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1997 Annual BAAS Observatory Report

NASA Goddard Space Flight Center
Laboratory for Extraterrestrial Physics

Greenbelt, MD 20771

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INTRODUCTION

The Laboratory for Extraterrestrial Physics (LEP) performs experimental and theoretical research on the properties and dynamics of the heliosphere, the interstellar medium, and the magnetospheres and upper atmospheres of the planets, including the Earth. LEP members study the chemistry and physics of planetary stratospheres and tropospheres and of condensed solar system matter including meteorites, asteroids, comets and planets. The LEP conducts a focused program in astronomy, particularly in the infrared and in short as well as very long radio wavelengths. We also perform an extensive program of laboratory research, including spectroscopy and physical chemistry related to astronomical objects.

The Laboratory proposes, develops, fabricates, and integrates experiments on Earth-orbiting, planetary, and heliospheric spacecraft to measure the characteristics of magnetic fields, electric fields, and plasmas in space. We design and develop spectrometric instrumentation for continuum and spectral line observations in the X-ray, γ-ray, infrared, and radio regimes; these are flown on spacecraft to study the interplanetary medium, asteroids, comets, and planets. Studies are conducted to investigate electric and magnetic fields and plasma-dynamic phenomena in the near-Earth space environment to determine the temporal and spatial variations influencing the motion and composition of plasma and neutral gases in the Earth's atmosphere and magnetosphere. Suborbital sounding rockets and ground based observing platforms form an integral part of these research activities.

This report covers roughly the period from October 1996 through September 1997.

I. PERSONNEL

Dr. Richard Vondrak continues as Chief of the Laboratory for Extraterrestrial Physics. Mr. Franklin Ottens is Assistant Chief. The Laboratory Senior Scientists are Drs. Richard Goldberg, John Hillman, Michael Mumma, Keith Ogilvie, Louis Stief, and Robert Stone. The Branch Heads are: Dr. Joseph Nuth (Astrochemistry); Dr. Thomas Moore (Interplanetary Physics); Dr. Drake Deming (Planetary Systems); Dr. Steven Curtis (Planetary Magnetospheres), and Dr. James Slavin (Electrodynamics). The Information Analysis and Display Office is currently headed by Dr. James Slavin, Acting. Mr. William Mish (ISTP Deputy Project Scientist for Data Systems) is also a member of the Laboratory senior staff.

The Civil Service scientific staff consists of: Dr. Mario Acuña, Dr. John Allen, Dr. Robert Benson, Dr. Thomas Birmingham, Dr. Gordon Bjoraker, Dr. John Brasunas, Dr. David Buhl, Dr. Leonard Burlaga, Dr. Gordon Chin, Dr. Regina Cody, Dr. John Connerney, Dr. Michael Desch, Mr. Fred Espenak, Dr. Joseph Fainberg, Dr. Donald Fairfield, Dr. William Farrell, Dr. Richard Fitzenreiter, Dr. Michael Flasar, Dr. David Glenar, Dr. Melvyn Goldstein, Dr. Joseph Grebowsky, Dr. Fred Herrero, Dr. Michael Hesse, Dr. Robert Hoffman, Dr. Donald Jennings, Mr. Michael Kaiser, Dr. John Keller, Dr. Alexander Klimas, Dr. Theodor Kostiuk, Mr. Virgil Kunde, Dr. Ronald Lepping, Dr. Robert MacDowall, Dr. William Maguire, Dr. Marla Moore, Dr. David Nava, Dr. Walter Payne, Dr. John Pearl, Dr. Robert Pfaff, Dr. Dennis Reuter, Dr. D. Aaron Roberts, Dr. Paul Romani, Dr. Robert Samuelson, Dr. Edward Sittler, Dr. Mark Smith, Dr. David Stern, Dr. Jacob Trombka, Dr. Aldofo Figueroa-Viñas, and Dr. Peter Wasilewski.

The following are National Research Council Associates: Dr. Richard Achterberg, Dr. James Clemmons, Dr. Nancy Charnover, Dr. Michael Collier, Dr. Steven Cummer, Dr. Neil DelloRusso, Dr. Nicola Fox, Dr. Robert Glinski, Dr. Susan Hallenbeck, Dr. Joseph Harrington, Dr. Vladimir Krasnopolsky, Dr. Thomas Moran, Dr. Pedro Sada, Dr. Michael Smith, Dr. Peyton Thorn, and Dr. Xingfa Xie.

Personnel on contract to GSFC or in the LEP as long-term visiting faculty include: (Hughes/STX) Dr. Ashraf Ali, Dr. Daniel Bedichevsky, Dr. Scott Boardsen, Mr. Mark Cushman, Dr. Rainer Fettig, Dr. Emily Greene, Dr. Roger Hess, Dr. Shrikanth Kanekal, Dr. Masha Kuznetsova, Dr. Brook Lakew, Dr. Carey Lisse, Dr. Paul Marionni, Dr. Nitya Nath, Mr. George McCabe, Dr. Vladimir Osherovich, Dr. Mauricio Peredo, Dr. Michael Reiner, Dr. Takehiko Satoh, Dr. Pamela Solomon, Dr. Adinarayan Sundaram, Dr. Adam Szabo, and Dr. Nikolai Tsyganenko; (Universities Space Research Assoociation) Dr. Mei-Ching Fok, Dr. Jesper Gjerloev, and Dr. Valeriia Troitskaia, Dr. Dimitris Vassiliadis, Dr. Hung Kit Wong; (Applied Research Corporation) Dr. Sanjoy Ghosh, Dr. Michael Goodman, Dr. Thomas Moran, and Dr. Edouard Siregar; (Computer Sciences Corporation) Dr. Larry Evans; (Catholic University) Dr. Pamela Clark, Dr. Tamara Dickinson, Dr. Michael DiSanti, Dr. Frank Ferguson, Dr. Nat Gopalswamy, Dr. Fred Nesbitt, and Dr. Richard Starr; (SSAI) Dr. Ronald Carlson, (University of Maryland Baltimore County) Dr. Marcos Sirota; (Georgia Southern University) Dr. Robert Nelson; (University of Maryland College Park) Dr. Dennis Chornay, Ms. Kelly Fast, Dr. Thejappa Golla, and Dr. Timothy Livengood; (Charles County Community College) Dr. George Kraus; (Cornell University) Dr. Barney Conrath, and Dr. Paul Schinder; (Rowan College) Dr. Karen Magee-Sauer; (University of Virginia) Dr. Lembit Lilleleht, and Dr. Patrick Michael; and (Challenger Center) Dr. Jeff Goldstein and Dr. Tilak Hewagama, (NOMAD Research) Dr. Dean Pesnell.

Significant awards during the past year were: L. Burlaga was elected to AGU Fellowship; Mario Acuña received the NASA Distinguished Service Medal; R. Pfaff the NASA Exceptional Achievement Medal; G. Bjoraker the Lindsay Award; and M. Mumma received the NASA Exceptional Scientific Achievement Medal.

II. SOLAR AND STELLAR RESEARCH

X-ray Solar and Sky Observations. Periodically, the NEAR X-ray/Gamma-ray team (led by J. Trombka and including P. Clark, L. Evans, S. Floyd, T. McClanahan, and R. Starr from LEP) have made observations of the Sun and/or sky with X-ray and Gamma-ray spectrometers being flown on the NEAR (Near Earth Asteroid Rendezvous) mission spacecraft as part of the calibration process. The spacecraft is now in cruise mode on its way to its late 1998 encounter with the asteroid 433 Eros. A differentially filtered set of sky-pointing proportional counters operating in the 1 to 10 keV region with 25 square centimeter windows and five degree fields of view have provided estimates of the amplitude and variation in charged particle induced background. As indicated on previous missions with proportional counters, this background is variable and enhancements in it appear to be correlated to some extent with solar activity, as indicated by the solar X-ray monitors which are taking measurements simultaneously. One solar monitor is a Si PIN detector, the other also a proportional counter with a graded shield filter and effective thirty degree field of view. Both M- and C-Flares have been detected by the solar monitors. Output from both detectors generally agrees with predicted output from detectors as a function of solar activity. Line structure in the solar spectrum has clearly been seen during flares by the higher resolution Si PIN detector. During periods of solar occultation (for the monitors), the output from the Si PIN detector generally agrees with predicted output for the diffuse X-ray sky. Work is underway to establish the quantitative relationship between NEAR solar monitor output, and solar temperatures as defined by GOES solar satellite output.

Background Gamma-ray burst detection. The NEAR Gamma-ray spectrometer, a NaI detector with a BGO shield to limit the field of view to 45 degrees, operates in the .5 to 10 MeV region. Since the special Gamma-ray burst mode became operational approximately one month ago, a series of Gamma-ray bursts have been detected and confirmed when correlated with output from other Gamma-ray burst monitors operating in the solar system. This multi-point detection will allow determination of source locations. Induced Background determination with Gamma-ray Detectors on NEAR, Mars Observer, and LAMB: Induced backgrounds have been determined during cruise phases of the NEAR and Mars Observer missions, as well as on a long duration balloon flight (LAMB), since 1992. The background continuum imposes the limit on signal to noise ratios that can be achieved when the detectors are used in space as surface composition detectors. The discrete line contribution must be known, because the may interfere with lines which are being measured. The effectiveness of the different shielding designed used on each of the missions to reduce induced background has also been tested in this manner.

Imaging Solar Polarimeter. D. Deming and T. Moran (ARC) made significant progress in their development of an imaging solar polarimeter which will utilize observations of the extremely Zeeman-sensitive line of MgI at 12.32 microns. This cryogenic (LHe) instrument, which they have named "Athena," has been deployed at the second FTS port of the McMath-Pierce telescope on Kitt Peak. In June 1997 Athena was operated to obtain the first images in the MgI line. These images were made at the solar limb, and show the prominent limb brightening which is characteristic of this NLTE emission feature. In early 1998, magnetic images will be made in both Stokes I and V. These are expected to reveal the structure of solar magnetic fields at heights near the temperature minimum, with unprecedented magnetic sensitivity.

Prominence Spectra. E. S. Chang (U. Mass) and D. Deming continued their analysis of high resolution spectra of solar prominences in the infrared. Their latest work analyzed the 8- to 20-micron spectra of both a quiescent and an active prominence, using Fourier transform spectrometer data taken at the National Solar Observatory on Kitt Peak by P. Foukal and C. Plymate. Chang and Deming have completely reanalyzed prominence observations by J. Zirker in this spectral region, and they have identified two new helium recombination lines as well as the n=16 to n=9 line of hydrogen. Their reanalysis shows clear evidence of prominent Stark broadening in the mid-infrared hydrogen lines. Because these lines are unblended in addition to being very Stark-sensitive (unlike the Balmer series lines in the visible), the derived electron densities are highly reliable. For the quiescent and two spectra of an active prominence, the derived electron densities are 2.4 (0.3), 9.1 (1.2), and 5.5 (0.6) in units of 10^{10} cm^{-3}.

Polar Coronal Hole Model of the Sun. E. Sittler and L. Guhathakurta (CUA) have developed a 2D MHD semi-empirical model of the solar corona and interplanetary medium using Skylab and Ulysses data. This steady state model uses empirically derived electron density and magnetic field models of the solar corona and solar wind and conservation equations of mass, momentum and energy. The equations are solved in the rotating frame of the Sun and provide 2D maps of flow velocity, effective temperature and effective heat flux. The spiraling pattern of the interplanetary magnetic field is naturally provided as well as an estimate of surface magnetic field strength of about 12-14 Gauss. The model shows that the dominant component of the large scale solar magnetic field is an octupole. They are now in the process of applying this model to SOHO LASCO and EIT data as part of the SOHO Guest Investigator Program. Assisting in this effort is D. A. Roberts.

Solar Chromospheric Heating. M. Goodman continued to develop MHD models to support the proposition that the chromospheric network, and possibly the internetwork, is heated by resistive dissipation of large scale electric currents associated with magnetic loops in weakly ionized plasma. The currents have typical scale heights of several hundred kilometers, and are dissipated in magnetic loops with horizontal spatial extents of several thousand kilometers. Although it is generally believed that the heating mechanism in the network is MHD, there is controversy as to whether the heating mechanism in the internetwork is primarily hydrodynamic or MHD. Recent observations of 500 G magnetic fields in the photospheric internetwork, and theoretical and observational evidence of a spatial correlation between regions of internetwork heating (bright points) and magnetic elements suggest that the bright points are MHD phenomena.

Solar Transition Region Modeling. M. Goodman developed an MHD model of the transition region (TR) which includes the classical thermoelectric and conductivity tensors, and electron pressure gradient effects in Ohm's law. The results of the model indicate that: heating by large scale current dissipation is insignificant; the magnetic field aligned electron heat flux driven by the temperature gradient between the corona and TR is sufficient to heat the TR; thermoelectric and electron pressure gradient effects, usually neglected, are important in determining currents and thermal energy flux; the TR may not be force free, contrary to what is usually assumed; anomalous transport processes are not important in determining the large scale properties of the TR. Here large scale refers to height ranges of 100 - 1000 km. The results on heating are consistent with the view that the TR is heated by a combination of thermal energy flux from the corona, and in situ heating due to small scale current dissipation.

Coronal Heating. D. A. Roberts, working with J. A. Miller (UAH) has produced a model for the production of tails on the distribution function of electrons in the lower solar atmosphere. The model assumes that waves are generated (perhaps by microflares) in the upper chromosphere that then cascade to small scales where they efficiently accelerate particles. The tails thus made may form the population required to produce a hot corona by "filtration" of the distribution function, as proposed by J. Scudder (U Iowa).

Stellar Water. D. Jennings and P. Sada (Consultoría Astronómica de Monterrey, México) detected hot water at 12.3 μm wavelength in the chromospheres of Betelgeuse and Antares. The water lines, which are 5-10% deep, are similar to the spectra of water identified recently in sunspots. Water absorption will be present in these stars throughout the pure-rotation region beyond 10 μm, and can be expected to be seen in other M-type supergiants as well. Infrared water spectra provide a probe of the temperature and structure of stellar atmospheres. The observations were performed with the Goddard high resolution cryogenic grating spectrometer "Celeste," at the McMath-Pierce Telescope at Kitt Peak.

Solar Radio Bursts. M. Reiner, M. Kaiser, J. Fainberg, and R. Stone have reported the first triangulation of a solar radio burst using the Ulysses/URAP and the Wind/WAVES instruments. This observation allows them to determine the three dimensional geometry of the heliospheric magnetic field and the electron density along the exciter path from the sun to 1 AU. The observation dramatically demonstrates proof-of-concept for the future solar STEREO mission.. Also with Wind/WAVES, these workers have observed a number of solar type II bursts associated with CME driven shocks. For some of these events, they were able to track the shock from near the sun to Earth and beyond, demonstrating the capabilities of radio techniques for an early warning system for Earth-impacting CMEs.

Circumstellar Chemistry. R. Glinski (TTU) and colleagues have examined the chemistry of very low pressure stellar environments and have noted some unusual phenomena. In the most general case, they found that the vibrational distributions of homonuclear diatomic molecules and ions were highly non-Boltzmann and were essentially determined by the competition between the rates of formation or destruction and the rate of interlevel energy transfer. Due to the very high rates of destruction, the bulk of the population of homonuclear diatomic molecules and ions remains near the nascent vibrational population distribution. Glinski and coworkers recently observed the spin-forbidden Cameron Bands in the low pressure environment of the Red Rectangle Nebula, while Glinski and J. Nuth propose that the Red Rectangle molecular emission bands may be due to C_3.

