eng. 264, 81 (1980). See also pp. 89 and 95.

#### **Microwave Methods in Sea-Ice and Oceanography Research**

F.D. Carsey R.H. Stewart

44.40.16.57

Active and passive microwave observations of the surface of the frozen and liquid ocean are currently made by satellite and aircraft instruments. Interpretations of fluxes of heat, mass, and momentum; ice motion, extent, and type; and currents, waves, and topography are made with different levels of confidence. The actual parameter extracted from the satellite record is rarely precisely that required by the oceanographer or climatologist, with the consequence that the application of these results to advancing our knowledge of the ocean is a complex task. The area of greatest present opportunity is in applying satellite data to specific modest-scale geophysics problems to demonstrate the utility of the data set, to test the overall value of existing data systems, to define optimum future systems, and to learn something about the ocean.

#### **Radar Remote Sensing of Waves, Winds, and Currents**

A. Jain

44.40.16.58

The research activity consists of developing techniques using radar systems to determine wave spectra, winds, and current-velocity profiles from airborne or spaceborne platforms. These include the Synthetic Aperture Radar, Scatterometer, Altimeter, and Doppler Radar systems. Verification of these techniques using SEASAT and aircraft data and application to oceanographic science and engineering problems is also a major thrust for this effort.

Previous work has been done on developing a theoretical model for imaging of ocean waves by the Synthetic Aperture Radar, analysing SEASAT data and data from field experiments to determine empirically the effects of environmental conditions on SAR wave imaging, developing an interferometric technique to measure wave heights from SAR data, and developing techniques to determine current velocities from the Doppler spectra of SAR data.

#### **Atmospheric Chemistry and Chemical Kinetics**

M.J. Molina

44.40.16.59

This research focuses on the study of chemical and photochemical reactions of atmospheric importance. New detection techniques are being developed in the laboratory to directly monitor reaction intermediates using equipment such as ultraviolet and Fourier-transform infrared spectrophotometers and tunable lasers coupled to flash-photolysis and fast-flow systems. Species of interest include OH, ClO, HO<sub>2</sub>, HO<sub>2</sub>NO<sub>2</sub>, HOCl, and HOSO<sub>2</sub>. Theoretical work on the interpretation of the results is also being carried out.

#### **The Physical Properties of Cometary Nuclei**

Z. Sekanina

44.40.16.60

The goal of this research is the understanding of the physical nature of a cometary nucleus. Because of the recognized diagnostic properties of the ejected dust, the investigation of a broad range of dust phenomena and their evolution in cometary atmospheres and tails is considered an integral part of the nucleus studies. The major objectives are (1) the nucleus structure and surface morphology, (2) the physical heterogeneity as a function of the spin vector, (3) evidence on the outgassing asymmetry and the identification of discrete dust-emission regions, (4) the nucleus precession and its long-term evolution, (5) the mechanical strength of cometary material on macroscopic and microscopic scales, (6) fragmentation and sublimation of refractory particles in the cometary atmospheres and tails, (7) the role of dust in cometary activity, (8) and the relationship between the observed dust phenomena and the expected properties of the particle-ejection mechanisms.

To address these objectives, a broad variety of techniques is applied ranging from dynamical studies of the split comets to photometric modeling of dust phenomena to methods of meteor physics. The emphasis is on a comparison of theory with interpretable observations of comets and on the characterization of the environment to assist the *in situ* investigations of comets.

#### **References**

- Z. Sekanina, *Annu. Rev. Earth Planet. Sci.* 9, 113 (1981).  
A. Sekanina & J.A. Farrell, *Astron. J.* 87, 1836 (1982).

#### **Chemical Kinetics and Photochemistry of Planetary Atmospheres**

M.T. Leu

44.40.16.61

This laboratory program is intended to provide the key kinetic and photochemical data used for atmospheric modeling in planetary atmospheres. A

low-pressure discharge-flow system is interfaced with a variety of detection devices such as mass spectrometry, resonance fluorescence apparatus, and infrared emission detector. High-pressure steady-state photolysis systems, incorporated with both a laser-induced resonance fluorescence apparatus and a high-resolution infrared interferometer, are also available for atmospheric mechanism analysis. Collaboration with modelers to analyze field measurement data is encouraged.

## Systems Division

### Satellite-Systems Dynamics

J.H. Lieske

44.40.85.01

This program consists of studying the motions of outer planet natural satellites to improve the knowledge of physical and dynamical parameters describing these complex systems. Physical parameters include size and shape of these bodies, and dynamical parameters include planet and satellite masses, lower-order zonal harmonics, spin-axis orientations, rotational rates, and ephemerides. Analytic theories would be used to model the motions of these systems for processing classical and modern positional observations. Classical observations would include conventional eclipse and photographic data, while modern observations would include photoelectric, radar, and Voyager spacecraft data. The program is concentrating primarily on the Galilean satellites of Jupiter and the major satellites of Saturn and Uranus.

#### References

- J.H. Lieske, *Astron. Astrophys.* 56, 333 (1977).  
J.H. Lieske, *Astron Astrophys.* 82, 340 (1980).

### Experimental Relativity

J.D. Anderson R.W. Hellings E.M. Standish, Jr. 44.40.85.02

Solar-system experimental tests of relativistic gravity are being conducted in several areas. First, tests of relativistic theories of gravity are being performed by fitting a variety of astrometrical data types to a computer model of solar-system orbital dynamics. In particular, we are currently solving for PPN parameters, the Nordtvedt effect, and for a time variation of  $G$ , as well as certain important Newtonian parameters such as planet gravity fields, asteroid masses, etc. Second, a search for a cosmic background of gravitational radiation is being performed by looking for effects in Doppler tracking of spacecraft and for secular perturbations in two-body orbits. We are also engaged in a related theoretical study of gravitational-radiation-dominated cosmologies. Finally, we are generally interested in new ideas for future relativity experiments, both in space and in the laboratory, and are actively studying several of these.

#### References

- J.D. Anderson *et al.*, *Astronautica* 5, 43 (1978).  
R.W. Hellings *et al.*, *Phys. Rev. D* 23, 844 (1981).

## Telecommunications Science and Engineering Division

### Remote Sensing with Radio and Acoustic Scintillations

R. Woo

44.40.95.01

Research is being conducted using the scintillations of spacecraft radio signals to probe planetary atmospheric turbulence and the solar wind. These studies consist of two parts: theoretical analyses of wave propagation in turbulent media and the processing of the radio-link data from various spacecraft missions.