J. Nuth recently reviewed studies of the formation and metamorphism of refractory grains in circumstellar environments. F. Ferguson and J. Nuth have continued studies of the nucleation of simple refractory grains in order to gain an understanding of the nucleation of refractory materials under relatively well controlled laboratory conditions before attempting to study such processes in the more complex natural environment. Laboratory measurement of the infrared spectrum of silicon disulphide by Kraus (CCCC) and others (including J. Nuth) demonstrates conclusively that this material can not be responsible for the yet unidentified 21 micron emission feature observed in carbon-rich, circumstellar outflows. New laboratory measurements by S. Hallenbeck and J. Nuth of the spectral evolution of initially amorphous magnesium silicate grains as a function of annealing temperature in vacuo provide a unique tool for the interpretation of the mid-infrared spectra of oxygen-rich circumstellar outflows by comparison of the observed spectra with a time evolved set of laboratory spectra of well-characterized magnesium silicate smokes.

Star Formation. Considerable progress has been made in understanding the chemical processes that might have occurred in the primitive solar nebula and that should still occur in the nebulae surrounding many protostellar systems. Karner (UNM) and coworkers (including J. Nuth) carried out the first in a series of experiments in which triggered lightning strikes were used to modify loosely aggregated refractory oxides to test this mechanism for the formation of chondrules. The experiments demonstrated the feasibility of the approach but also showed that new experiments need to be performed in vacuo in order to duplicate the texture of the natural materials. In a second set of experiments Withey (WVW) and Nuth demonstrated that vapor-phase nucleation can lead to the formation of single magnetic domain iron grains, thermodynamically more stable as magnetic dipoles than as non-magnetic grains. Long range magnetic interactions between single domain iron grains and multidomain or superparamagnetic materials could greatly speed the coagulation of small dust aggregates that are otherwise very closely coupled to the gas. Finally, Nuth recently examined the consequences of a chemical process for the mass independent fractionation of oxygen isotopes in the primitive solar nebula (and in protostellar systems) during the condensation of refractory grains. Among other tests for the operation of such a mechanism in the solar nebula, Nuth showed that this process would predict that the oxygen isotopic composition in comets is both much lighter than and non-mass-dependently fractionated compared to any other naturally occurring bulk sample of protosolar oxide.

III. PLANETARY SCIENCE

Molecular Spectra. Working toward the goal of a Planetary Modeler's Atlas, Fourier transform (FTS) and tunable diode laser (TDL) spectra of ethylene in the 10 μm region have been observed, measured, calibrated, assigned and line intensities measured by J. Hillman, D. Reuter, W. Blass (U of Tennessee) and M. Sirota. A spectrum taken in double pass configuration at the 1-m, McMath-Pierce FTS instrument at Kitt Peak National Observatory has been measured and calibrated against CO_2 laser band lines with a calibration standard deviation of 2.0×10^{-4} cm^{-1}. Using the results of a previous analysis, we have assigned the FTS spectrum and have measured over 500 intensities of ethylene lines in the 900-1000 cm^{-1} region. Using measurements of 15 well isolated transitions in this region measured independently at the University of Tennessee and GSFC using TDL spectrometers, the FTS intensities have been calibrated and transformed to line intensities at 296K. A benefit of this calibration approach is the improvement of the accuracy of intensity determination as well as compensation for the pressure and temperature uncertainties associated with an FTS spectrum taken for line position determination. Using a calculated spectrum, including mixing coefficients for ν_4, ν_7, ν_{10} and ν_{12} Coriolis interactions and calculated relative intensities, we have used the calibrated FTS intensities as the independent variable in a non-linear regression to determine the vibrational band intensities of ν_7, ν_{10} and ν_{12} (ν_4 is not determined by the data). These vibrational band intensities (scaled dipole moment derivatives) make it possible for us to generate an ethylene atlas at temperatures of our choice which will be useful to the planetary atmosphere modeling community. This atlas is now available at our web site http://aurora.phys.utk.edu/~blass/ethyatlas/ .

Low-Temperature Vapor Pressures. Interpretation of planetary observations and modeling of planetary atmospheres are both critically dependent on accurate laboratory data. It is important that these data be taken over the appropriate range of parameters: temperature, pressure, and composition. First-order equilibrium and photochemical models of clouds and hazes in the atmospheres of the outer planets and their satellites are particularly dependent on thermodynamic data; however, this information often does not exist or does not extend to the low temperatures that are prevalent in these environments. To support the planetary community in this area, J. E. Allen, Jr. and R. N. Nelson (GSU) have modified the existing vapor-pressure system so that a base pressure of ~10^{-7} Torr and a temperature as low as 62 K can be achieved. . Additional modifications to the system are planned to lower the attainable temperature even further. The system was calibrated by measuring the vapor pressure of propane (C_3H_8) from 84 to 240 K and the results agree very well with previous determinations. The vapor pressure of ethylene (C_2H_4) was then measured from 67 to 96 K, corresponding to pressures of 5×10^{-6} to 131 Torr, respectively. The vapor pressure of C_2H_4 has been well determined above its triple point (`104 K, 0.907 Torr), but the data only extend 10 K below this point. Our measurements are in excellent agreement with the previous measurements where they overlap - between 93 and 96 K - but extend the existing data by another 25 K or three orders of magnitude in pressure. The vapor pressures of methane (CH_4) and monodeuterated (CH_3D) methane above the solid phase from 62 to 90 K have also been measured, significantly extending the previously available data. A program to measure the vapor pressures of other hydrocarbons at these low temperatures is underway.

Mercury

Exploratory Studies. The latest two issues of the Mercury Messenger (edited by P. Clark) summarize the data now available on the atmosphere and surface of Mercury from the latest ground-based observations. Recent striking results include detection of material at the poles and in the unimaged hemisphere with unusual radar and/or spectral signatures, further refinement of distribution models for atmospheric components, and detection of anomalies in atmospheric K distribution that could be correlated with surface features. These data were used as input to X-ray spectral models to determine the capability of the X-ray detectors being developed for a proposed Discovery mission, the Mercury Messenger.

Venus

Winds on Venus. D. Buhl and G. Chin collaborated with J. J. Goldstein (Challenger Center) in a study of the winds of Venus using the mm radio astronomy telescope at Kitt Peak operated by NRAO. The J=2-1 rotational line of CO was used to measure Doppler shifts caused by global circulation in the Venus mesosphere. Dramatic changes were observed in the solar driven wind field showing a return flow from the dark side of the planet in 1989 followed by a reversal in 1993 from a return flow in March to a direct flow in the equatorial region in April approximately 50 days later. This program of mm and infrared planetary astronomy is providing preliminary results on the Venus atmosphere and receiver development which will be a model for future space craft missions (such as Venus 2000) to Venus and other planets to probe the winds and circulation patterns in the planetary atmosphere.

Infrared Spectra. Using a newly developed near-IR, acousto-optic tunable filter (AOTF) based camera, (see XI. Instrument Development) J. Hillman, D. Glenar and N. Chanover made spectrophotometric observations of thermal emission from the Venus nightside atmosphere and polarization measurements of the scattered solar flux from the crescent. Venus was observed from the Apache Point Observatory, Sunspot, NM using the 3.5-m telescope. Spatial resolution (FWHM) was 1.5 arcsec with 0.2 arcsec pixel sampling. The spectral resolution in the 2.35 μm Venus atmospheric window was 350. Data were also taken in the 1.74 μm window, which provided our deepest view, down to a pressure of approximately 20 bar (T_B = 550K). Spectral images of Venus were taken within and outside absorption bands of SO_2, CO and H_2O, in an attempt to separate the variation of sulfuric acid cloud opacity from the variation of gas absorption below the clouds. A discrete ordinate, multiple scattering algorithm has been implemented in order to more fully explore the near-IR emission from the Venus nightside. Since the AOTF camera is intrinsically a polarization sensitive device, we also made Venus crescent polarization observations. An obvious latitudinal asymmetry in the two orthogonal polarizations is evident. Attempts to understand this in the context of multiple scattering of polarized light using adding/doubling methods is being explored.

Earth

Solar Radiation and Atmospheric Transmission. In collaboration with R. N. Nelson (GSU) and R. N. Halthore (Brookhaven), J. E. Allen, Jr. has developed algorithms based on MODTRAN and a laboratory calibration procedure to extract trace-gas and particulate column abundances from data obtained with their infrared (1.2 to 4.5 µm) sunphotometer. Comparison of spectra obtained at Sunspot, NM with those obtained at Greenbelt, MD show differences in column abundances of the major traces gases. However, the most significant difference is a contribution from particulates that were present at Sunspot, but not at Greenbelt. Efforts are being made to correlate the Sunspot data with solar coronal and boundary layer particle measurements. A second channel is being added to the instrument to cover wavelengths from 0.45 to 1.2 µm. This visible channel slightly overlaps the lower wavelength of the infrared channel, so that atmospheric transmission can be covered from 0.45 to 4.5 µm in a single field-deployable instrument.

Ozone. The reaction $O(^3P)$ + IO I + O_2 is part of a catalytic cycle suggested as being responsible for some of the observed destruction of stratospheric ozone. Although it is now believed that there is insufficient IO present in the atmosphere for iodine chemistry to be significant in determining the concentration of ozone, this situation could change should iodine compounds gain additional use as fire retardants or fumigants. Because of this possibility, W. Payne, L. Stief, P. Thorn and F. Nesbitt (Coppin State) made a direct, absolute measurement of the rate constant for the reaction of IO with $O(^3P)$. The result, k = (1.2 0.20) 10^{10} cm^3 $molecules^1$ s^1 at 298 K, demonstrates that the reaction occurs at essentially every collision, has little or no energy barrier and will have approximately the same rate at stratospheric temperatures. The result confirms the only previous experimental value which was less precise and was based on modeling with a three parameter fit to the observed formation and decay of the IO signal.

Earth's Moon

X- and γ-rays. In preparation for the NEAR encounter with 433 Eros, where no ground truth will be available, work is being done with available lunar data to establish the quantitative relationship between iron as detected by spectral reflectance and gamma-ray spectrometers. The one micron feature in the reflectance data results primarily from iron found in orthopyroxene and to a much lesser extent in olivine. Gamma-ray spectral output in the 6 to 8 MeV region correlates well with bulk iron content of the soil, regardless of iron mineralogy. Variations within the major terranes, such as farside highlands, on the Gamma-ray derived map are well-correlated with mapped geological features, and are largely non-existent on the spectral reflectance derived map. The discrepancy between the 'global' iron maps derived from recent Clementine orbital spectral data and the Apollo orbital Gamma-ray data is the result of the presence of iron in olivine or metallic form. The Clementine derived map, recently published as the latest global iron map is, in actuality, largely a pyroxene map. We are now in a position to understand such discrepancies we will undoubtedly encounter at the asteroid. Available data on potential asteroid compositions for S Class asteroids were used as input to X-ray spectral production models to help in the design of hardware and software for the NEAR mission (Clark and Trombka, 1997b).

Mars

Magnetic Field. The Surveyor measurements (M. Acuña and J. Connerney) of the intrinsic Martian magnetic field have verified the theoretical work of S. Curtis and N. Ness who predicted in 1988 that the intrinsic Mars magnetic field would be due to remnant magnetism caused by an earlier, now extinct, planetary dynamo. Additional work by Curtis, Ness, and R. Mewalt has shown that the expected dynamo strength was insufficient to generate a magnetic field strong enough to deflect life destroying cosmic rays and hence that life on Mars would be confined to the subsurface unless there were atmospheric pressures comparable to those of Earth on ancient Mars.

Composition. Krasnopolsky, Bjoraker, Mumma, and Jennings measured the D/H ratio in water on Mars and obtained upper limits to H_2O_2, H_2CO, and HCl at a level of a few parts per billion (ppb) from high-resolution spectroscopic observations at 3.7 and 8 µm. The measurements do not preclude a possible presence of CH_4 at a level of a few tens ppb. Oxygen and carbon isotope ratios in CO_2 on Mars were also obtained from these observations. These isotopic ratios have important implications for atmospheric evolution. They are determined by the present water ice amount, the regolith-atmosphere-polar-cap reservoir of CO_2, the carbonate abundance, the initial abundance of CO_2, and losses of H_2O and CO_2 to space. The Goddard high-resolution spectrograph on HST was used to search for D Lyman-alpha emission from the upper atmosphere of Mars, which could provide a measure of the D/H escape ratio. This ratio should differ from D/H in the lower atmosphere and is important for Mars' evolution. Analysis of HST data is in progress.

Krasnopolsky proposed a concept for photochemical mapping of ozone on Mars, updating the early spectroscopic measurements of Traub and Carleton. Mumma and DiSanti incorporated this into their existing program for global mapping of water, temperature, and CO on Mars, and Mumma, DiSanti, and Krasnopolsky made initial mapping observations of ozone and temperature above 20 km on Mars using the CSHELL spectrometer at IRTF. This mapping may be especially fruitful when combined with Mars Global Surveyor observations of H_2O vapor and temperature profiles, and ground-based telescopic maps of water, CO_2, CO, and ozone and its temperature above 20 km on Mars. The combination will provide a complete set of data for photochemical modeling of Mars' atmosphere. Analysis is in progress.

Atmosphere. J. Pearl continued his activities as a Co-Investigator on the Mars Global Surveyor Thermal Emission Spectrometer (TES) experiment; P. Christensen (Arizona State U) is the TES Principal Investigator. Following insertion of the spacecraft into Martian orbit, data gathered by the instrument have been used to assess the state of the first four scale heights of the atmosphere. Temperature profiles are obtained utilizing the CO_2 15 micrometer band and a correlated-K transmittance formulation; this employs a large database constructed by R. Thompson from line-by-line calculations made by W. Maguire. The atmosphere is following seasonal trends, with evidence for large scale wave structure superimposed. The dynamical implications of the data are being investigated by B. Conrath (Cornell) and M. D. Smith.

Mariner 9 Data. A final calibrated, documented version of the Mariner 9 Infrared Interferometer Spectrometer data, obtained from Martian orbit in 1971, was submitted to the Planetary Data System.

Jupiter

Cometary Impact. D. Deming and J. Harrington continued their ballistic and hydrodynamic modeling of the infall of the ejecta material from the collision of comet Shoemaker-Levy 9 with Jupiter. This so called "plume infall" is believed to have produced the very bright infrared emission which has been referred to as the "main event". Deming and Harrington have modeled it using a Monte-Carlo ballistic calculation, coupled to a 1-D hydrodynamic model of the Jovian atmosphere, including radiative transfer. The emergent infrared intensity versus time is computed for multiple runs of the hydrodynamic code, representing different latitude and longitude points on the Jovian disk. These intensities are integrated over area to produce a synthetic light curve appropriate for comparison to the Earth-based and Galileo observations. Although the synthetic light curve has significant features in common with the observations, there are indications that horizontal "sliding" of plume material is an important effect. Since horizontal motions of this type cannot be realistically modeled with a 1-D code, additional calculations are underway using a version of ZEUS-3D, modified to include radiative transfer.