A similar and related field of interest is the use of acoustic fluctuations for studying and monitoring the statistics of ocean finestructure.

#### References

- R. Woo & J. Armstrong, *Nature* 292, 608 (1981).  
R. Woo & A. Ishimaru, *Nature* 239, 383 (1981).

### Propagation Problems on Earth-Space Paths

E.K. Smith

44.40.95.02

Radio propagation constraints in the earth-space environment must be accounted for in the design and specifications of space communication systems. Opportunities exist in a wide range of engineering and scientific problems relating to propagation between earth stations and satellites in the geostationary orbit at frequencies of 0.1 to 100 GHz. At present, there are active programs in both ionospheric and tropospheric effects on the transfer functions with application to the planning of space systems and to international standards through the CCIR.

### Radar Astronomy

R.F. Jurgens G.S. Downs

44.40.95.03

During the past ten years, a large volume of radar backscatter data, yielding maps of the planets Mercury, Venus, and Mars, and limits on the models of the Galilean satellites and the rings of Saturn, have been acquired using the radar facilities of the Goldstone tracking station. Much of these data have had only preliminary analysis, while new data are being acquired continually. New programs have been added to determine detailed topography of Mercury and Venus, while the Mars program has been augmented to include both S- and X-band data, thus allowing a refinement of the models of the regolith. Potential research problems include (1) comparison of Martian radar results with Viking optical, IR, and UV images; (2) determination of the spin vector of Mercury to improve cartography; (3) comparison of Mercury radar results with the optical images of Mariner 10; (4) detailed modeling of the surface of Venus from the altimetry and reflectivity maps; (5) measurement of the surface properties of the asteroids and comets; (6) studies of the atmosphere of Venus using X-band radar; (7) determination of the scattering models of the rings of Saturn; and (8) the moons of Jupiter.

#### References

- R.M. Goldstein *et al.*, *J. Geophys. Res.* 81, 4807 (1976).  
G.S. Downs *et al.*, *Icarus* 33, 441 (1978).

### **Astrophysics of Compact Radio Sources**

A.E. Niell R.A. Preston

44.40.95.04

Extragalactic radio sources play a significant role in several programs at JPL. VLBI observations are being used to study the compact structure of these objects and to measure their positions accurately. Current projects include (1) VLBI observations of the galactic source SS433 to study its kinematics and its relation to the extragalactic sources that it resembles, (2) the introduction of the new sensitive Mark III VLBI system into the Deep Space Network to provide the most sensitive possible observations of compact radio sources, (3) the development of a network of antennas in the Southern Hemisphere to provide the first VLBI images of much of the southern sky, and (4) high-dynamic-range VLBI maps of 3C273 and 3C345.

We seek proposals that are related to these programs or that lead to a better understanding of these objects.

#### **Reference**

A.E. Niell *et al.*, *Astrophys. J.* 250, 248 (1981).

### **Lunar Laser-Ranging Data Analysis**

J.G. Williams

44.40.95.05

Ranges have been measured from an observatory on the Earth to four retroreflectors on the Moon for ten years. With a typical accuracy of 12 cm and a best accuracy of 5 cm, these ranges are sensitive to the rotation of the Earth, the geocentric coordinates of the observatory, the orbit of the Moon, the physical librations of the Moon, and the selenocentric coordinates of the retroreflectors. The comparison of the range data with numerical models yields solutions for a number of physical parameters of astronomical, geophysical, and geodetic interest. The improvement of the physical models leads to more accurate data analysis.

### **Asteroids**

J.G. Williams

44.40.95.06

The asteroid belt is a sample of bodies, modified by collisions, that dates back to the origin of the solar system. Planet-crossing asteroids continue to bombard the surfaces of the inner planets. Samples of the faint members of the present population of asteroids can be achieved with photographic surveys for new objects followed by orbit determination of sufficient accuracy to allow recovery and study of physical properties. The dynamical and collisional evolution of asteroids can be studied by numerical techniques. The goal is the understanding of the origin and evolution of asteroids and their interaction with planets and satellites.

### **Pulsar Timing Studies**

G.S. Downs R.W. Hellings

44.40.95.07

Opportunities exist to study pulsating radio sources (pulsars) including (1) acquisition and analysis of pulsar timing data, (2) characterization of residual timing noise, and (3) theoretical studies of pulsar noise mechanisms. A large

data base now exists in which up to thirteen years of pulse-phase measurements have been obtained about once per month (once per week on the Vela pulsar) in one polarization on 24 pulsars and about three years on six newly discovered pulsars. The phase measurements are available for analysis as geocentric and barycentric arrival times. Raw data records are available as 500- to 1500-pulse integrations for durations of one to three hours. This data set continues to grow using the NASA Deep Space Network facilities at a frequency of 2295 MHz. There is the possibility of augmenting the data set with timing data intended for a particular study. For example, full polarization data has recently been collected on strings of individual pulses to search for subtle phase effects such as spin-axis wobble. Other activities in progress include statistical studies of the timing residuals as outlined by Cordes (1980) and an experiment to detect gravitational waves by searching timing data for the effects of wave-induced perturbations in the Earth-pulsar distance. Preprints of work recently submitted for publication are available upon request.

#### *References*

- G.S. Downs, *Ap. J.* 249, 687 (1981).  
J.M. Cordes, *Ap. J.* 237, 216 (1980).

#### **Frequency Standard Research**

L. Maleki

44.40.95.08

Efforts are presently under way to develop ground-based and spaceborne frequency standards for navigation, VLBI, and radio-science applications. The program includes research and advanced development in the area of Hydrogen Masers to achieve stabilities of parts in  $10^{17}$  for short to medium range averaging times. Research is also under way to study and develop an rf quadrupole mercury ion trap as a precision frequency source by applying a microwave-optical double-resonance scheme. This latter effort is for the development of a high-stability frequency standard for long-averaging time intervals. The laboratory is well equipped with power supplies, rf equipment, lasers and other light sources, optical components, detectors, and other related equipment.

### **Control and Energy Conversion Division**

#### **Coal Beneficiation Studies**

J.J. Kalvinskas

44.40.10.01

JPL is pursuing studies in various areas of coal beneficiation, including desulfurization, ash and trace metal reduction, etc. Laboratory work on coal desulfurization has led to a low-temperature chlorinolysis process that oxidizes both the pyritic and organic sulfur contained in the coal to water-soluble sulfates that can be removed by a water wash at moderate temperatures. Preliminary laboratory results on coal desulfurization show high pyritic and organic sulfur removal combined with attractive process-cost estimates, indicating a very promising potential for commercialization.



Extensive research will be required on the chlorinolysis process to elucidate the mechanisms of chemical reaction and mass transfer, controlling both the rates and limits of desulfurization, and to optimize the process-operating conditions. Other chemical beneficiation studies of coal are also under preliminary laboratory investigation and will require extensive laboratory development studies.

#### **Experimental and Analytical Study of High-Temperature Thermoelectric Materials**

R.A. Lockwood

44.40.10.02

Thermoelectric generators using radioisotopes as a heat source have been used successfully for space missions including Apollo, Viking, and Voyager. These generators have utilized thermoelectric materials such as PbTe and SiGe. However, other classes of semiconductor compounds that are potentially suitable for high-efficiency thermoelectric conversion at temperatures ranging up to 1500°C merit investigation. Materials including rare-earth chalcogenides are to be investigated for their thermoelectric properties from a physics viewpoint, such as the band-gap and carrier mobility.

#### **Thin-Film Growth and Device Fabrication for Advanced Electron Devices**

R. Stirn

44.40.10.03

Ongoing work at JPL includes exploring the use of chemical vapor deposition, magnetron sputtering, spray pyrolysis, and physical evaporation techniques for the growth of thin-film materials suitable for electron device application. Examples of applications are solar cells of higher-conversion efficiency, lowered cost, and improved radiation resistance for space and terrestrial application including GaAs and copper indium diselenide/cadmium sulfide materials and GaAs heterostructures for high-speed, low-power FET's.

In the area of CVD research, the use of low-pressure and glow-discharge enhancement is of interest in low-temperature deposition, improved growth rates, and abrupt interfaces between semiconductors.

Characterization facilities available for these investigations include (1) scanning electron and optical microscopy, X-ray diffraction, EDAX, ion-microprobe, photoluminescence, and reflection and transmission spectrophotometry laser scanning for annealing and/or recrystallization and (2) instrumentation for Hall Effect and van der Pauw measurements and for spectral response, current-voltage, and capacitance-voltage measurements of solar cells.

#### **Fundamental Studies of Materials and Processing for Infrared Detectors**

R.J. Stirn

44.40.10.04

Fundamental studies of materials growth-and-processing techniques are of interest to JPL for solid-state photon detection of infrared radiation in the micrometer-to-millimeter range. Emphasis should be on intrinsic-type detec-

tors operating in the photoemissive, photovoltaic, or photoconductive mode. The research will determine those aspects of material growth or processing that limit the performance of detectors and detector arrays in quantum efficiency, signal-to-noise, extended-wavelength response, response time, uniformity of response, and yield. Novel approaches that may dramatically improve any of the above properties are especially welcomed.

#### **Basic Research on Advanced Lithium Batteries**

R.B. Somoano

44.40.10.05

Opportunities exist to participate in a basic research program in the area of high-performance secondary lithium batteries. The work involves electrochemical studies of cathode, anode, and electrolyte materials. The objective is to obtain an understanding of basic physical and chemical processes which contribute to the battery performance in order to optimize its efficiency and reliability. This type of battery is required for future near-Earth, geosynchronous satellites or long-term planetary missions.

#### **High-Energy-Propellant Combustion Studies for Space Applications**

K.N.R. Ramohalli

44.40.10.06

Despite the fact that solid-propellant rockets represent maturing technology, deficiencies in understanding their fundamentals are frequently reflected in the occurrence of frustrating combustion problems even at fairly advanced stages of development. "Fixing" these problems as they occur tends to be costly and wasteful. Hence a fundamental study of the basic phenomena in solid-propellant combustion has been in progress for some years. A model has been developed to predict quantitatively and explain several experimental data. The concept of planned variations in the processing of high-energy propellants to study the influences of such variations upon time-independent and oscillatory combustion is in progress. The combustion is characterized in standard combustors and small-scale test-rocket motors. When completed, these studies are expected to yield guidelines for permissible variations in the processing of high-energy propellants for future space applications.

#### **References**

- K.N. Ramohalli & K.R. Magiawala, *AIAA J.* 19, 92 (1981).  
K.N. Ramohalli, *Combust. & Flame* 39, 53 (1980).

#### **Fuels and Chemical Production through Concentrated Solar Energy**

K.N.R. Ramohalli

44.40.10.07

Several candidate processes are pursued at JPL in an attempt to identify processes that can produce transportable, storable fuels (and valuable chemicals) utilizing concentrated solar energy. Some of these are high-risk/high payoff ventures aimed at long range application (year 2000 and beyond). For more immediate applications, integrated fuels production from biomass, peat/lignite/low-rank coal processing with rapid heating and heavy oil stripping are investigated.

JPL has demonstrated experimentally the production of a valuable pseu-

doaromatic aldehyde (furfural) and the biological fermentation of the spent mass into alcohols and a ketone; the feed stock was corncocks. An innovative process for the wet oxidation of peat has demonstrated the direct conversion to methanol in a simulated solar experiment with electrical heat. Photocatalytic and free-radicals-augmented reactions have been identified for efficient conversion of biomass (and coal) to fuels. Novel process diagnostics are being developed utilizing the acoustic emissions from reaction zones. In addition to simulated solar thermal sources available at Pasadena facility (Fresnel lenses, arc-imaging furnaces, and electrical steam generators), two parabolic dish concentrators (11 m diameter, 80 kw thermal) are available at a remote facility for all solar demonstrations of promising processes. A four-cylinder diesel engine is also available for testing the applicability of the solar-generated fuels

#### **Propulsion for Sample-Return Missions**

W.L. Dowler

44.40.10.08

The return of samples from above, on, or below the surface is being rapidly recognized as a main objective of planetary exploration for the next several decades. The amounts of energy required by this class of missions taxes severely both the capability of Earth launch vehicles — necessitating in many cases multiple launches accompanied by orbital assembly — as well as of planetary landing systems where entirely new braking devices have to be devised owing to the very large quantities of chemical propellants needed.

An attractive way to overcome these difficulties is to produce chemical propellants at the planet from local materials, exploiting the fairly long residence time (typically from one half to one year). Current work focuses on Mars, for which sample-return missions are actively studied, on the Viking flights, and on the techniques for obtaining oxygen, the heaviest component of a propellant system, from carbon dioxide. Mission options under consideration include the local manufacture of fuel from local water and its transport from Earth.