T. Livengood (LEP and UMD), T. Kostiuk, and H. Käufl (European Southern Observatory) presented a report at the 1997 Division for Planetary Sciences meeting on the spectral content in images of the thermal emission from the Shoemaker-Levy 9 impact sites, measured with the ESO TIMMI camera. Preliminary results suggest that the thermal emission spectrum of impact sites from hours to several days after impact roughly resembles the spectrum of thermal emission from cometary dust. If a cometary-dust spectrum is accepted, it appears to imply that the residual material from the impacts resides at relatively high temperatures, found at high altitude, which is difficult to understand from the expected settling time of impact-derived dust. We are presently examining the viewing-angle dependence of the impact-site emission to determine whether a constraint on the temperature/emissivity comparison can be identified.

Thermal Waves. D. Deming and colleagues completed their analysis of longitudinal thermal waves on Jupiter, using infrared (7 to 20 micron) data. The observations were made at the NASA Infrared Telescope Facility on Mauna Kea, and show that long-wavelength, slowly-moving, structures are ubiquitous at tropical latitudes on Jupiter. They identify these as Rossby waves, forced by the interaction of a deep zonal flow with structure in the Jovian interior, as a "princess and the pea" effect. Additional observations and analysis of these waves are planned, in collaboration with J. Harrington (now at Cornell).

Ultraviolet Emissions. T. Livengood (LEP and UMD) was co-author of a report by R. Prangé (Institut d'Astrophysique Spatiale) at the 1997 DPS, presenting the first quantitative results from the 1996 International Ultraviolet Explorer (IUE) observing campaign to study Jupiter's UV emissions. Jupiter's UV aurorae were found to exhibit strongly conjugate behavior between the north and south aurorae. A unified auroral index was developed which showed the state of auroral variability during the six weeks of the study, to be compared with variability in other phenomena measured by IUE, measured from the Galileo orbiter, or observed from the ground. The aurorae were found to be continuously variable, rather than fluctuating episodically between states of temporary stability. This has important implications for the possibility of auroral response to the Shoemaker-Levy 9 events, during which period auroral activity on Jupiter at all wavelengths (Mid-IR, NIR, UV) was found to be exceptionally weak for at least two weeks, followed by a recovery marked by a UV aurora with unusual spectral characteristics.

Radio Emission. M. Kaiser has made observations of Jupiter's decametric wavelength radio emission with the Wind/WAVES instrument. The observations help to fill in a 'gap' in latitude-frequency space by observing Jupiter from southerly latitudes and low frequencies. In this parameter regime, the Io-A and B sources are not dominant; rather, the Io-C and, particularly, the Io-D sources are the most easily detected. Kaiser has shown that these sources must come from the Jovian southern auroral zone.

M. Kaiser has also reanalyzed Ulysses/URAP observations of Jovian 'type III' bursts and has shown that these occur so frequently that their low-frequency 'tails' merge into a semi-continuous band of emission that has previously been mislabeled as escaping continuum. He showed that this same phenomena likely occurs at Earth to a much lessor extent in association with the terrestrial LF bursts.

Infrared Emission. T. Kostiuk, C. Lisse (UMD and LEP), H. Käufl (ESO), and T. Livengood (LEP and UMD) acquired Mid-IR spectral images of Jupiter using the ESO Thermal Infrared MultiMode Imager (TIMMI) camera. Enhanced hydrocarbon emissions from both North and South polar regions as well as their global distributions were imaged. Data are being analyzed in support of on-going studies of global stratospheric constituent distribution and of auroral morphology and intensity.

Ionosphere. F. M. Flasar and P. Schinder, with D. P. Hinson (Stanford) and A. J. Kliore (JPL), have analyzed Galileo radio occultation data. Although the loss of Galileo's high-gain antenna precluded detailed studies of Jupiter's neutral atmosphere, the signal-to-noise ratio of the spacecraft's low-gain antenna is sufficiently high to allow retrieval of vertical profiles of electron density of Jupiter's ionosphere and its satellites. The retrievals thus far indicate that Jupiter's ionosphere is quite heterogeneous, with a topside electron density peak ranging in altitude from 900 to ~2000 km above the 1-bar level. Often there are regularly spaced narrow peaks situated below the main peak that are suggestive of ionospheric layers forced by vertically propagating gravity waves. Occultation measurements of Io indicate an ionospheric peak densities that vary by more than an order of magnitude horizontally. The observed upstream-downstream asymmetry, with respect to Jupiter's corotating magnetospheric plasma, is remarkably consistent with that retrieved from the Pioneer 10 radio occultation. The ionospheres of the other Galilean satellites are much weaker. An ionosphere has been detected on Europa, with a peak electron density of 10^4 cm^{-3}.

Titan

Zonal Winds. T. Kostiuk, K. Fast (UMD and LEP), T. Livengood, D. Buhl, and F. Espenak, with J. Goldstein, T. Hewagama, and K. Ro (Challenger Center) determined the probable direction of equatorial zonal wind flow on Titan. A combination of data from 1993, 1995, and 1996 indicates with 99.7% significance that the stratospheric mean zonal flow is prograde, in the direction of Titan's slow rotation. This result is important to preparations for the Cassini Huygens Probe release, and provides a constraint on theoretical models of atmospheric circulation on slowly-rotating bodies (*i.e.*, Titan and Venus). Results were presented at the EGS Titan Symposium in Vienna, Austria in April 1997, and the DPS meeting in Boston in August, 1997.

Ethane. The same data as in the above wind study were used to determine the global abundance of ethane on Titan and to constrain the stratospheric temperature profile. Results were published in a special issue of Planetary and Space Science on Titan in August 1997.

Hydrocarbon Chemistry. Reactions of the C_2H_3 free radical play a prominent role in the hydrocarbon chemistry of the atmosphere of Titan. L. Stief, P. Thorn, W. Payne, and F. Nesbitt (Coppin State) have completed an extensive study of the rate and products of the reaction C_2H_3 + CH_3 at T = 298 K and 200 K. This completes a series of studies on reactions of C_2H_3 which now includes H + C_2H_3, N + C_2H_3, C_2H_3 + C_2H_3 and CH_3 + C_2H_3. These atom-radical and radical-radical reactions are very difficult to study quantitatively in the laboratory and the present studies provide the only data available at the low pressures and low temperatures appropriate for Titan's atmosphere. For all four X + C_2H_3 reactions there is competition between an abstraction channel (which reforms C_2H_2) and an addition channel (which leads to larger hydrocarbon species such as C_2H_4, CH_3CN, C_4H_6 and C_3H_8) for X= H, N, C_2H_3 and CH_3 respectively. This competition is strongly dependent on both temperature and pressure with low pressure favoring C_2H_2 reformation (abstraction) and low temperature favoring larger molecule formation (addition). For example, in the CH_3 + C_2H_3 reaction, the yield of C_2H_2 at T = 298 K increases from 0.22 at 130 millibar pressure to 0.87 at 1.3 millibar pressure while the yield of C_3H_8 at 1.3 millibar pressure increases from 0.13 at T = 298 K to 0.47 at T = 200 K. Future photochemical models of Titan's atmosphere should use the more appropriate low temperature/low pressure data for all C_2H_3 reactions. The temperature and pressure dependent competition between abstraction (C_2H_2 formation) and combination (C_2H_4, CH_3CN, C_4H_6, and C_3H_8 formation) for reaction of H, N, C_2H_3 and CH_3 with C_2H_3 has a pronounced effect on the altitude profile of these species which will be revealed by the Huygens probe on the Cassini mission to Saturn/Titan.

Photochemistry. P. Romani gave an invited talk on Titan photochemistry at the 22nd General Assembly of the European Geophysical Society. Using a simple photochemical model he analyzed the vertical profiles of cyanoacetylene (HC_3N) and ethane. In Titan's lower stratosphere (z < 350 km) these species have different altitude profiles (HC_3N varies more rapidly with height than C_2H_6), yet their photochemistry is similar (production aloft followed by downward transport to a condensation sink). With the simple model a consistent picture of the eddy mixing profile in the lower stratosphere of Titan can be constructed. The profile, like the Neptune work, suggests a stagnant lower stratosphere with a rapid transition to vigorous eddy mixing. With this as a starting point, along with other constraints on eddy mixing, or chemical production, more complete photochemical models can be constrained and/or analyzed.

Atmospheric Observations and Modeling. R. Samuelson and coworkers have used Voyager 1 IRIS spectra to infer that the condensate/vapor ratio for dicyanoacetylene (C_4N_2) in Titan's north polar hood near vernal equinox is about two orders of magnitude larger than expected under steady-state conditions. Apparently, photolytic decomposition of C_4N_2 vapor occurs above the advancing sunlight/shadow boundary at the same time that condensation increases below the boundary due to continued cooling. In separate studies, Samuelson and coworkers have also inferred relative abundances of molecular hydrogen and methane in Titan's troposphere, and have obtained estimates for upper limits to argon, depending on the model. Methane appears to have an abundance approximately 150% that of saturation over an extended region in the upper troposphere, decreasing toward the poles. If methane vapor is in saturation equilibrium with the surface, the derived latitudinal gradient of the near-surface methane vapor mole fraction implies the liquid content of the surface is ethane-enriched near the poles. A steady-state particle growth and evaporation model has been developed that predicts the observed amounts of methane supersaturation and explains the latitude-dependence observed. Particle precipitation rates of about 0.1 particles cm^{-2} day^{-1} are derived.

Saturn

Infrared Emission. T. Kostiuk, T. Livengood (LEP and UMD), C. Lisse (UMD and LEP), H. Käufl (ESO), and Y. Fernandez (UMD) acquired Mid-IR spectral (5-17 µm) imaging of Saturn in which the rings were clearly detectable. The spectrophotometry data of Saturn and its rings is being analyzed. A comparison of the spectral content on the East ansa *vs.* the West ansa of the rings indicates a distinction in emission intensity and spectral distribution between the ansae. Follow-up observations are planned for late 1998 to pursue this in greater detail.

Neptune

Atmospheric Ethylene. W. Maguire continued his research on the abundances of minor constituents in the atmospheres of the outer planets. Using recent laboratory band intensity measurements of the 10 µm ethylene (C_2H_4) fundamentals, he rederived the mole fraction for this gas in Neptune's atmosphere. The new abundance agrees within error bars with the abundance he previously derived using his earlier molecular model. In addition, using band intensity measurements recently published by another laboratory, he calculated a mole fraction for dicyanoacetylene (C_4N_2). These gases are seen in emission in Neptune's stratosphere. C_4N_2, a linear molecule, is similar to other nitriles observed in outer planets' atmospheres.

Atmospheric structure. P. Romani collaborated with other researchers in interpreting Voyager 2 Ultraviolet Spectrometer (UVS) solar occultation light curves of Neptune. The observed light curves were compared with one-dimensional methane photochemical-transport models to infer hydrocarbon abundances and the strength of eddy mixing in the stratosphere. Superior fits to the light curves where obtained with models having a stagnant lower stratosphere, a rapid transition to vigorous eddy mixing around the millibar level, and a decrease in the eddy mixing in the upper stratosphere (microbar level). In line with previous work, methane mixing ratios on the order of 10^{-4} were required to obtain good agreement between the photochemical model and the UVS light curves.

IV. COMETARY PHYSICS AND CHEMISTRY

Polarized Resonance Fluorescence of Comet Hale-Bopp. In collaboration with M. J. Penn and D. Branston (both at NSO/NOAO) and M. A. DiSanti (Catholic University/NASA GSFC), J. E. Allen, Jr. has initiated a program to study the polarized fluorescence from comets. Because it is basically a vector-related technique, polarization spectroscopy can provide information not obtainable using traditional (scalar) spectroscopic methods. Typically polarization measurements are associated with the characterization of the dust continuum. Although not as frequently studied, resonance fluorescence can also exhibit polarization and the information can be related to physical properties of the comet, e.g., magnetic-field direction. Observations of comet Hale-Bopp were made shortly after perihelion (April 4 - 14, 1996) using the Vacuum Tower Telescope at the National Solar Observatory in Sunspot, NM. Images were taken through a variety of line and continuum filters and spectra of the sodium (Na) doublet and C_2 Swan system were acquired using the high-resolution horizontal spectrograph. In both cases data were acquired with and without polarization analysis. Data from the polarization images and spectra of the Na D_1 and D_2 lines are currently being reduced to determine the magnetic-field directions.

Infrared Images of Hale-Bopp. C. Lisse (UMD and LEP), T. Kostiuk, H. Käufl (ESO), T. Livengood (LEP and UMD), M. A'Hearn (UMD) and Y. Fernandez (UMD) acquired thermal infrared spectral images of comet Hale-Bopp. The images provide multi-wavelength (2-20 µm) photometric data on the comet and its coma, its morphology and temporal changes over 8 months, and evidence of jet structure. Data are being analyzed and compared to that obtained at other spectral regions to extract information on the size of the cometary nucleus and the dynamics and composition of the emitted dust. Preliminary results, including retrieved dust to gas ratio (~8) and morphological rotational periodicity (11.3 hours), were presented at the DPS meeting in Boston in August, 1997.

Cosmic Ices. Laboratory studies of the infrared spectral properties of cosmic ices before and after proton irradiation are conducted using a unique set-up designed specifically for the ion bombardment of thin films of low temperature ices. The focus of these investigations is to understand physical-chemical and radiation-chemical processes and identify products in irradiated icy materials thought to exist in cometary ices, in interstellar icy grain mantles, and in some cases on the surfaces of icy satellites. M. H. Moore and R. L. Hudson (Eckerd College) have completed experiments on H_2O+CO ice mixtures, studying products formed by proton irradiation. Mid-IR spectra of irradiated H_2O+CO samples show the synthesis of H_2CO (formaldehyde) and CH_3OH (methanol). These products are explained on the basis of successive H atom addition to CO, the H atoms being formed by dissociation of H_2O. Since the incident radiation also produces OH (hydroxyl radicals) from H_2O, the product of both OH and H addition to CO was sought and found, namely HCOOH (formic acid). These results are of astrochemical interest as HCOOH has been identified as a cometary molecule (Comet Hale-Bopp), a gas-phase interstellar molecule, and, very recently with ISO, has been proposed as a component of ice around NGC 7538:IRS 9, a young stellar object. Laboratory measurements of absolute spectral band strengths ("A" values) will allow precise conversions rates of CO to H_2CO, HCOOH, and CH_3OH to be determined. Supporting radiation experiments have been done on H_2O+H_2CO and H_2O+HCOOH ices. Finally, measurements of band strengths for a number of stable interstellar molecules, such as acetic acid, acetone, and acetaldehyde, are being undertaken to aid in the interpretation of these, and future, experiments.

Investigation of Parent Volatiles. A team led by M. Mumma investigated the volatile fraction of comets Hyakutake and Hale-Bopp, using infrared spectroscopy at high and moderate spectral resolution. High resolution spectroscopy with CSHELL at the NASA Infrared Telescope Facility (IRTF) atop Mauna Kea resulted in the discovery of methane (CH_4) and ethane (C_2H_6) in comets, the first secure detections of CO, HCN, NH_3, and OCS at infrared wavelengths, and detections of many other species (CH_3OH, H_2O, etc.). Many unidentified spectral lines are present throughout the 3 - 5 µm region. Some are as strong as the identified lines, and many are common to Hale Bopp and Hyakutake. We are attempting to identify the gases responsible. Low resolution spectroscopy and imaging with NSFCAM at IRTF resulted in the discovery of water and hydrocarbon ices in Hale-Bopp. Team members include: N. Dello Russo, M. DiSanti, M. Fomenkova (UCSD), K. Magee-Sauer (Rowan U), M. Mumma, R. Novak (Iona Coll.) and T. Rettig (Notre Dame).