Challenging opportunities exist for experimental work on components of the fuel processor and also for studies of both process engineering and the design of mission strategies in which the planetary refueling concepts are employed.

#### *Reference*

R.L. Ash *et al.*, *Acta Astron.*, **E**, 705 (1978).

#### **Applications of Microbiological Genetics to Anaerobic Digestion**

G. Bertani

44.40.10.09

Anaerobic digestion of biomass to methane occurs in underwater sediments, the rumen of cows, and man-operated digestors. In all cases, the process involves large and varied communities of different microbial species, many of which are strict anaerobes. Current work at JPL aims at improving control over the microbial populations involved in these processes toward greater

efficiency of anaerobic digestion, methane production, and, possibly, production of other chemicals.

Research opportunities are available for the study of two topics: (1) reconstruction of defined microbial communities consisting of a small number of species that are able to perform the complete degradation process to methane *in vitro* and (2) isolation and characterization of mutants from certain strains of methanogenic bacteria with the aim of developing methods for genetically manipulating these bacteria.

Good laboratory facilities exist at JPL for working with the most fastidious anaerobic micro-organisms.

### **Higher Plants and Modified-Gravity Environments**

T. Hoshizaki

44.40.10.10

One goal in the Space Biology Research Program of NASA is to understand gravity's effect on development, adaption, and evolution by studying the survival of plants through many generations in space. Another goal is to enhance the knowledge of normal physiological adaptive mechanisms in plants and thereby provide new insight into both normal and pathological mechanisms.

Within the first goal, JPL's research programs are designed to determine and characterize the asexual and sexual reproduction processes of higher plants under weightlessness and modified-gravity environments to gain new insight on gravity's role in the initiation and development of the plant root, flower, fruit, and seed. Information on the mechanisms of hormonal action and mineral interaction in these processes will also be sought.

Within the second goal, JPL has undertaken studies on the effect of gravity on the biological adaption of higher plants. Research will be focused on the physiological mechanisms of selected plants under modified gravity in the area of nutrition, light responses, and mechanical stress.

### **Global Biology**

M.N. Dastoor

44.40.10.11

An understanding of the natural metabolism responsible for the maintenance of the steady-state composition of the atmosphere, oceans, and sediments on the surface of our planet is of significance not only to the science of comparative planetology but also to many applied problems concerning the persistence of the environment that supports human and other life. Since such a metabolism is now and has for some time in the past been dynamic — with physical, chemical, and biological processes inextricably linked — quantification of the biotic contribution is essential to a complete understanding of global processes.

One way of determining this contribution is through modeling. Even the most comprehensive models of exogenic cycles suffer from a dearth of valid global ground data. It would be safe to contend that most, if not all, of the existing values for global-reservoir content and interreservoir fluxes are gross extrapolations of very meager and somewhat outdated ground-based meas-

urements. In addition, owing to the relatively recent acceptance of the hypotheses of biotic factors as potential homeostatic controls of some biogeochemical cycles, global data about the biota have traditionally lagged behind those relating to inorganic and nonbiological transformations. The recognition of the biota in providing global homeostatic control factors can be attributed to biological reactions that characteristically allow for extremely high chemical fluxes and quite often are masked by what appears to be a very modest net synthesis on a global scale. Hence, an endeavor to collect relevant global data on biogenic molecules would allow us to advance our understanding of global chemistry.

#### **Regenerative High-Temperature Removal of SO<sub>2</sub>, H<sub>2</sub>S on Supported Molten Sorbent Catalysts**

M. Flytzani-Stephanopoulos

44.40.10.12

Sulfur removal from industrial gases is an extremely important operation, integrally linked to the utilization of coal and other sulfur-containing fuels. Currently available gas-cleaning processes operating at low temperatures incur considerable loss in thermal efficiency. High-temperature operation is more attractive and offers ample scope for creative and fundamental work.

In a collaborative effort recently started between JPL and Caltech in the area of high-temperature sulfur-removal chemistry, various absorbent-catalysts are being considered with reference to absorptive capacity, reactivity and selectivity to desired products (e.g., elemental sulfur), and regenerability. Exploratory experiments have demonstrated the feasibility of using certain sorbent catalysts as a melt to coat the inner surface of porous supports for the oxidative absorption of SO<sub>2</sub> and the production of elemental sulfur during reductive regeneration. Further studies will involve experimental and modeling work emphasizing creative application of tools from chemical-reaction engineering and heterogeneous catalysis to obtain interesting and practically significant results in the area of gas cleaning.

#### **Advanced Propulsion Concepts for Planetary Spacecraft**

M.W. Dowdy

44.40.10.14

The objective of this program is to identify, evaluate, and select for technology development advanced propulsion concepts that offer performance significantly better than that available from state-of-the-art propulsion systems.

Flyby missions to the primary solar-system targets will have been flown by the end of the decade. Orbiter/probe missions to Venus, Mars, and Jupiter and an orbiter/lander mission to Mars will have been accomplished. The next phase of exploration for the inner planets requires larger, more sophisticated lander/sample return spacecraft. Advanced high thrust-to-weight ratio propulsion systems will be required to enable these missions. Orbiter/probe missions to the outer planets require flight times of 10-15 years with the most advanced chemical and nuclear electric-propulsion systems planned for development. Significant advances in propulsion system performance, operational life, reliability, and autonomy will be required to enable these

missions. Further reductions in trip time for this mission or for more ambitious missions will require the development of new propulsion concepts.

Ongoing work at JPL is directed toward the development and evaluation of new advanced propulsion concepts. Concepts are evaluated analytically and experimentally when feasible. Technology development requirements are generated for promising advanced concepts.

#### **Enhancing Laser-System Performance for Signal and Power Propagation through the Atmosphere**

N.I. Marzwell

44.40.10.14

Various high-energy laser systems have been developed for commercial research and defense applications. Atmospheric transmission and propagation problems have attenuated and reduced the quality of the laser beam and limited its application. To overcome this limitation, research has been initiated to understand how various laser wavelengths are being impacted with humidity, crosswind, turbulence, slew rate, aperture, and range. Methods to tune the laser wavelength and optimize the beam quality inside the resonator and the outgoing beam as it propagates through the atmosphere are being investigated. Emphasis is being placed on new and tunable laser sources and methods of active control of the optical systems to optimize in real time the optical wave fronts in the presence of random distributions. The simplest active optical systems are those controlling focus and tilt; they range in complexity from controlling a mirror in two degrees of freedom up to systems employing segmented or deformable mirrors that may possess more than a hundred degrees of freedom. The purpose of this research is (1) to control the outgoing wave systems for maximizing the power density of a laser beam on a target and (2) to enhance the properties of received wave systems for maximization of the angular resolving power of a telescope or an array of sensors viewing a distant object through a turbulent atmosphere.