Water (H_2O) N. Dello Russo , M. Mumma, M. DiSanti, K. Magee-Sauer, R. Novak, and T. Rettig developed a new technique using infrared non-resonance fluorescence to directly detect and quantify water in comets using ground-based infrared spectroscopy. They detected numerous hot-band lines at 2 and 5 μm which enabled them to measure water in comets Hyakutake and Hale-Bopp over a wide range of heliocentric distances. The ground-based infrared measurements utilized a 30" long slit, which permitted them to separate the direct and extended sources of cometary volatiles. The apparent production rate of volatiles was found to increase with distance from the nucleus, until a steady value is reached. The dust continuum reaches a steady state production rate much more quickly, by comparison, suggesting that an extended source exists for most parent volatiles. This phenomenon gives crucial information on the spatial distribution, sources, and outflow dynamics of cometary volatiles.

Methane (CH_4) and Ethane (C_2H_6). M. Mumma, M. DiSanti, N. Dello Russo, K. Magee-Sauer, T. Rettig, M. Fomenkova, and R. Novak studied emission in the ν_3 band of CH_4, and in the ν_7 band of C_2H_6, in comet C/1995 O1 (Hale-Bopp) both pre- and post-perihelion, over a wide range of heliocentric distance. Both bands fall in the 3.3-3.4 μm region. These fully saturated hydrocarbons are observable only in the infrared, since neither possesses a dipole moment and hence has no pure-rotational spectrum. The observational program targeted 6 lines of CH_4, and 8 Q-branches of C_2H_6, sampling a sufficient range of rotational levels in each molecule to provide a measure of the rotational temperature. Mumma and colleagues found a large abundance ratio C_2H_6/CH_4, approaching unity, similar to that measured for comet C/1996 B2 (Hyakutake) in March-April 1996. Mumma et al. (1996) argued that this supports the importance of chemical reactions on the surfaces of ice-mantled interstellar grains, prior to incorporation of these grains into the cometesimals which subsequently became the constituents of the nuclei of these Oort Cloud comets. C_2H_6 cannot be made by gas phase chemistry in interstellar cloud cores, but the measured high abundance can be explained by addition of gas-phase H-atoms to previously adsorbed acetylene ice, or by CH_4-

CH_4 interactions on grain surfaces. Values of C_2H_6/CH_4 ² 10^{-3} are predicted by models of gas-phase nebular chemistry.

Acetylene (C_2H_2). K. Magee-Sauer (Rowan University), M. Mumma, M. DiSanti, N. Dello Russo, and T. Rettig detected C_2H_2 emission from comets Hyakutake and Hale Bopp . The R1, R3, P3, P7 ro-vibrational lines of the ν_3 band were detected. We expect to obtain a rotational temperature for C_2H_2, C_2H_2 production rates, and its abundance relative to water. The spatial character of the emission will also be probed.

Carbon monoxide (CO). M. DiSanti (GSFC/CUA), M. Mumma, N. Dello Russo, K. Magee-Sauer, T. Rettig, M. Fomenkova, and R. Novak measured CO v = 1 - 0 fundamental band emission (at ~4.67 µm) in C/1995 O1 (Hale-Bopp) on 17 dates between June 1996 (R_H = 4.1 AU pre-perihelion) and September 1997 (R_H = 2.9 AU post-perihelion). On each date, sufficiently many CO lines (typically 6 to 8) were observed to characterize the rotational temperature as a function of position along the (30" long) slit . Spatial profiles of CO emission exhibit a central ρ^{-1} brightness distribution, indicative of a native source, superimposed upon a relatively flat underlying profile representing a distributed source of CO. This dual-source nature was also observed by DiSanti and colleagues for CO in comet C/1996 B2 (Hyakutake), in March-April 1996. Extended maps of CO emission in the coma of Hale-Bopp were also obtained on several dates by DiSanti et al., by offsetting the slit from the nucleus both parallel and transverse to the slit length. The parallel maps provide information on the scale length and production rate of the "parent" of the distributed CO. The transverse maps address questions related to azimuthal asymmetries in the coma and, by inference, possible heterogeneity in the nucleus ice composition, when compared with similar maps for other native volatile species, such as C_2H_6 and H_2O.

Hydrogen cyanide (HCN). K. Magee-Sauer (Rowan University), M. Mumma, M. DiSanti, N. Dello Russo, and T. Rettig detected many lines from the R- and P- branches of the HCN ν_3 ro-vibrational band. Preliminary analysis of the relative intensities of the emissions indicates that at 1 AU, the rotational temperature for Hale Bopp was 83 K, where for Hyakutake it was 75 K. The rotational temperatures were determined from observations of the P2, P3, P4, P7, P8, R2, R6, R7 lines for comet Hale Bopp, and the P2, P3, P4, P7, P8, R1, R2, R6, R8 lines for Hyakutake. Complete analysis of the data will lead to production rates, information regarding an extended source for HCN, and the abundance of HCN relative to water.

Ammonia (NH_3). K. Magee-Sauer (Rowan University), M. Mumma, M. DiSanti, N. Dello Russo, and T. Rettig detected NH_3 in comet Hale Bopp. This is the first detection of the infrared spectrum of NH_3 in comets. The sQ(3,3) line of the ν_1 band of NH_3 was detected. Complete analysis will provide a production rate for NH_3 and its relative abundance to water. The spatial character of the emission will also be probed.

Carbonyl sulfide (OCS). N. Dello Russo (GSFC/CUA), M. Mumma, M. DiSanti, K. Magee-Sauer, R. Novak, and T. Rettig detected 9 ro-vibrational lines of the ν_3 band of carbonyl sulfide (OCS) during investigations of comet Hale-Bopp in April, 1997. Our derived OCS production rates from mid- and late- April combined with production rates obtained at larger heliocentric distances at radio frequencies help to constrain the cometary sulfur inventory.

Detection of Water and Organic Ices. M. Fomenkova (CASS, UCSD), M. Mumma, M. DiSanti, K. Magee-Sauer (Rowan U), and M. Moore obtained near-IR spectra of comet Hale-Bopp at heliocentric distances of 4.1 and 3.0 AU pre-perihelion and at 2.8 AU post-perihelion. The earliest spectrum displays three absorption features centered at 1.6, 2.0 and 3.0 µm, which correspond to the absorption bands of water ice. These measurements confirm the presence of an icy grain halo in comets and will provide estimates of the thickness of the ice coatings of the grains. An additional ice component (e.g. methanol ice) may be required to explain the depth and shape of the 3-µm absorption feature. Analysis of the later sets of data is in progress in order to study the possibility of survival of icy grains at higher temperatures.

Noble Gases in comet Hale-Bopp. V. Krasnopolsky, M. Mumma, and M. Abbott (CEA/UCB), B. Flynn (CEA/UCB), D. Yeomans (JPL), P. Feldman (Johns Hopkins U), and C. Cosmovici (IFSR, It.) (1997) detected emission of He 584 A for the first time in comets, using the Extreme Ultraviolet Explorer. Helium appears in comets due to charge exchange of solar-wind alpha-particles with cometary neutrals, a process which is essentially similar to that which excites X-rays. They also obtained the first sensitive upper limit to neon in comets. This limit shows that cometary neon is depleted relative to the solar abundance by more than factors of 25 and 200 for cometary gas and gas plus dust, respectively. This means that the cometary ices formed at or experienced temperatures higher than

25 K.

X-ray Emission from Comets. M. Mumma reported the discovery of X-rays in comets, using observations of comet C/1996 B2 Hyakutake by the Roentgen Satellite (with C. Lisse) and the Extreme Ultraviolet Explorer (with V. Krasnopolsky and others). V. Krasnopolsky, M. Mumma, and M. Abbott (CEA/UCB), B. Flynn (CEA/UCB), D. Yeomans (JPL), P. Feldman (Johns Hopkins Univ.), and C. Cosmovici (IFSR, It.) (1997) reported detection of soft X-rays in comet Hale-Bopp, while Mumma, Krasnopolsky, and Abbott (1997) reported detections from comet d'Arrest, and an upper limit for comet Bradfield, and analyzed the emissions from all four comets. The spatial distribution of X-rays in comets Hyakutake, Hale-Bopp, and d'Arrest were measured. Along with ROSAT observations of Hyakutake and other comets, EUVE observations demonstrated that X-ray emission from comets exceeds the level expected for scattering and fluorescence of solar X-rays by three orders of magnitude, and revealed that comets are a new general class of X-ray emitters.

Krasnopolsky calculated intensities for six processes of X-ray excitation in cometary dust and eight processes in gas, to identify the X-ray excitation process. The calculations showed that only charge transfer of solar wind heavy ions (proposed by T. E. Cravens) and scattering of solar X-rays by very small (10^{-19} g) dust particles could contribute significantly to the observed cometary X-ray emission. Mumma (with T. Northrop, C. Lisse, and M. Desch) examined excitation of X-rays by electron bremstrahlung. Correlation of X-ray luminosities with gas and dust production rates, intensities at brightness maxima and their sunward offsets from nuclei favor charge transfer as the dominant process for X-ray excitation in comets.

Origin of Cometary Particles. Recent laboratory results by R. Cody and collaborators suggest that not all of the carbonaceous particles (the "CHON" particles) in the cometary outflow date from the early solar system. Some fraction of these cometary particles may be produced in situ from the photolysis and subsequent reaction of organic molecules, released from the ice and entrained in the escaping water vapor. Using a new laboratory technique, R. Cody is producing small carbonaceous particles by laser photolysis (193 nm) of gas mixtures of parts per million of small aromatic molecules and water in a carrier gas at atmospheric pressure. Nitrogen, Argon, and Helium have been used as carrier gases. The size range of the particles is submicron according to the amount of time needed to settle by gravity. Particulate samples have been heated treated at 315 K for varying lengths of time. FTIR spectra are measured of the particles from 2.5 - 14 microns (4000 - 750 cm^{-1}). Differences in the spectra of the particulate samples depend upon the carrier gas used and whether the sample was heat treated. Work is continuing to understand the formation of these grains.

Studies of the spectral evolution of magnesium silicate smokes annealed in vacuo for various times have shown that the spectra of comets displaying a feature near 11.3 microns previously attributed to "crystalline olivine" probably contain only amorphous silicates. Hallenbeck and colleagues found that the 11.3 micron feature arises naturally as a consequence of thermal annealing well before the amorphous silicate begins to crystallize. Deconvolution of the magnesium silicate laboratory spectra yield a series of peaks that can be applied directly to cometary observations: the peak positions remain invariant while the widths become narrower as the grains become more ordered. Application of this indicator to the widths of the deconvolved cometary spectra demonstrate that even comets that display the "crystalline olivine" feature at 11.3 microns are highly amorphous glasses containing no signs of crystallinity.

Sodium. K. Ogilvie, M. Coplan (UMCP), and L. McFadden (UMCP) observed that comet Hale Bopp possessed a tail structure containing an unexpected quantity of sodium. During its flyby through the tail of comet Giacobini-Zinner, the ICE ion composition instrument showed an unexpectedly high concentration of an ion with mass/charge 23±1Amu/e. At the time this was identified with C_2^+, even though there were some problems with this interpretation. After reviewing the data, which was taken at a distance of 7800 km form the nucleus of the comet, we have changed our interpretation, and now assert that the species observed was Na^+. Observing this ion at this distance has consequences for the composition of the comet and the distribution with position of sodium, which are discussed in a paper presently submitted.

V. SUN-EARTH CONNECTIONS

Heliospheric Physics

Distant Heliospheric Magnetic Field. Voyagers 1 and 2 are now in the distant heliosphere, where the pressure of the pickup ions greatly exceeds that of the magnetic field and solar wind plasma. Voyager 2 has moved beyond 50 AU and is at a latitude of ~ 16S, while Voyager 1 is beyond 62 AU at a latitude of ~ 32N. From 1990 through 1995, Voyager 1 (V1) moved from 39.9 AU to 61.7 AU in the distant heliosphere, at a latitude of 32 1N. During this period of declining solar activity, the latitudinal extent of the sector zone (the region containing sectors and the heliospheric current sheet) was decreasing. From 1990 through 1992, V1 observed both positive and negative magnetic polarities, indicating that it was in the sector zone. From 1993 through 1995, V1 observed primarily positive magnetic polarities, indicating that it was above the sector zone. The transition in the V1 polarity distribution at the beginning of 1993 implies that the maximum latitudinal extent of the sector zone was then 32 N. This transition is related to a decrease in the maximum latitudinal extent of the computed neutral line in the solar corona. The "classic model" of the neutral line provides a better description of the V1 polarities than the "radial model". The latitudinal extent of the sector zone was nearly constant from the sun to 50 AU.

The distribution of elevation angles of the magnetic field was gaussian both at V1 in the distant heliosphere and near 1 AU during each of the years from 1990 through 1995. The width of the distribution did not change significantly at V1 from 1986 through 1995, consistent with little (<5) or no variation with radial distance from 40 to 62 AU and latitude from 31 to 33. The width of the distribution of elevation angles at 1 AU did vary with solar activity, being 5 greater at solar maximum than at solar minimum, possibly owing to the extreme north-south fields in many ejecta, which are more frequent near solar maximum.

During 1993 and 1994, the solar coronal holes and the heliospheric current sheet were relatively stationary, and recurrent streams and interaction regions with periods of the order of the solar rotation period were present within 5 AU. One expects that during 1994 Voyager 2 (V2) (located at 43 AU and at 12S latitude, in the sector zone) would have observed some evolutionary form of corotating streams and interaction regions. A study by L. Burlaga and Ness found some surprising results. Correlated, quasi-periodic variations in B and N with a period of 26 days (corotating merged interaction regions) were *not* observed at 43 AU. Yet, the speed and temperature profiles were quasi-periodic. A $f^{-5/3}$ spectrum of the magnetic field strength B was observed at 43 AU, indicating the dominance of Kolmogorov turbulence in the range ($2.7\ 10^{-6}$-$2.3\ 10^{-5}$)Hz. Nevertheless, the speed fluctuations had a f^{-2} spectrum in the range ($8.8\ 10^{-7}$-$2.3\ 10^{-5}$)Hz, suggesting the dominance of shocks. There is a qualitative difference between the observations made earlier at 14 AU and those made 43 AU, suggesting a change in the state of the solar wind as it moves between these two positions. This change involves a transition from a quasi-periodic (ordered) state in B and N at 14 AU to a disordered state at 43 AU and from an aperiodic state in V and T at 14 AU to a quasi-periodic state at 43 AU. It was suggested that this transition is a consequence 3-D MHD effects, the intermediate-scale fluctuations, and the interstellar pickup ion pressure.

Timing Accuracy for Magnetic Field Structures. The emphasis on multi-point measurements resulting from the plethora of spacecraft currently operational raises important questions including the degree of accuracy expected in extrapolating upstream solar wind measurements downstream to points on the Earth's magnetosphere. A team of investigators at Goddard Space Flight Center including M. Collier, J. Slavin, R. Lepping, A. Szabo, and K. Ogilvie using data from the WIND and IMP 8 spacecraft have evaluated using a cross-correlation analysis the timing accuracy expected from multi-point measurements. Given the WIND and IMP 8 trajectories, about 88% of the time the timing accuracy will be good to within 25%.

Solar Wind Oxygen Isotope Ratios. Oxygen isotopic composition provides invaluable information on the formation and evolution of a variety of astrophysical systems. In particular, solar isotopic abundances establish a basis for interpreting isotopic abundances and their variations in meteorites and planetary reservoirs and provide constraints on and input for solar and stellar atmosphere models. M. Collier along with a team of scientists at the University of Maryland, College Park and the University of Bern, Switzerland using data from the MASS instrument on the WIND spacecraft, a high resolution mass spectrometer, have observed the isotope oxygen-18 in the core solar wind for the first time. The results indicate an oxygen-16 to oxygen-18 isotopic abundance of 450+/-130, consistent with previous measurements of this ratio from solar energetic particles and solar spectra as well as with the terrestrial value of about 500. With more data, the oxygen-16/oxygen-18 as well as other isotopic ratios, will be even more tightly constrained and, with corresponding refinements in SEP results, will provide a sound basis for comparison.

CIRs. During the period covered by this report a study has been carried out using plasma observations from the SWICS instrument, magnetic field observations, and energetic particle measurements made by the Hi-Scale instrument, aimed at a better understanding of the structure of Co-rotating Interaction Regions (K. W. Ogilvie, E. C.

Roelof and R. J. Forsyth). This has shown that the interplanetary magnetic field plays a large part in the distribution of energetic (up to 5 MeV) particles within the region.

L1 Wind Measurements. In collaboration with MIT and the University of Maryland, work is proceeding on the study of the differences between solar wind measurements taken at L1 and near the earth. Besides being useful for "space weather" studies, we expect these and other similar studies to inform us on the scale size of irregularities in the solar wind.

Lunar Wake. The Wind spacecraft has spent most of its orbital life up to this time in double lunar swingby orbits. It has interacted closely with the moon on fourteen occasions to date, at distances from the moon ranging from five to more than twenty-five lunar radii. Effects were observed due to the moon by the plasma wave and plasma instruments, allowing studies of the lunar wake to be carried out and the results compared with theory (Ogilvie et al., 1994, Owen et al, 1994). Longer and more comprehensive papers than those cited here are in preparation, generalizing the interaction of the solar wind plasma with the moon to its interaction with other smaller bodies such as asteroids and other solar system objects.

Strahl. The payload of the Wind spacecraft contains a specialized detector system to measure the characteristics and variability of the solar wind (Strahl, Fitzenreiter et al., 1997) a beam of electrons in the energy range of hundreds of eV which escape to corona and follow the interplanetary magnetic field away from the sun. A full reduced set of observations of this phenomenon are available form launch to date, at a time resolution of one complete measurement every six minutes. The first application of this data set is for a study of the polar rain, being carried out in collaboration with the HYDRA instrument on the POLAR spacecraft. The polar rain is thought to result from the entry of electrons from the solar wind to the Earth's tail at great distances. The conservation of the adiabatic invariant during the motion of the electrons form the low to the high field regions causes them to fill a large solid angle over the poles.

Simulation of Solar Wind Turbulence. A new MHD code using a Flux Corrected Transport algorithm has been modified by A. Deane (UMD), D. A. Roberts, and M. Goldstein to include the spherical expansion of the solar wind. Roberts and Goldstein have now applied the code to sheared flow, and extensions to include the Parker spiral and current sheets are underway. In addition to demonstrating wave acceleration of the wind, the results establish that a Kolmogoroff spectrum can result in an expanding medium, as in the solar wind.

Magnetic correlations in the solar wind: S. Ghosh, M. Goldstein, and A. Roberts have collaborated to show that the well-known two-component structure of two-dimensional correlation function measurements of solar wind magnetic fluctuations (Maltese Cross) can be reproduced from time averaging the nonlinear evolution of field-aligned Alfvén waves with pressure-balanced magnetic structures and velocity shears. This introduces an alternate explanation for the observations, which have previously been cited as examples of quasi-2D dynamics embedded in nearly-incompressible 3D MHD turbulence. The results suggest that Alfvén wave interactions with structures and velocity shear in the expanding solar wind may correctly reproduce several features that have historically been assigned to fully nonlinear MHD turbulent relaxation.

Hall and FLR effects on MHD turbulence spectra: Solar wind power spectra often steepen at frequencies above the Doppler-shifted proton cyclotron frequency. S. Ghosh, M. Goldstein, V. Jayanti, and A. Roberts have studied finite-Larmor radius (FLR) and Hall effects in a multidimensional MHD model. They demonstrated that the FLR and Hall terms can lead to spectral steepening at the ion inertial scale of the fluid MHD system independent of wave-particle dissipation effects. Spectral steepening is particularly significant during states of high cross-helicity turbulence.

Density fluctuation levels in MHD turbulence: S. Ghosh, A. Roberts, and M. Goldstein have collaborated with A. Bhattacharjee (U. Iowa) to investigate density fluctuations scalings in MHD turbulence in the presence of magnetic inhomogeneities. Theoretical calculations suggest that density scalings should vary as the sonic Mach number in the presence of magnetic inhomogeneities and as the square of the sonic Mach number in their absence. This research may explain the dual presence of Mach-number and Mach-number-squared density fluctuations in the solar wind.

Spectral anisotropies in MHD turbulence: S. Ghosh and A. Roberts collaborated with W. Matthaeus (U Delaware) and S. Oughton (U College London) to measure the degree of spectral anisotropy of decaying MHD turbulence in the presence of a mean magnetic field. They found a simple predictive model for the scaling of spectral anisotropy as a function of fluctuating magnetic field over total magnetic field. The relation is valid for incompressible and weakly compressive MHD systems.

Nonlinear Alfvén Waves. The derivative nonlinear Schrödinger (DNLS) equation has been used by several investigators to study the nonlinear behavior of finite amplitude Alfvén waves near shocks and comets and in the solar wind. The exact solution of the DNLS equation is a soliton. V, Jayanti, in collaboration with B. Buti, performed 1D MHD simulations with the soliton as the initial condition to study the validity of the solution. They found that for β (the ratio of thermal pressure to magnetic pressure) < 1, the soliton steepens at the trailing edge for right-hand polarization, while for left-hand polarization the steepening occurs at the leading edge. However when $\beta > 1$, the steepening is reversed for both polarizations. To see the effects of the wave-particle interaction on the nonlinear evolution of Alfvén waves, they introduced a heat-flux into the equation of state. The thermal conductivity was modeled to mimic the wave particle interaction. Parallel propagating linearly and elliptically polarized Alfvén waves evolve into S-shaped rotational discontinuities, while quasi-parallel circularly polarized Alfvén waves evolve into arc-shaped structures.

Kinetic Effects in th Solar Wind. Recent findings of the anisotropies of the proton and heavy ion core distributions in the fast solar wind has renewed interest in the potential role of cyclotron interaction processes in contributing to these anisotropies and in the fast wind acceleration. E. Siregar, in collaboration with A. F. Viñas and M. L. Goldstein, has initiated a study of proton cyclotron interactions in low collisional regimes. We showed that the evolution of the principal pressures has a strong anticorrelations in time (up to -0.96) with the ensemble-averaged wave energy density. These results hold true for both the single wave and broadband spectrum of waves and for various resonance strengths. These anticorrelations were predicted in a previously published quasifluid model. Current efforts focus on the departure from adiabatic invariance as a function of resonance strength and plasma beta, for the cases of a single wave and broadband spectrum of waves and the incorporation of electron dynamics and its role in the evolution of a parallel electric field and heat flux.

Magnetic Clouds. Magnetic clouds were discovered by LEP scientists in 1980. They are interplanetary ejecta defined by intense magnetic fields, a smooth rotation of the magnetic field direction through a large angle as the structure moves past a spacecraft during the course of a day, and low proton temperatures. An extraordinary magnetic cloud was observed by the WIND spacecraft in January, 1997, which was analyzed by L. Burlaga and several other WIND investigators. The magnetic field configuration in the magnetic cloud was approximately a constant-, force-free flux rope. The $^4He^{++}/H^+$ abundance in the most of the magnetic cloud was similar to that of the streamer belt material, suggesting an association between the magnetic cloud and a helmet streamer. The most notable feature was a plug of material at the rear of the magnetic cloud, which was very cold and had exceptionally high density. This dense region had an unusual composition, including a) a relatively high (10%) $^4He^{++}/He^+$ abundance (indicating a source near the photosphere), b) $^4He^+$, with an abundance relative to $^4He^{++}$ of about 1%, and c) the unusual charge states of O^{5+} and Fe^{5+} (indicating a freezing-in temperature of (1.6 - 4.0) 10^5 K, which is unusually low but consistent with that expected for prominence material). This is the most complete and convincing evidence for the existence of prominence material in the solar wind. The CME was seen in the solar corona on January 6, 1997 by the LASCO instrument on SOHO shortly after an eruptive prominence. A helmet streamer was observed near the latitude of the eruptive prominence a quarter of a solar rotation before and after the eruptive prominence. These observations are consistent with recent models for a quasi-static helmet streamer containing a force-free flux rope, which supports prominence material.

Magnetic clouds expand, and the magnetic field strength profile is asymmetric as a result. In a magnetic cloud, the electron temperature greatly exceeds the proton temperature and it is anticorrelated with the density. The model of magnetic cloud as a static constant- force-free configuration controlled only by magnetic forces provides a zeroth order description of the magnetic cloud, but it cannot explain the dynamic and thermodynamic properties. A similarity solution of the MHD equations was found which describes many features of the structure, dynamics and thermodynamics of magnetic clouds. This solution and its relation to the observations were reviewed by V. Osherovich and L. Burlaga.

E. Sittler and L. Burlaga have recently analyzed Voyager plasma electron data for specific magnetic cloud identifications. The analysis shows that the electrons obey a polytrope relation where the polytrope index is less than 1. They trace this phenomena to the non-Maxwellian character of electrons within magnetic clouds. Although the core and halo electron components themselves may obey polytrope laws with indices greater than 1, the total electron gas does not. The relatively large contribution of halo electrons to the total electron pressure within magnetic clouds contributes to this phenomena.

October '95 Magnetic Cloud Study. R. Lepping, L. Burlaga, A. Szabo, K. Ogilvie, and W. Mish, and D. Vassiliadis [in collaboration with A. Lazarus, J. Steinberg (MIT), C. Farrugia, J. Janoo (UNH), and F. Mariani (U Roma, Italy) studied the dramatic magnetic cloud of October 18-20, 1995, in terms of its interplanetary characteristics and it effects on the Earth's magnetosphere. Such interplanetary field structures have been shown to have helical field topology, know as magnetic flux ropes, which are believed to be common among astrophysical plasma objects throughout the universe. Employed is a simple magnetic field model of these cloud structures that depends on their special property, which is that their internal forces are almost entirely magnetic. From this model the cloud's tilt, amount of magnetic flux, cross-sectional size (0.27 AU diameter), and other geometrical properties were determined. For example, its axis was estimated to be nearly perpendicular to the Sun-Earth line and close to the ecliptic plane.

Magnetic Flux in Magnetic Clouds: R. Lepping and A. Szabo were joined by GSFC solar physicists (C. DeForest and B. Thompson) to study the magnetic flux characteristic of a large set (30)of interplanetary magnetic clouds (flux ropes) observed over many decades and categorized according to their occurrence during either solar max or min. Also three specific examples of the 30 which occurred during the SOHO time-frame were focused upon, in order to try to compare their flux content to apparently related solar photospheric magnetic flux, since the flux rope's field is believed to be anchored in the photosphere. Relatively good correspondence of these fluxes (by a factor of about 2) has been shown. Curvature of interplanetary discontinuity surfaces:

Discontinuities. A statistical study of the curvature of the surfaces of rotational and tangential discontinuities in the solar wind at 1 AU, on the scale of 10's of Re's, using WIND and IMP-8 magnetic field and solar wind velocity data has been initiated (R. Lepping and A. Szabo). Programs are presently being developed now for the dual spacecraft study, but plans include the possibility of data from a third spacecraft, among ACE, GEOTAIL, or INTERBALL.

Heliospheric Current Sheet. A. Szabo and R. Lepping, in collaboration with K. Paularena (MIT), identified heliospheric current sheet (HCS) crossings in the IMP 8 Earth magnetosheath data corresponding to interplanetary measurements made by the WIND spacecraft. Correlating the two sets of observations, it was found that the HCS is significantly distorted in the magnetosheath in such a way that its surface normal bends towards the local bow shock normal direction. Also, the magnetohydrodynamic type of the HCS discontinuity often changed as it crossed the Earth bow shock most often changing from rotational to tangential

Solar Radio Bursts. D. Lengyel-Frey (U. Maryland), G. Thejappa, R. MacDowall, R. Stone, and J. Phillips (Los Alamos) published Ulysses results showing that Langmuir and lower-frequency electrostatic waves occur primarily upstream of interplanetary shocks, which indicates that type II solar radio burst emission is generated in the upstream or transition region of the associated shock. M. Reiner, M. Kaiser, J. Fainberg, and R. Stone published the first dual-spacecraft, 3-D triangulation of the trajectory of a solar type III radio burst, using Wind and Ulysses radio observations, leading to the unambiguous determination of a density-distance scale in the solar wind. G. Thejappa and R. MacDowall analyzed the wave activity associated with a local type III event, which shows evidence for near simultaneous occurrence of ion-acoustic, whistler, and Langmuir waves which suggest the coexistence of weak and strong turbulence processes.

Wave Particle Interactions. Ulysses observations were used to explore a number of the wave particle interactions that occur in the heliosphere. R. Hess, R. MacDowall, and others presented ion-acoustic wave observations near interplanetary shocks, showing that the probability of wave occurrence is highly correlated with the ratio of electron to ion temperatures. N. Lin (U. Minnesota), P. Kellogg (U. Minnesota), R. MacDowall, and others studied Langmuir waves associated with solar wind discontinuities at low and high-heliolatitudes, showing that the wave-associated discontinuities are primarily rotational at low latitudes, but tangential at high latitudes, i.e., in fast solar wind; the discontinuities at high latitudes have a larger probability of Langmuir wave associations. R. MacDowall, R. Hess, N. Lin, and G. Thejappa published an overview of the Ulysses wave observations during the spacecraft's fast latitude scan, which show significant differences between the wave characteristics in fast and slow solar wind. N. Lin, P. Kellogg, R. MacDowall, and others also studied Ulysses VLF wave observations to understand the mechanisms that regulate electron heat flux. It is found that VLF electrostatic waves are enhanced during periods of reduced hear flux, suggesting that these waves are involved in heat flux regulation.

Solar Ejecta. D. Berdichevsky and coworkers found evidences at the Sun and upstream of the Earth for the occurrence of multiple ejecta during the April 7-11, 1997 ISTP Sun-Earth Connection Event. This event had strong geomagnetic consequences with local observation of auroras as South as Boston. The proposed interpretation of the event is of relevance to a better understanding of space weather.