#### **Catalytic Processing of Hydrocarbons and Synthesis Gas**

G.E. Voccks

44.40.10.15

Catalytic processes used by industry employ heterogeneous catalyst systems that have changed little in the past 15 years. The catalyst being the heart of these processes dictates the design of the plant, which then must compensate for catalyst limitations in activity and bring the plant efficiency to as high a level as possible. However, these catalyst systems are often heat-transfer limited and therefore suffer in performance because of the use of conventional catalyst supports. In the work that has been conducted at JPL in the Fuels Conversion Group, a novel approach to supporting catalysts has been investigated. Based on experimental evidence in exothermic and endothermic reactions and on modeling efforts recently initiated, heat-transfer limitations on catalysts can be reduced through the use of novel catalyst supports. This impacts the catalyst type, formulation, activity, and specificity that can be applied to conventional and unconventional catalytic processes. Reactions that have been, and are continuing to be, examined at JPL have been high

(combustion, steam reforming) to moderate (methanol dissociation) in temperature. Other commercial processes that can also benefit from this novel modification to heterogeneous catalysis will be examined in subsequent tasks.

#### **Unconventional Food Sources for Space Applications**

J. Moacanin

44.40.10.16

As planned manned space missions increase in length and complexity, food regeneration becomes necessary. While high-productivity plant farming is the obvious method of choice for food regeneration, weight-volume constraints suggest alternative approaches.

Photocatalysis and photoelectrocatalysis research is being carried out for the conversion of selected waste products to usable substrates for further biological conversion. Likewise, efforts are under way to develop microorganisms that convert efficiently chemical substrates to staple and supplementary food sources. The biochemistry of the food-production pathways is being studied. In addition, exploratory development is being planned on reactor design and necessary controls for operation in zero gravity.

#### **Physics of Electron Devices**

J. Lambe

44.40.10.17

The research of special interest pertains to quantum effects that can be observed in solid-state devices employing electron tunneling as a key mechanism. We are applying such techniques to the understanding and development of solid-state chemical sensors. Tunneling is used as a spectroscopic technique to identify chemical species and to elucidate mechanisms that could lead to new sensors. As an example, we have recently identified the existence of surface states on metal surfaces. Such states are particularly important to the understanding of solid-state chemical sensors.

#### **Effects of Radiation and Gravity on the Development of the Nematode *C. elegans***

G.A. Nelson

44.40.10.18

Critical problems in development and embryology are those of how differentiation and pattern formation of an organism properly proceed, and how the developmental instructions are coded and transmitted genetically. Two factors unique to the space environment that may affect these processes are high levels of background radiation and zero gravity. The simple nematode *C. elegans* is being used as a model organism to evaluate the fidelity of animal development over multiple generations in space-like environments. Opportunities exist at JPL to conduct genetic, physiological, and cell biological research on *C. elegans* to evaluate radiation and gravity effects on embryogenesis, aging, behavior, and genome stability. Ground-based genetic experiments have begun to construct strains useful for radiation dosimetry and behavioral assays for the detection of gravity responses. The eventual goal is to use *C. elegans* for Space Shuttle/Spacelab flight experiments in animal development.

### **Thin-Film Amorphous Metal Coatings**

S.K. Khanna

44.40.10.19

Amorphous metals or metallic glasses are a novel class of materials having unique properties such as soft magnetic behavior, high corrosion resistance in acidic or neutral aqueous solutions, and high mechanical strength. Opportunities exist at JPL to conduct research in the electrical, magnetic, and chemical properties of amorphous metal films. The objective of the JPL program is to investigate and understand the influence of deposition conditions on the microstructural, chemical, and magnetic properties of amorphous metal films. The materials currently being investigated are amorphous metals based on refractory metals and metalloids such as MoRuB. The development of high corrosion-resistant and magnetic/electronic coatings are of great interest to JPL and other Federal agencies.

### **Research in Catalysis of Multielectron Processes**

V.M. Miskowski

44.40.10.20

Fundamental research is being performed on the electrochemical and photoelectrochemical reductions and oxidations of small molecules such as CO<sub>2</sub> and H<sub>2</sub>O. Major current interests include the development and characterization of new catalysts for efficient and selective electrochemical processes. Also included are the photophysical characterization of potential catalysts in homogenous solution by flash photolytic methods, the investigation of the interactions of molecules with semiconductor surfaces by electronic absorption/emission and ESR, and synthesis of new conducting and/or catalytically active polymers for application to electrode surfaces.

## **Applied Mechanics Division**

### **Finite Deformation Behavior of Elastomers**

R.F. Landel

44.40.04.01

The large-strain or finite deformation behavior of noncrystallizing elastomers is still a subject of considerable controversy. Both continuum and statistical mechanical (molecular) theories of behavior have been proposed and there are at least two competing approaches in each of these types of theory. To choose between competing theories as well as to enhance the further development of both approaches, studies are needed on carefully controlled networks prepared from a family of monomer systems with a systematic change in side-chain length. Moreover, the viscoelastic response of these networks must be examined under pure biaxial loads or strains.

The studies will be carried out with the unique JPL biaxial stress relaxometer using specially made gum stocks that have already been synthesized.

#### **References**

- K. Tsuge *et al.*, Rubber Chem. Technol. *51*, 948 (1978).  
J. Glucklich & R.F. Landel, J. Polym. Sci., Polym. Phys. Ed. *15*, 2185 (1977).



### **Glass Research**

M. Weinberg

44.40.04.02

JPL is involved in activities in support of the materials processing in space (MPS) program. These activities include planning for Space Shuttle experiments as well as ground-based research programs in the field of glass. The ground-based efforts being pursued in glass science fall into three categories: (1) nucleation and crystallization of glasses, (2) gas bubbles in glassmelts, and (3) gel-prepared glasses. The properties and behavior of silicate, borate, and fluoride glasses are being investigated with the special emphasis of providing the background information required for the interpretation of microgravity experiments. The program is primarily experimental in nature, but mathematical modeling of glass processing and theoretical exposition of processes occurring in glasses are also being considered.