Magnetospheric Physics

Ring Current Modeling. M. Fok and T. Moore have been working on extending their ring current model. The early version of the model assumed a dipole magnetic field. The model has been recently extended to include a realistic, time-varying magnetic field configuration. The improved model is able to simulate the enhancements in the ring current ion fluxes and the associated ion precipitation in the ionosphere during a dipolarization event. The effect of drift-shell splitting on the ring current ion pitch-angle distribution has also been studied. The energetic neutral atoms (ENA) emitted from the ring current contain information of the energetic ions and can be used as a imaging tool of the ring current. This neutral atom imaging of the ring current is one of the scientific objective of the IMAGE mission. Two particle detectors on IMAGE are designed to measure ENA from the ring current. Medium-Energy Neutral Atom (MENA) imager and High-Energy Neutral Atom (HENA) imager measure neutrals from 1-30 and 10-200 keV, respectively. Our ring current model is used to generate ENA images that MENA and HENA would see. Instrument counts along the IMAGE orbit are generated according to the instrument parameters of MENA and HENA. The simulated results provide information on the sensitivity range, spatial and temporal resolution requirements for the imaging instrumentation.

Multi-spacecraft Substorm Study. D. H. Fairfield, with numerous colleagues, has investigated a magnetospheric substorm using data from the Geotail spacecraft and five other supporting ISTP (International Solar Terrestrial Physics) spacecraft plus ground data. The Geotail data were taken at 2300 Local Time and 13 Re (Earth radii) in the geomagnetic tail during a typical substorm. Geotail plasma, magnetic field, electric field, and energetic particle data, when analyzed together, revealed a one minute interval of time at substorm onset when plasma convected earthward with a velocity of 2000 km/s, the highest flow velocity ever recorded in this region. Such flows are probably not unusual but are difficult to detect because of their limited spatial scale and their unexpected magnitude. Such flows carry a substantial fraction of the substorm energy and the magnetic flux increase seen in the inner magnetosphere, even if the spatial scale of the flow is as small as 1 Re. This event demonstrates how substorm energy is transported largely in sudden discrete bursts of limited spatial extent rather than slower long-duration flows of broad spatial scale. The flow onset time agreed within a fraction of a minute with the onset of auroral kilometric radiation observed by the Wind spacecraft, thus demonstrating an intimate connection between these phenomena. The largest-ever 50 mV/m electric field associated with the fast flows is undoubtedly important in accelerating the energetic particles which in this case were observed at geosynchronous orbit 3 minutes after the onset. These results strongly support the simulations of J. Birn of Los Alamos National Laboratory and M. Hesse of LEP that indicate substorm onset is the result of reconnection in the magnetotail near 23 Re.

Sudden Impulses. The ISTP program allows investigators the opportunity to study the effect of solar wind pressure discontinuities on the magnetospheric system routinely using multiple spacecraft. This represents the magnetospheric response to a step function impulse. M. Collier, J. Slavin, R. Lepping, K. Ogilvie, and A. Szabo are investigating the effect of pressure discontinuities in the solar wind on the magnetotail using data from the WIND and IMP 8 spacecraft. Two events have been analyzed in detail to date. It has been shown that a simple model in which a uniform field is compressed by a step function constriction accurately predicts characteristic time scales, which are on the order of minutes, and the magnetic field profiles. The results of this study indicate that the magnetotail maintains an approximate MHD equilibrium as it responds rapidly to interplanetary pressure discontinuities.

Simulations. In an effort lead by S. Curtis, a new generation of global simulations of the terrestrial magnetosphere are being developed. This simulations use both tetrahedral and cubic meshes that are adaptively refined during the calculations to produce the highest resolution in volumes which have the greatest changes in physical parameters. The choice of refinement parameter is variable and can involve spatial gradients or as a specific example normalized electrical current densities which are particularly useful for resolving magnetospheric boundaries. Although presently restricted to the magnetohydrodynamic (MHD) fluid approximation, schemes to include finite ion gyroradii and Hall effects are being actively pursued. The incorporation of these effects will allow the computations to extend beyond the ion gyroradius scale length limit of the MHD approximation and resolve some of the physics of astrophysical plasma boundary layers. Although there exist codes that can treat regions of the magnetosphere with a greater inclusion of kinetic effects, the lack of self consistency in these micro and mesoscale codes across greater scales makes them of doubtful utility in our attempts to understand the magnetosphere as an integrated, multiscale system.

Collisionless Magnetic Reconnection and Thin Current Sheet Formation. M. Hesse and M. Kuznetsova used 2-1/2 dimensional hybrid simulations of the driven response of the current sheet to demonstrate the formation of new thin current sheets within the larger equilibrium current sheet. A boundary layer on scales less that ion skin depths formed in which Hall electric fields cause a reduction of the ion and strong enhancements of the electron current density. Analytical considerations of momentum conservation showed consistency with this result.

As a next step M. Hesse and M. Kuznetsova developed a new code to study in detail the role of thermal versus bulk electron inertia in collisionless dissipation as required for magnetic reconnection. Analytic scaling shows that for finite electron beta thermal effects should require a slightly larger scale length that bulk inertia effects. The investigation shows that reconnection driven by electron bulk flow inertia appears to be highly nonstationary whereas thermal anisotropies tend to lead to more laminar reconnection regions. They developed fully three-dimensional hybrid and electromagnetic particle codes to generalize their studies. The particle has been applied to the problem of magnetic reconnection in high beta plasmas. First runs find similar results to the hybrid simulations, where thermal inertia effects dominate over bulk inertia in the generation of a reconnection electric field. First runs using the three-dimensional code show essentially two-dimensional behavior, until a lower-hybrid-drift instability influences the geometry significantly.

Hybrid simulations were also applied by M. Hesse and M. Kuznetsova to the problem of current driven instabilities such as the kinetic kink mode. First results here show that long wavelength kink-like perturbations can grow with growth times of tens of ion cyclotron times in sufficiently thick current sheets. In thinner sheets, kink mode growth is dominated by strong lower-hybrid-drift evolution.

Magnetohydrodynamic Simulations of Magnetospheric Dynamics. M. Hesse and J. Birn investigated the formation of thin current sheets on the basis of an adiabatic ideal MHD model. The primary applications are the substorm growth phase in the Earth's magnetotail and evolving structures in the solar corona which may lead into an eruption such as a disappearing filament or a flare. Thin current sheets are found to form both in the high-beta and low-beta case (where beta is the ratio of plasma pressure over magnetic pressure). They form in the closed field region even though the external electric field and the footpoint displacement are applied predominantly in the surrounding open field region. Larger amplitudes of the current density and a stronger localization of the current sheet are found when the applied electric field decays more rapidly away from the Earth or the solar surface. New investigations involving particle tracing in self-consistent MHD fields show that ion injections as well as electron injections in the inner magnetosphere can be explained by particle acceleration caused by a large scale magnetotail instability. Here, surprisingly, the strongest electric fields are not to be found in the reconnection region, but closer to the Earth in the region of dipolarizing magnetic field. The strong induction electric fields associated with the tail field collapse provide sufficient particle acceleration to explain the observed substorm injection at geosynchronous orbits.

Earth's Bow Shock. A. Szabo in collaboration with D. Huterer and K. I. Paularena (MIT) analyzed selected IMP 8 and WIND bow shock crossings observed in late 1994. They found that while the fitted shock normal orientations are consistent with model bow shock shapes, the shock speeds were not. In particular, the Rankine Hugoniot (RH) fit results show outward motion of the shock from Earth for all but one of the considered cases. It was concluded that the standard RH equations that were used may be missing some terms which would provide an accurate description of the balance on both sides of the bow shock. Specifically, the bow shock acceleration at its flanks is not taken into account by these equations.

Magnetic field models. N. Tsyganenko devised a new mathematical method for representing the magnetic field of the substorm current system, intended to be used in the future dynamical models of the disturbed magnetosphere. In collaboration with GEOTAIL, WIND, IMP-8, and ISEE-1/2 Principal Investigators, N. Tsyganenko has created a new modeling data set and performed a study of the global geometry of the Earth's magnetotail and its response to the azimuthal component of the interplanetary magnetic field (IMF) and Earth's dipole tilt. In this work, a new method was suggested for modeling the magnetotail twisting caused by the IMF and it was shown that (i) the twisting effect is quite significant even close to Earth, and (ii) the tilt-related warping of the plasma sheet extends well into the distant magnetotail.

Substorm Onset. D. Fairfield and A. Sundaram have analytically investigated the symbiotic effects of MHD current-gradient and pressure-gradient instabilities in an anomalously resistive current sheet region. The investigation has been carried out seeking both two-dimensional and three-dimensional perturbations. In a two-dimensional case, the study shows that the current-gradient instability is controlled by the roles of the plasma compressibility and the Lundquist number which is defined as the ratio of anomalous diffusion time to Alfvén time. For low Lundquist numbers, the fluid compressibility helps to enhance the instability and the normal magnetic field component plays only a weak stabilization role. In the three-dimensional situation, on the other hand, the work demonstrates that a linear coupling of the pressure gradient and the magnetic field curvature causes the excitation of a new class of current-gradient and pressure-gradient instabilities with their growth rates dependent on anomalous resistivity. The resistive pressure-gradient instabilities, excited in the field reversal layer, are shown to enhance the current and the magnetic field gradients in the center of the plasma sheet and thereby provide the source for the current-gradient mode with a typical growth time of 5 s. The results in the three-dimensional case have a direct bearing on recent AMPTE/IRM, GEOS 2, and Geotail data which indicate the presence of compressional mode oscillations as precursors to plasma sheet thinning and magnetic island formation.

Current Sheet Waves. D. Fairfield, A. Sundaram and D. Vassiliadis have investigated the excitation of electrostatic and electromagnetic lower hybrid waves in the magnetic field reversal region of the plasma sheet using a two-fluid theory. For a two-dimensional magnetotail configuration, the dispersive properties of lower hybrid waves near the weak field region is examined by considering nonlocal effects. The model demonstrates that a new electrostatic lower hybrid mode is excited by the magnetic field gradient and a electromagnetic lower hybrid mode becomes unstable due to the combined effects of the magnetic field gradient and the electron fluid drift across the equilibrium magnetic field. The electrostatic and electromagnetic lower hybrid modes are shown to grow in a few milliseconds and a few tens of milliseconds, respectively, the former for wavelengths shorter than the current sheet width and the latter for long wavelengths. A simple model developed here is aimed at explaining recent Geotail observations of lower hybrid waves in the entire plasma sheet region. The waves generated in the field reversal region may provide the anomalous dissipation and are therefore important for substorm onset.

Terrestrial Plasma Energization. M.-C. Fok and T. E. Moore explored the physics of geomagnetic storms and the ring current plasma that is associated with them, using comparisons of model and simulation results with published data sets. This work is also being used as the basis for simulations that anticipate the neutral atom fluxes that will be seen by the IMAGE mission neutral atom instruments. Collaborating with G. Khazanov and J. Horwitz of the Univ. of Alabama in Huntsville, and D. Delcourt of the CETP in St. Maur, France, they also explored the outflow of ionospheric plasmas through the auroral zones and polar cap regions, and the energization of plasmas of terrestrial origin in diverse contexts.

Mars. Among the terrestrial planets the least is known about the high altitude plasma environment of Mars due to the high priority given to making measurements which relate to the "search for life" as opposed to other disciplines. J. Slavin remains active in the analysis of the Phobos 2 particles and fields observations taken at Mars in 1989 as a Guest Investigator. The results continue to be very interesting. Verigin and others (some at GSFC) recently found that the dimensions of the near-tail expand and contract in response to changing upstream solar wind pressure in the much the same manner as the Earth's magnetosphere. However, in contrast, Kotova and coworkers find strong solar wind deceleration upstream of the Mars bow shock apparently due to mass loading by photo-ionized planetary neutrals in much the same manner as has been observed for cometary magnetospheres where there is no intrinsic magnetic field. Finally, McKenna-Lawlor and colleagues have evaluated the entire Phobos 2 energetic particle measurements and found no evidence of local charged particle acceleration other than that associated with interplanetary shocks and upstream photo-ion pickup. J. Slavin hopes to conduct new studies on the Martian plasma environment in the coming years as a Participating Scientist in the Mars Global Surveyor Mission.

Mercury. Despite having been taken in 1974-5, Mariner 10 observations continue to be analyzed because they are the only source of information on this very small and highly dynamic magnetosphere. J. Slavin and coworkers re-examined the Mariner 10 magnetic field measurements for evidence of the field-aligned currents (FACs) in the near-tail. At Earth these currents are the primary means by which energy and momentum are transferred from the magnetosphere to the ionosphere. At Mercury it was anticipated that the presence of a resistive regolith might quickly dissipate such currents, however, Slavin et al. found intense, Earth-like FACs following a well studied substorm event in the Mariner 10 data. While a determination of whether or not steady-state FACs can be supported at Mercury will have to await a dedicated orbiter mission, these new results strengthen the case for terrestrial-type substorms and substorm processes in this unique magnetosphere.

Magnetopauses of the outer planets. A. Szabo, in collaboration with D. E. Huddleston, C. T. Russell, and G. Le (UCLA), conducted an extensive review study of all the magnetopause crossings of the outer planets by the Voyager spacecraft. In comparing the observations, particular attention was placed on the role of reconnection when signatures of this process could be found

Ionosphere-Thermosphere-Mesosphere

Ionograms. Digital ISIS 2 topside-sounder ionograms are now available from the National Space Science Data Center (NSSDC) at the NASA Goddard Space Flight Center (GSFC). These digital ionograms are being produced by a team at the GSFC, led by R. F. Benson of the LEP, directly from a collection of the original analog telemetry tapes that have been preserved. The tapes were selected from 23 telemetry stations from the years 1972 - 1984 so as to obtain global coverage of the topside ionosphere over a solar cycle and to accommodate special requests. Presently, approximately 200 ISIS 2 satellite passes/month are being digitized. More than 1,500 satellite passes have been digitized to date, mainly from tapes recorded at the Quito, Ottawa and Alaska telemetry stations. Since most of the data selected for digitization were not processed into the conventional 35 mm analog film format, the new data base (still growing) is analogous to a new satellite mission with old data (ISIS 2 was launched in 1971). The ISIS 2 digital ionograms can be obtained through the NSSDC's NDADS/SpyCat system. Some are available for viewing on the NSSDC CDAWeb system. There are also plans to produce digital topside-sounder ionograms from selected ISIS 1 and Alouette 2 analog telemetry tapes. For information about the project and how to obtain the available data, see the ISIS page available (1) through the NSSDC space physics page at http://nssdc.gsfc.nasa.gov/space or (2) directly at http://nssdc.gsfc.nasa.gov/space/isis/isis-status.html.

Substorm Ionosphere. J. Gjerloev and R. Hoffman used data from DE-1 and DE-2 to study the electrodynamic parameters in the nighttime high latitude ionosphere during substorms. Auroral substorm passes of the low altitude DE-2 were superimposed onto auroral images obtained by the high altitude DE-1, thereby enabling a organization of the individual DE-2 passes with respect to visual key features of the auroral substorm. They used this to construct models of the height integrated Pedersen and Hall conductivities (conductance) and the DC electric field distribution. Among the characteristic features they have found are: (a) a dawn and a dusk channel of enhanced Hall and Pedersen conductance separated in latitude, (b) very high Hall conductance peak values >300 mho located in the surge sector produced by energetic electron precipitation and (c) a characteristic peak in the E-field located poleward of the convection reversal at all local times. Calculations of the Pedersen conductance from orthogonal E- and B-field variations are in good agreement with their calculations from the electron precipitation. Knowing the DC electric field and the conductance distribution enables us to calculate the ionospheric Pedersen and Hall currents and from the divergence of these the Field Aligned Current distribution has been calculated. This provided the first complete model of the electrodynamics in a auroral substorm. The results are in excellent agreement with the results of the FAC distribution found from the magnetic field perturbation, consequently serving as a confirmation of the compiled conductance and electric field models.

Equatorial Ionospheric Dynamics. In August 1994, the MALTED (Mesospheric And Lower Thermospheric Equatorial Dynamics) Program was conducted from the Alcântara rocket site in Brazil as part of the International Guará Rocket Campaign to study equatorial dynamics, irregularities and instabilities in the ionosphere. Analysis of these data has provided the first experimental evidence for gravity wave breaking in the mesosphere.

Electron Precipitation. Other studies have centered around the influence of relativistic electron precipitation on mesospheric and upper stratospheric ozone. Earlier studies from rocket data and a GSFC 2-D model prediction had concluded that highly relativistic electron events (HREs) could induce up to 30% depletions of daytime ozone near 65 km altitude at high latitude. Current studies of UARS data during the intense HRE during May, 1992, using electron data from PEM/HEPS and ozone data from CLAES and MLS show that the ozone depletion during that event was significantly lower; i.e., below 10%, which is the minimum signal that could be detected by these instruments near 60 km Unfortunately the S/N level deteriorates even further with increasing altitude making extraction of useable data above 60 km nearly impossible. However, newly developed algorithms for HALOE and HRDI may make mesospheric ozone data available there. This is the subject of an ongoing study.

Influence of Meteor Showers. With interest growing for the anticipated spectacular visual display of the Leonid meteor showers during 1998/1999, it is natural to presume that the increased fluxes of incoming particles would produce enhancements in the ionospheric concentrations of metallic ion species. If so, ionospheric composition measurements would provide a direct measure of the average elemental composition of the cometary body responsible for the stream. More than 40 rocket flights through the main meteoric ionization layer, which peaks near 95 km, have sampled the meteoric metallic ion concentrations. Five of these flights were conducted during or near the peak times of a meteor shower. These measurements were not complemented by baseline observations made for similar ionospheric conditions immediately before the shower and no rigorous quantitative comparisons were made using average non-shower distributions. Recently, J. Grebowsky and coworkers provided a detailed analysis of the impact of showers on the ionosphere by scanning, and developing a digital data base of all published meteoric ion concentration altitude profiles obtained from sounding rockets. These data provide the first empirical model of the metallic ion altitude distribution and show that meteor showers do indeed have a measurable impact on the average ionosphere composition. Although there was much variability in the observed meteoric layers, the peaks in the total metallic ion concentrations at midlatitudes observed during meteor showers had concentrations comparable to, or exceeding, the highest concentrations measured in the same altitude regions during non-shower periods.

VI. OPERATIONAL MISSIONS

International Solar-Terrestrial Physics (ISTP) Program

The International Solar Terrestrial Physics program (ISTP) has been successfully accomplishing its science goals, leading to an understanding of the influence of solar emissions on the near-Earth space environment. The Global Geospace Science (GGS) portion of this program has been scientifically managed out of the LEP with M. Acuña the ISTP Project Scientist. The fleet of satellites and ground-based facilities of the program have been tracking solar eruptions from the Sun to the Earth, with those during the intervals January 6-11 and April 7-11 of this year especially noteworthy. These surprisingly intense events for solar minimum attracted considerable media attention, with various LEP scientists providing media briefings. Since September the Sun has become considerably more active, with a large number of Earth-directed coronal mass ejections causing moderate (80 to 150 nT) geomagnetic storms with aurora extending as far south as Boston. To study these events effectively, LEP scientists, especially M. Peredo and N. Fox with B. Thompson from the SOHO Project, have arranged a series of workshops, each attracting about 125 scientists working to coordinate the diverse measurements and simulations into a global understanding of the propagation of energy from the Sun to the Earth. These workshops heighten the awareness of the community to this international endeavor, which has led to increased collaborations, even among groups who have not previously contributed. Each workshop has been better attended, with already 145 scientists registered for the workshop planned in early November. ISTP science has been featured at the international scientific meetings, including the fall and spring meetings of the American Geophysical Union, the European Geophysical Society, International Association of Geomagnetism and Aeronomy in Sweden, and topical conferences of the Global Environmental Modeling program, CEDAR, the ESLAB Symposium at ESTEC and the International Symposium on Solar-Terrestrial Coupling Processes in Greece. Polar and Wind Project Scientists R. Hoffman and K. Ogilvie and other LEP scientists have provided overviews of the missions. At least forty papers are being submitted to a special issue of *Geophysical Research Letters* on Sun-Earth Connections. The Science Planning Operations Office for GGS within LEP has developed an ISTP web site, including extensive educational and outreach material. The Sun-Earth Connection science has been the main thrust of two TV documentaries, one of which will be released in England by the end of October featuring Nicola Fox, the GGS Operations Coordinator. Among current activities led by the GGS Education and Outreach Coordinator, M. Carlowicz, an educational poster is under preparation and two proposals have been submitted for utilizing ISTP science as a learning tool for different age groups.

WIND

Magnetic Fields. The WIND MFI magnetometer system (R. Lepping, P.I.) continue to operate properly and its data contributes to countless space science studies for researchers around the world. The MFI team often collaborates directly in many of these studies, as well as take the lead in a variety of other studies, including those concerned with the heliospheric current sheet, huge magnetic clouds and their effects on Earth (part of Space Weather), interplanetary shocks, the recently discovered dual-discontinuity (MHD), magnetic holes, the lunar wake, and attempts to associate large-scale solar wind structures with their solar source, and many magnetospheric studies. The MFI investigation's Web Homepage has been significantly augmented over the last year. For example, the team' science is now described, with some examples, and an extensive bibliography has been added. Also listed are the timing of recently discovered magnetic clouds, and some of their estimated characteristics, and identified WIND bow shock crossings, both of which are useful to the space physics community for a variety of investigations, from solar physics to magnetospheric boundary studies. Negotiations are underway to join forces with an NRL team to display the results of their solar wind prediction algorithm whose aim is to foretell the probability of a solar wind feature being geoeffective as it passes the WIND spacecraft; predictions will be compared to future magnetic field data measured by MFI. Other Lab members of the MFI team are M. Acuña, J. Byrnes, L. Burlaga, W. Farrell, R. Kennon, P. Panetta, J. Scheifele, J. Slavin, A. Szabo, and E. Worley.

POLAR

Electric Fields. NASA's Polar satellite continues to acquire unprecedented data in the Earth's inner and outer magnetosphere and cusp regions. The payload includes the first vector electric field instrument to be flown in the Earth's magnetosphere. R. Pfaff and M. Hesse constitute the LEP electric field team, and F. Mozer (UCB) is the P. I of the Electric Field instrument. In depth studies of electric fields in the cusp are among the projects undertaken by LEP scientists during 1997.

Polar Wind. The Thermal Ion Dynamics Experiment-Plasma Source Instrument (TIDE-PSI) on the POLAR spacecraft made possible the first ever observations of the polar wind at high altitude, in a region of space that had previously been thought to be essentially devoid of plasma. The plasma source instrument effectively neutralizes the spacecraft, which ordinarily floats at a potential 30-50 V positive of the plasma medium through which it travels in the high altitude polar cap. This potential would otherwise repel the plasma ions, making it impossible to observe them at all. With PSI running, POLAR now routinely observes the supersonic outflowing plasma, known as the polar wind, throughout the polar regions. This supersonic plasma escape from the Earth, has now been unambiguously shown to travel through the polar lobes of the magnetosphere, after which it travels far down the magnetospheric tail and supplies plasma to the energetic processes that generate plasma storms in the magnetosphere. TIDE also has made new observations of plasma heating in the auroral zones, which is responsible for the escape of the heavier atmospheric components including Oxygen and its molecules. Comparison with auroral imagery allows the relationship of plasma heating and auroral activity to be studied with unprecedented detail and comprehensiveness.

Ulysses

The Ulysses spacecraft is now in the second orbit of its exploration of the high-latitude heliosphere. In late 1997, the spacecraft passed through the ecliptic into the southern hemisphere, on its way to a latitude of -80°. When it overflies the southern solar pole in 2000, the sun will be near maximum activity. It is expected that the high latitude heliosphere will appear more similar to that at low latitudes than was the case for the first orbit. The GSFC contributions to Ulysses include involvement with two of its instruments: the Unified Radio and Plasma Wave investigation (URAP) and the Solar Wind Ion Composition Spectrometer (SWICS). URAP co-investigators at GSFC are M. Desch, J. Fainberg, M. Goldstein, M. Kaiser, R. MacDowall (Principal Investigator), M. Reiner, and R. Stone (PI Emeritus); K. Ogilvie is a co-investigator on the SWICS team. The research activities of these groups are detailed above.

Stimulated Emission. R. Benson and colleagues in the LEP found support for an earlier interpretation of plasma emissions stimulated by the relaxation sounder of the unified radio and plasma wave instrument (URAP) during the encounter of Ulysses with Jupiter's Io plasma torus. This interpretation attributed the observed emission spectra to eigenmodes of cylindrical oscillations of electromagnetic fields as first proposed by V. Osherovich. The cylindrical structures involved can be considered to be magnetic-field aligned electron-density irregularities. The interpretation has special significance because it is also believed to apply to commonly observed magnetospheric emissions stimulated by natural processes. Thus it can be used to yield electron density measurements even in low density planetary magnetospheric environments where other techniques often fail. It was used earlier to determine both the electron density and the magnetic field strength in the Io plasma torus. The new work explains why some spectral features prominently observed by radio sounders operating in the terrestrial plasma environment were not observed by URAP in the Io plasma torus. .

FAST

R. Pfaff is the NASA Project Scientist for NASA's FAST mission; C. Carlson (UCB) is the P. I.. The FAST satellite continues to acquire excellent data and provides an exciting new look on acceleration processes at the interface of the hot, magnetospheric plasma and the cool, ionospheric plasma. Several major discoveries have already been reported by the FAST science team. In 1997, an in-depth campaign period was conducted in Alaska and in Sweden that brought together concentrated satellite and ground-based observations. Instruments on FAST include fast energetic electron and ion spectrometers, vector DC and AC electric and magnetic field detectors, and an energetic ion composition instrument

IMP-8

Particles and Fields. IMP-8 has now been providing useful fields and particles data for over 24 years and continues in its role as participant in the ISTP (IS THERE A NEW NAME?) program. It functions as either an upstream solar wind monitor providing information on solar wind energy and the specific magnetic field state-function for studies of the magnetosphere, and increasingly as a source of in situ magnetospheric data, especially magnetotail data, since other solar wind monitors, such as WIND and ACE, are in orbit. IMP-8 has contributed valuable data to solar, solar wind, magnetospheric, and cosmic ray physics for over a complete solar cycle (i.e., 22 years), and is unique in that regard. IMP-8's role has been enhanced by assuming a partnership with many other spacecraft by helping to form various constellations with them for ISTP correlative studies. J. Slavin and A. Szabo have recently been officially approved for the role of co-investigators on the IMP-8 magnetometer (MAG) team (R. Lepping, P.I.). The magnetometer team continues to develop MAG's Web Homepage, which now provides IMP-8 magnetic field data in a useful form to the public, a description of the investigation, and its role in the ISTP program. Major areas of study by the team are large-scale interplanetary structures, the bow shock and magnetosheath (A. Szabo and R. Lepping) as well as the magnetotail (J. Slavin).

Mars Global Surveyor

The Mars Global Surveyor spacecraft has recently begun science operations in orbit about Mars. The science payload includes a Magnetometer and Electron Reflectometer experiment (M. Acuña, P.I.) to measure the magnetic field and plasma in the near space environment of Mars. The magnetometer and flight processor was built at GSFC and the Electron Reflectometer was provided by the CESR in Toulouse, France, under the direction of Henri Reme and in collaboration with colleagues at the University of California at Berkeley. The investigation is currently acquiring data throughout the aerobraking phase of the mission, in which the highly elliptical orbit of the MGS spacecraft is circularized by repeated passage through the Mars atmosphere at periapsis altitudes of approximately 100 km.

Preliminary findings include the discovery of many crustal magnetic anomalies scattered about within the crust of Mars, the outer shell of the planet's surface with a thickness of a few tens of km to perhaps 100 km. Only a small fraction of the surface has been mapped thus far but it is clear that the magnetic anomalies are characterized by various orientations and magnitudes. These are presumed to be the relics of an early (now extinct) Mars global magnetic field, produced by dynamo action in the planet's interior. The electron instrument, operated in a Langmuir Probe mode near periapsis, measures ionospheric electrons both inbound and outbound from periapsis demonstrating that the MGS spacecraft penetrates beneath the Mars ionosphere during aerobraking. The mapping phase of the mission, to begin in 1998, will provide full global spatial coverage of mars from a circular or nearly circular orbit at higher altitude (approximately 350 km). Over the life of the mission we will characterize the near space environment of Mars (bow shock, solar wind interaction with the ionosphere and magnetized crust of Mars), the Mars ionosphere, crustal magnetic anomalies and their relationship to crustal mineralogy, the Mars topography and gravity fields, and imagery (IR and visual). GSFC researchers are M. H. Acuña, J. E. P. Connerney and P. Wasilewski.

Cassini

Composite InfraRed Spectrometer. With the successful launch of the Cassini spacecraft and the beginning of its long journey to the Saturn system, several members of the LEP can take satisfaction in the success of their efforts in planning this mission and building instruments for it, and look forward to the data acquisition and analysis in the coming years. The Composite Infrared Spectrometer (CIRS), on the orbiter, is a Fourier-transform spectrometer that will measure planetary radiation over two decades, from 10 cm$^{\1}$ (1 mm wavelength) to 1400 cm$^{\1}$ (7 µm), with a spectral resolution up to 0.5 cm$^{\1}$. The instrument was built at the Goddard Space Flight Center, but with key components fabricated at Oxford University and the Service d'Astrophysique/Saclay in France. The international science team, led by V. Kunde, includes LEP scientists G. Bjoraker, J. Brasunas, F. M. Flasar, D. Jennings, P. Romani, J. Pearl, R. Samuelson, D. Glenar, and R. Achterberg. J. Brasunas, B. Lakew, D. Walser and R. Fettig (Karlsruhe University, Germany) constructed, aligned and tested the CASSINI CIRS focal plane #1 sub-assemblies-detectors, non-imaging concentrators, and impedance-matching transformers for the long wavelength channel (16 to 1000 m wavelength) .In addition to the institutions indicated above, the science team includes investigators from Observatoire de Paris-Meudon, Queen Mary and Westfield College/University of London, Instituto di Astrofisica Spaziale in Rome, Gesamthochshule Wuppertal in Germany, JPL, Marshall Space Flight Center, Cornell University, and the University of Hawaii. CIRS spectra will permit a detailed spatial mapping of temperatures, gas composition, and aerosols in the atmospheres of Saturn and Titan that will address fundamental questions pertaining to their meteorology, chemical processes, and evolution. In addition, the spectra will characterize the composition and thermal properties of the surfaces of the other icy satellites and Saturn's rings, which bear on issues related to their origin and evolution.