### **Non-Newtonian Fluids**

S.T.J. Peng

44.40.04.03

Dissolved polymeric additives are under study because of their ability to prevent a liquid from being dispersed into a fine mist by wind shear. One application for such a modified fluid is in aircraft safety. A jet fuel so modified would not form a mist in a crash, and hence the potential hazard from fire in a crash would be lessened.

The polymers are of a very high molecular weight and are used at concentrations of 0.1% to 0.5%. The non-Newtonian behavior of such dilute polymer solutions is being investigated in order to ascertain the mechanism of the antimisting behavior. Previous work has been concentrated on elongational flow using novel JPL-developed apparatus. Future studies will extend these results and investigate more complex systems (e.g., those which can be caused to gel by shear flow), as well as amplify and modify current molecular and continuum mechanical theories of the flow of non-Newtonian fluids.

#### *References*

- S.T.J. Peng & R.F. Landel, *J. Appl. Phys.* 47 (1976).  
S.T.J. Peng & R.F. Landel, *Proceedings of 8th International Congress on Rheology*, 1980.

### **Pulse Radiolysis on Polymers in the Solid State**

A. Gupta

44.40.04.04

Pulse radiolysis on liquids and solutions has been used to yield information on charge-recombination processes and reactivity and decay modes of excited states and ion radicals. Recent work on solid polymer films has demonstrated the existence of these processes in the solid state, which implies migration of charges and excitation energies along polymer chains. Pulse radiolysis is also found to be an excellent tool for producing large populations of triplet excited states in these systems, which may then be monitored by time-resolved spectroscopy.

### **Physical and Chemical Aging of Polymers and Composites**

R.F. Landel

44.40.04.05

Engineering properties (e.g., creep, stiffness, durability) of glassy-like materials such as plastics, structural adhesives, or polymer matrix composites depend strongly on history, because glasses are not in a state of thermodynamic equilibrium. Thus to predict behavior for the duration of long-life missions (10—30 yr), it is essential to apply a combined theoretical and experimental approach to predict both rates of changes of properties and how these rates may be affected by concurrent chemical degradation reactions.

For the macroscopic description of the glassy state, PVT studies are being carried out as a function of thermal and mechanical load history. Studies on the effect of time-dependent volume changes on physical properties include a number of mechanical property (e.g., dynamic modulus, stress relaxation, Poisson's ratio) and spectroscopic (e.g., FTIR, ESR, fluorescence) measurements. The overall aim of these studies is to develop, based on molecular parameters, a comprehensive semiempirical predictive description of the behavior of polymeric glasses.

### **Multiphase Polymer Systems for Advanced Composite Materials**

S.D. Hong

44.40.04.06

Fiber-reinforced organic-matrix composites, by virtue of their exceptionally high specific strength and specific stiffness, are finding increasing uses in aircraft and space structures, as well as in civil fields. The current state-of-the-art composite materials, however, suffer a major deficiency — they have very low resistance to impact. The lack of fracture resistance poses a severe limitation on the usefulness of advanced composites. Extensive research is currently under way in developing advanced composites of improved toughness.

Opportunities exist at JPL to explore the possibility of toughening advanced composites by the use of a multiphase polymer matrix. The objective of the research is to obtain an understanding of the mechanisms involved in fracture and their relationship to the structure in the matrix. The emphasis in this study will be on thermodynamics of phase separation and the corresponding kinetics of phase separation, as well as the morphology of the polymer systems and its dependence on the processing conditions.

### **Coal Mixtures**

S.A. Qader

44.40.04.07

JPL has initiated research on the production and utilization of coal-oil and coal-water mixtures. The objective of the work is to prepare mixtures that can be used for fueling oil-fired boilers. As part of this program, research is planned in coal beneficiation to reduce ash down to 3—5%, in preparation of coal-oil-water mixtures by novel methods, and in the study of flow characteristics of the mixtures.

## Information Systems Division

### Research in Computational Mathematics and Mathematical Software

F.T. Krogh C.L. Lawson E.W. Ng 44.40.32.01

This research involves the study and development of computational algorithms and software for classes of mathematical problems and the techniques and software tools useful in implementing high-quality mathematical software that is portable across different computer systems. Mathematical topics of special interest include constrained surface fitting, quadrature, ordinary differential equations, nonlinear least squares, optimization, symbolic and algebraic computation, and VLSI algorithms.

#### References

- F.T. Krogh, *Mathematics of Computation* 33, 1265 (1979).  
C.L. Lawson, *Mathematical Software III*, (Academic, New York, 1977), p. 161.  
E.W. Ng, *Symbolic and Algebraic Computation* (Springer-Verlag, Berlin, 1979), p. 330.

### Electrostatic Control and Manipulation of Bulk and Dispersed Materials

D.D. Elleman 44.40.32.02

Laboratory and theoretical study of electrostatic control and manipulation of both bulk and dispersed materials is under way. Applications include freeze drying of cells, purification of materials, experiments in quantum fluids, study of the liquid surface of reactive materials, *in situ* characterization of spaceborne particulates, and study of reactions on dust grains.

The aim of the research is to develop apparatus that will meet the requirements of the applications and to formulate interesting experiments that make use of the apparatus.

There are two research opportunities for the study of the electrohydrodynamics of free liquid drops. One opportunity is for theoretical and computational study of the modes of electrically excited compound liquid drops. The other is for experimental study utilizing neutral buoyant liquids in the laboratory and free drops in the microgravity afforded by aircraft flight along ballistic trajectory.

### Medical Applications of Ultrasound

J.A. Rooney 44.40.32.03

Ultrasonic imaging techniques and instrumentation have gained wide acceptance as safe, noninvasive diagnostic tools. Further research is needed to increase the resolution of these systems, develop a capability to make reproducible serial measurements, improve image processing, and develop instrumentation for new applications.

Current research projects include studies of the progression and regression of atherosclerosis, investigation of cardiovascular deconditioning in spaceflight, and left-ventricular image processing and monitoring the onset of decompression sickness. The research is conducted with collaborators at the University of Southern California School of Medicine and the Johnson Space

Center. Opportunities to be involved in these activities exist for applicants with backgrounds in biophysics, ultrasound, biomedical engineering, physiology, and signal or image processing.

*References*

- R.C. Heyser & D.H. Le Croisette, *Ultrasound Med. Biol.* 1, 119 (1979).  
J.A. Rooney *et al.*, *IEEE Trans. Sonics Ultrason.* SU-28, 291 (1981).

**Properties of  $^4\text{He}$  and  $^3\text{He}$  in Zero Gravity**

P.V. Mason D. Petrac E. Tward 44.40.32.04

Experimental and theoretical studies of the properties of  $^4\text{He}$  and  $^3\text{He}$  in near-zero gravitational fields are being undertaken. These properties are of interest both from a fundamental and a technological point of view. From a fundamental point of view, phenomena can exist in zero gravity, which may lead to a deeper understanding of the physics of the substances, e.g., low-frequency capillary waves in thin films of superfluid  $^4\text{He}$ . From a technological point of view, both liquids are of great interest as cryogens for cooling other substances and devices, such as IR detectors to temperatures between 0.3 K and 2 K.

The physical state and thermal-transport properties of superfluid helium have been studied in zero-gravity rocket and aircraft flights and will be studied further, in conjunction with studies of capillary waves, in upcoming Shuttle experiments.

$^3\text{He}$  is to be studied theoretically and in the laboratory in order to determine the best way of utilizing it in space to attain temperatures near 0.3 K.

This opportunity may involve analysis of experiments already performed, participation in currently planned experiments, or the conception of entirely new scientific and technological experiments in zero gravity.

**Development and Application of Far-Infrared Detectors and Ultrastable Frequency Standards**

P.V. Mason V. Hadek E. Tward 44.40.32.05

Programs are under way at JPL to develop two types of low-temperature devices. These programs have need for an experimental scientist with interests and experience in one or more of these fields to participate in the development, test, and evaluation of such devices. Improved semiconductor detectors are being developed for the wavelength band between 0.1 and 1.0 mm for astronomical, planetary, and earth observations. These devices are expected to be more sensitive than existing detectors by at least an order of magnitude. In addition, a program has been initiated to construct an ultrastable frequency standard using a completely cryogenic superconducting cavity oscillator.

**Dynamics of Liquid Drops and Bubbles**

T.G. Wang D.D. Elleman E.H. Trinh 44.40.32.06

This program provides opportunities for individuals to participate in basic research in the area of the dynamics of liquid drops and bubbles. The objective is to obtain an understanding in the basic fluid mechanics associated

with equilibrium shapes of rotating drops and bubbles, nonlinear amplitude oscillation and decay, and collision and coalescence of drops and bubbles. Opportunities exist in both experimental and theoretical studies

#### **Foam Material Studies**

T.G. Wang D.D. Elleman 44.40.32.07

This program offers an opportunity to participate in developing technology applicable to the production of a novel, high-strength, low-weight, structural material. The latter is in the nature of a rigid foam, composed of binary alloys or amorphous materials, and containing highly-ordered pores. Although the work is motivated by engineering need, the fundamental principles of fluid dynamics, elasticity and structure of materials, physical metallurgy, and adhesion and bonding technology are emphasized. The work is principally experimental.

#### **Physical Acoustics**

T.G. Wang M.B. Barmatz 44.40.32.08

This program provides opportunities for individuals to participate in basic research in nonlinear acoustics. Detailed experimental and theoretical studies of acoustic properties associated with high intensity and high temperature will be performed. The results of this study will lead to a better understanding of the manipulation capabilities of an acoustic levitation device to be flown on the Space Shuttle program.

#### **Fusion-Target Technology Study**

T.G. Wang M.C. Lee 44.40.32.09

The objective of this program is to provide improved understanding of the various physical processes relevant to the production of inertial confinement fusion targets, both in the laboratory and in a weightless environment. The technology being developed rests on the disciplines of fluid dynamics of viscous media, the rheology of liquids near their solidification temperatures, and the physics of metallic and amorphous materials. These are applied to processes for pellet fabrication, for rendering the pellet spherically symmetric, and to the technology of applying multilayer coatings to the exterior surface. Opportunities exist for both experimental and theoretical studies.

#### **Fiber-Optic-Data Transmission**

A. R. Johnston 44.40.32.10

The technology of fiber-optic-data transmission is finding its way into many and varied applications because of its immunity to electromagnetic interference, its large bandwidth capability, and the small size and weight of optical-fiber cables. Investigations are being carried out at JPL related to understanding the capabilities and limitations of the technology for specific applications. One area of interest is in very-high-rate data transmission into several Gbit/sec or several GHz range. Techniques for semiconductor laser modulation are being investigated, as well as ideas for detection at microwave bandwidths.

These capabilities will be important in the future to handle the large volume of data generated by applications satellites.

Another area of interest is the generation of picosecond pulses using semiconductor lasers. Mode-locking techniques are being studied, as well as specialized nonlinear waveguide-detection techniques for measurement of pulse widths. Opportunities exist for participation in the investigation of microwave modulation and picosecond pulse generation using injection lasers and the application of these techniques to optical data processing, computer networking, or timing and measurement.

#### **Application of NMR to Material, Imaging, Metabolic, and Biochemical Studies**

S.L. Manatt D.D. Elleman

44.40.32.11

The great utility of nuclear magnetic resonance (NMR) stems from the variety of parameters that affect the spectra, and the fact that conditions can be chosen such that signal amplitude is directly proportional to the concentration of the nuclei being observed. There has been work carried out in the field of NMR continuously at JPL since 1956. There is currently interest in applying our experience in this area along with JPL's extensive experience in cryogenic techniques and biochemical image processing to NMR imaging. Currently, we are advising the University of Southern California/County General Hospital on the selection of a high-field, whole-body NMR imaging system. Joint research problems are under consideration that would utilize the above-mentioned system and microimaging NMR systems in investigations of polymers, fundamental biochemical studies, pathological sample studies, whole-body imaging studies, development of high-field NMR imaging techniques for  $^{31}\text{P}$ ,  $^2\text{H}$ ,  $^{13}\text{C}$ ,  $^{23}\text{Na}$ , and  $^{14}\text{N}$  and the application of image-processing techniques to NMR imaging. Research related to the application of high-resolution NMR techniques to characterization of complex molecules and polymers is also possible. For such problems, JPL has access to the Caltech Southern California Regional High-Field NMR Facility (Bruker WM-100 Spectrometer).

#### **Medical Imaging Techniques for Bone-Mineral Measurements**

S.L. Manatt

44.40.32.12

The extent and mechanism(s) of bone-mineral changes that accompany zero gravity and extended immobilization are not well understood. Accurate and precise *in vivo* bone-mineral-measurement techniques are required to gain information that bears on these problems. Commercially available X-ray instruments and software have a number of drawbacks and usually expose the subject to considerable radiation during the course of such measurements. The University of California/San Francisco, with NASA support and in collaboration with JPL, is developing a  $^{153}\text{Gd}$  dual-energy, gamma-ray, charge-transfer (CT) prototype system that has the potential to yield higher accuracy and precision and subject patients to 20-50 times less radiation than available techniques. A small  $^{153}\text{Gd}$  dual-energy, gamma-ray CT scanner

has been assembled at JPL. Another possible new technique that might contribute to a fuller understanding of the factors that influence bone mineral measurements is nuclear magnetic resonance (NMR) imaging.

Opportunities exist at JPL to explore the use of the JPL gamma-ray CT scanner in construction of a more complete dual-energy error model, the application to other types of biomedical problems, and the study of certain inorganic systems. In addition, NMR imaging and topical NMR studies directed toward a better understanding of the nature of trabecular bone are of interest.

#### **Biomagnetic Studies of Cognitive and Neurophysiological Processes**

J.D. Hestenes

44.40.32.13

Experimental and theoretical studies will be undertaken of evoked magnetic fields and evoked potentials from the brain during cognitive task performance under various stresses such as zero gravity, accelerations, and high cognitive work load. Principle interest is in the measurement of endogenous components of the evoked responses. These responses will be related to human workload studies and assessment of residual cognitive capacity for basic research in cognitive psychophysiology and for applications in man-machine interactions. Brainstem responses, particularly from the vestibular system, will be examined to determine their characteristics and relationship to motion sickness. Miniaturized neuromagnetometer research and development work aims at an array of sensors suitable for high-performance human-machine studies. These incorporate modern dc SQUIDS and cascaded Joule-Thomson refrigerator systems. This opportunity may involve participation in currently planned experiments or the conception of new scientific or technological advances. Applications may include studies of human behavior and performance in Shuttle experiments or in space-station environments as well as studies in several ground-based environments. Applicants should have backgrounds with experience in combinations of cognitive psychology, neurophysiology, biomedical engineering, physics, laboratory computers, signal processing, SQUID devices, or low-temperature physics.

#### **Observational Systems Division**

##### **Optical Sciences Research**

J.B. Breckinridge

44.40.55.01

Advances in optical and infrared instrument science and technology stimulate new scientific discoveries. Optical sciences research encompasses the study of radiation in the optical and infrared portions of the electromagnetic spectrum between 0.1 and 20  $\mu\text{m}$  wavelength. Research activity is conveniently partitioned into several areas, depending on the mathematical tools applied to model the radiation for a particular application. Six of these are (1) first-order layout of optical systems (described by ray tracing), (2) diffraction and wave aberrations (described by scalar-wave theory), (3)

polarization and interaction of light with matter (described by vector-wave theory), (4) statistical optics, (5) laser physics, and (6) radiometry and detection. A Prime 550 computer with interactive graphics ACCOS V ray-trace program and two well-equipped modern applied physical optics laboratories are available for use. This is an opportunity to perform basic and applied research in the optical sciences to develop those technologies fundamental to optical and infrared remote scientific measurement systems having new capabilities.

#### **Millimeter- and Submillimeter-Wave Technology**

W.J. Wilson

44.40.55.02

Millimeter- and submillimeter-wave components are being developed for spacecraft radiometers for atmospheric and astronomical applications. These include quasi-optical components, ambient and cooled mixers, and solid-state local oscillator sources using frequency multipliers. Analytical and low-frequency modeling techniques are utilized in the component design. A complete microwave/millimeter-wave test laboratory is utilized in the component development. The components developed will be assembled and used in ground-, aircraft-, balloon-, and satellite-based systems for remote sensing of the atmosphere for observations of planetary and interstellar molecules. Research opportunities are available in all areas of microwave design and development. Possibilities for cooperative research with interested scientists at Caltech also exist.

#### **References**

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I.W. Waters *et al.*, J. Geophys. Res. *84*, 7034 (1979).

#### **A Medical Image Analysis Facility**

R.H. Selzer

44.40.55.03

The function of the Medical Image Analysis Facility is to develop and apply image-processing techniques to biomedical problems related to the NASA Life Sciences program and to maintain the Biomedical Image Processing Laboratory at JPL as a NASA state-of-the-art resource for biomedical image analysis. Studies are under way involving X-ray and light microscope images. In the area of X-ray image processing, emphasis is on the development of noninvasive or semi-invasive methods to detect latent coronary artery disease. Studies to quantify peripheral artery disease from angiographic images are also under way, and a Medical Image Processing Station for "hands-on" use by cardiologists is being developed. In the area of light microscopy, emphasis is on the development of pattern recognition techniques for cell classification. Research involving chromosomes, muscle fibers, and cervical cells is currently under way.

#### **Submillimeter- and Infrared-Wavelength Astronomy from Space**

P.N. Swanson

44.40.55.04

Astronomical observations in the wavelength region between approximately 1  $\mu\text{m}$  and 30  $\mu\text{m}$  are severely limited by the Earth's atmosphere. Studies



are being conducted and some hardware is being developed for a dedicated orbiting astronomical observatory in this spectral range. Present plans call for a 20- $\mu$ m diameter Cassegrain telescope with an actively controlled, segmented surface. Instruments will include IR photometers, broadband bolometers and heterodyne detectors.

Opportunities exist in the areas of overall systems studies, system analysis and simulation software, mission planning, optics and submillimeter and far-infrared instrumentation.

#### **Research and Development of Charged-Coupled Imaging Devices**

T.H. Reilly

44.40.55.05

Charged-coupled devices (CCD's) are being developed for use in both earth and spaceborne observatories for imaging in the spectral range extending from X-ray through near IR. The devices are developed under JPL direction at selected semiconductor manufacturers. CCD evaluation and optimization is performed at JPL using various laboratory cameras and image-processing support equipment. The test results form the basis for analytical modeling that provides feedback to the manufacturers for device modification and improvement.

Research opportunities exist in several areas including analytical modeling to relate measured performance to CCD processes and architecture.

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