Radio Observations. F. M. Flasar is also a member of the Cassini Radio Science facility instrument team. This experiment uses the spacecraft high-gain antenna to transmit and receive monochromatic signals at three bands, S (13-cm wavelength), X (3.6 cm), and Ka (0.9 cm). Doppler tracking of the frequency shifts received by the Deep Space Network stations is used in a variety of investigations, including: a) a test of General Relativity to high accuracy by determining the bending of the radio signal emitted by the spacecraft at solar conjunction; b) measurements of the solar corona plasma; c) detailed measurements of the gravity moments of Saturn and Titan and measurements of the gravity fields of the other icy satellites; d) determination of Saturn's ring structure from the observed attenuation and scattering of the radio signal; and e) retrieval of the vertical profiles of ionospheric electron density of Saturn and the other icy satellites and vertical profiles of atmospheric temperature and pressure of Saturn and Titan, from the inferred refraction of the radio signal as it traverses the atmospheres/ionospheres.

CAPS. The plasma group in Code 690 has provided key high-voltage and electronic sub-systems for the Cassini Plasma Spectrometer (CAPS). This effort is headed by E. Sittler (Co-I) with support from T. Vollmer, M. Johnson, and A. Ruitberg. One of the key items is a ±16 kV supply which provides nearly 30 kV across the Linear Electric Field section of the spectrometer. The other key item is the Spectrum Analyzer Module (SAM) which accumulates mass spectra and deconvolves them using a high speed deconvolution algorithm. The CAPS instrument will provide important measurements of the plasma environment within the Saturn system and provide compositional information about Saturn, its moons, its rings and Titan.

Voyager

Magnetometers. The magnetometers on Voyagers 1 and 2 continue to function as designed and return data from unexplored regions of the distant heliosphere en route to the termination shock and heliosheath. L. Burlaga is responsible for the reduction of the data and is active in the analysis of these data, which are now the weakest magnetic fields ever measured in space.

ACE

Magnetometer. ACE was successfully launched in August, 1997. L. Burlaga is a Co-investigator on the magnetic field experiment. The magnetometer was built at GSFC by M. AcuÒa, and the experiment is managed by N. Ness at Bartol Research Institute, with the support of members of his institution.

NEAR

Hign-energy observations. The Near X-ray/Gamma-ray team (led by J. Trombka and including P. Clark, L. Evans, S. Floyd, T. McClanahan, and R. Starr) is involved in developing software and planning for the NEAR encounter with 433 Eros. T. McClanahan has developed a powerful interactive package, now being used by other NEAR instrument teams as well, to allow quick look and analytical capabilities for the spectral data on a daily basis. Relational database and spatial mapping capabilities are being developed in conjunction with colleagues at Cornell University and the University of Arizona. Solar and stellar related results obtained during the cruise phase of the mission have been reported in the Solar and Stellar Research section above.

VII. DEVELOPMENT PHASE MISSIONS

IMAGE

The IMAGE mission made the transition from definition to fabrication this year as the instruments and spacecraft passed through both their preliminary and critical design reviews. T. Moore assumed the roles of IMAGE mission scientist and lead coinvestigator for the low energy neutral atom (LENA) imager.

An active theory and modeling effort continues in support of the analysis and quantitative physical interpretation of the images to be obtained from IMAGE. T. Moore has been participating in this effort in collaboration with J. Green/630, M.-C. Fok, G. Wilson of MRC (Nashua, NH), and J. Perez (Auburn U).

Radio Sounder. A sounder known as the Radio Plasma Imager (RPI) will be one of the instruments flown on the IMAGE (Imager for Magnetopause-to-Aurora Global Exploration) satellite scheduled to fly in January, 2000 as the first Medium-class Explorer (MIDEX). The RPI (Instrument PI: B. Reinisch, U. Mass., Lowell) is one of a complement of remote sensing instruments on IMAGE (PI: J. L. Burch/Southwest Research Institute). It will employ on-board digital signal-processing techniques and will be capable of measuring echo amplitude, phase, time delay, Doppler spectrum, polarization and direction-of-arrival as a function of sounding frequency. R. F. Benson is a member of the RPI team and has helped to develop the concept of magnetospheric radio sounding based on his experience with ionospheric topside sounding. For more information on the IMAGE mission, see http://image.gsfc.nasa.gov.

LENA. M. Smith, K. Ogilvie, and F. Herrero brought the LENA instrument through its preliminary design review, upon which M. Smith departed GSFC for the UK. T. Moore was recruited to assume science leadership for LENA, with support from K. Ogilvie and F. Herrero, who continued as experiment scientist for LENA. Engineering support from LEP J. Lobell, M. Johnson, J. Johnson, and P. Rozmarynowski. In addition, science support was provided by J. Keller, D. Chornay (UMD), and M. Collier (NRC). LENA has now completed its Critical Design Review, and a subsequent review of its pioneering new surface technology for converting fast atoms to negative ions.

During the preparation of the Lena instrument for the IMAGE spacecraft much work has been carried out in collaboration with the Universities of Maryland, New Hampshire, and with the Lockheed Martin Corp. In the design of the conversion surface to the detection system. This work includes steps to reactivate the surface, a process to be carried out periodically.

Mars 2001

Gamma-rays. J. Trombka, L. Evans, S. Floyd, and R. Starr are part of a Gamma-ray remote instrument team for Mars 2001 being led by a colleague at the University of Arizona. The final design of the instrument is now being developed.

Electrical Discharge Detector. M. Kaiser, M. Desch, W. Farrell, and J. Houser have designed a combined radio and optical instrument to detect electrical discharges in dust storms on Mars. With this instrument, they will measure many of the electrical properties of the dust and deduce the sub-surface conductivity. They have submitted their design as a proposal for the Mars 2001 Lander mission.

Space Weather. A Mars radiation and space weather investigation, entitled MARIE, has been submitted to NASA Headquarters in response to the Mars 2001 Announcement of Opportunity by a joint Johnson Space Center, GSFC and Naval Research Laboratory team of scientists. The purpose of this investigation is to measure the ambient radiation in Mars orbit and on the surface for the purposes of assessing their impact on astronaut health. The secondary purpose is to investigate the Martian ionosphere and study methods of forecasting variations in the ambient radiation environment. The Principal Investigator is G. Badhwar of the Johnson Space Center. The GSFC Co-Investigators are J. Slavin and R. Pfaff. They will be responsible for providing Langmuir Probe and Plasma Wave Detector flight hardware packages and conducting a variety of space weather related investigations.

CLARK

High-energy photon detectors. R. Starr is the principal investigator for an X-ray/Gamma-ray detector package which includes CZT and APD detectors operating in the 2 to 20 keV region which is to be launched on the Clark spacecraft as part of the Small Satellite Technology Initiative. He has completed final testing on the detectors, which are now being integrated on the spacecraft in preparation for launch on a Lockheed Launch Vehicle some time late this year.

NMP/EO-1

Spectral Imager. D. Reuter and D. Jennings are developing the LEISA Atmospheric Corrector for the New Millennium Program's Earth Observer-1 (NMP/EO-1) satellite. LEISA (Linear Etalon Imaging Spectral Array) is a joint project of Codes 693 and 718 at Goddard. The Atmospheric Corrector is an inexpensive, versatile, low-mass, spectral imager using wedged filter technology. This hyperspectral imager can remove the effects of atmospheric variability in data from next generation land imagers such as ETM+, Advanced Landsat, and Resource21, as well as the Advanced Land Imager on EO-1. This instrument will provide scientific return both in improved imagery and in hyperspectral sensing capabilities. It is advancing wedged filter technologies that are relevant to wide-field coverage for many remote sensing applications.

EQUATOR-S

The EQUATOR-S mission is scheduled for launch on November 25, 1997, from Kourou, French Guyana, on board an Ariane 4 launch vehicle. EQUATOR-S is a joint German-US science mission designed to complement and enhance the International Solar-Terrestrial Physics Program (ISTP) by providing scientific measurements in the equatorial magnetosphere. Detailed science objectives include studies of the dayside magnetopause where the transfer region of mass, energy, and momentum from the solar wind to the Earth's magnetosphere take place, studies of the nightside particle acceleration and energization regions, studies of particle sources and loss mechanisms, and investigations of the Earth's radiation belt. M. Hesse serves as the US project scientist for the EQUATOR-S mission

VIII. SOUNDING ROCKETS

Electric Field Measurements. Pfaff leads an LEP electric field experimental group that designs and builds electric field double probes for flights on sounding rockets and satellites in the Earth's ionosphere. In the past year, instruments were prepared for four payloads, including antenna and electronics to measure both the DC and AC vector electric field components as well as Langmuir probes. These experiments will be launched on sounding rockets into the cusp from Spitzbergen, Norway late in 1997 and into sporadic-E layers from Puerto Rico in early 1998. On-board processing electronics have also been developed to gather burst memory data of significant flight events and on-board FFT processing was developed that extended the measured frequency regime to several MHz.

Cleft Accelerated Plasma Experimental Rocket (CAPER). The CAPER payload is scheduled for launch in Jan-Feb. 1998, with final integration during November-December, 1997. T. Moore guided the final design of the Thermal Ion Capped Hemisphere Spectrometer (TICHS), which complements the Thermal Electron Capped Hemisphere Spectrometer of C. Pollock (SwRI) to provide comprehensive core plasma observations for this payload. Mechanical fabrication for the pair of instruments is being completed at MSFC, while electronics systems have been designed and are being fabricated at SwRI.

The objective of this mission is to observe and diagnose the mechanisms of plasma heating in the topside ionosphere of the polar cleft region. Analysis has continued on the data set obtained from a previous and closely related rocket payload called Sounding the Cleft Ion Fountain Energization Region (SCIFER). M. Adrian (UAH and MSFC) and V. Coffey (MSFC and UAH) are pursuing dissertation work at UAH on the thermal plasma observations from SCIFER, while assisting in the preparations of TECHS and TICHS for the CAPER flight. SCIFER observed plasma ion heating transverse to the local magnetic field, and made the first differential directional observations of the core plasma electrons. The focus of analysis is currently on the measurement of electron heat fluxes and core drifts in the plasma heating regions.

IX. FUTURE MISSIONS

Solar Terrestrial Probes

A concept study of future Solar Terrestrial Probe missions to explore the near earth plasma environment has been led by S. Curtis and P. Pannetta with extensive GSFC partnering with private industry. Known as Geospace Multiprobes, the spacecraft are in the micro to nano class (10-100 kg). The microspacecraft employ advanced commercial-off-the-shelf technology to produce missions well beyond the those presently flying and typically have 4-6 spacecraft per mission concept. The nanospacecraft involve technologies well beyond those presently commercially available and involve 10 to more than 100 spacecraft per mission. Panetta is directing an intensive GSFC effort to identify key approaches to developing the enabling technologies for these nano-class missions. The missions are the next logical step beyond the International Solar Terrestrial Physics program which addresses the global scale aspects of the Sun-Earth Connection and will uniquely separate space and time on all scales of relevance to understanding the Sun-Earth connection through the magnetosphere into the Earth's upper atmosphere.

The Science Definition Team for the Geospace Multiprobes is chaired by D. Rust of JHU/APL, with S. Curtis as Study Scientist. Study Team members include J. Clemmons, R. Pfaff, and R. Vondrak. There are presently three missions planned in the Geospace Multiprobes line. They are Magnetospheric Multiscales, Global Electrodynamics, and Constellation. The first two missions are based upon microspacecraft. The third is based on nanospacecraft.

The Magnetospheric Multiscales mission is a 6 spacecraft magnetospheric mission composed of a Grand Tour Cluster-lite derived set of four identical spacecraft flying in a tetrahedral formation throughout the magnetosphere which make space time separated measurements on scales from 10 km - 60000 km combined with two neutral atom imaging remote sensing micro spacecraft at a different set of separations to give a global context for the cluster measurements.

The Global Electrodynamics mission is a four identical spacecraft mission with both in situ and remote sensing capabilities which can repeatedly hypersonically dip into the upper atmosphere and give space time separated measurements of the Earth's upper atmospheric response to input from the magnetosphere.

The Constellation mission is at this point in time not so much a specific mission as a mission-class effort directed toward the enabling of technologies which would allow the construction of highly capable, autonomous nanospacecraft to uniquely separate space and time at multiple points simultaneously throughout the magnetosphere, the atmosphere, the heliosphere, and the sun through either in situ or remote observations or both from many platforms. The present focus is on technologies needed for many platform magnetospheric missions.

All of these missions will incorporate advanced visualization and simulation technologies built into evolvable ground data systems data which will allow access by anyone, anywhere, at any time.

Remotely Piloted Aircraft

In a conceptual study, R. Goldberg and coworkers are attempting to develop an instrumental package to be flown on a remotely piloted aircraft (RPA) to measure electrodynamic quantities in the vicinity of thunderstorms. The recent high interest in upward lightning caused by the discovery of red sprites and blue jets provides the first direct evidence that there is a strong AC component of current contributed to the global electric circuit by such processes. The RPA provides an ideal platform from which to measure the necessary parameters to determine the importance of this energy input to the circuit by measuring the required parameters in an in situ environment.

New Millennium

Champollion. J. Trombka, L. Evans, S. Floyd, and R. Starr are part of a team being led by JPL, which will develop an instrument for a mission to a comet.

Solar Probe

Plasma Instruments. The plasma group in the Interplanetary Physics Branch was selected to develop a plasma instrument for Solar Probe. This effort is being headed by E. Sittler with the support of J. Keller, K. Ogilvie, D. A. Roberts, F. Hunsaker, D. Chornay (UMD), M. Coplan (UMD) and W. Vaughn (Langley). The proposed instrument will provide an essential ingredient for the Solar Probe plasma instrument, namely nadir viewing of the solar wind which allows one to observe solar wind ions and electrons moving radially away from the Sun during all phases of the mission, including closest approach where the spacecraft comes as close as 4 solar radii from the Sun. The proposed instrument uses a novel idea to use electrostatic mirrors to redirect the solar wind ions and electrons coming from the Sun to enter the plasma spectrometer which is safely behind the primary heat shield of the spacecraft. One of the electrostatic mirrors must be protected by a miniature heat shield. The design implements new technologies because of the high temperatures and corresponding use of high voltage. If this project is chosen for flight, we expect to collaborate with our present partners and with JPL.

Mercury Orbiter and Solar Probe SWTs

The Mercury Orbiter and Solar Probe Science Working Teams (SWTs) have satisfied their respective charters to define the science objectives for this missions, suggest strawmen science payloads, support spacecraft engineering studies and mission design efforts at the Jet Propulsion Laboratory and to contribute to NASA Headquarters' Space Science Strategic Plan development. D. Winterhalter and B. Tsurutani of the Jet Propulsion Laboratory are the Study Scientists for these missions, respectively. J. Slavin serves on both SWTs representing magnetometer instrumentation, substorm processes. R. Vondrak is a member of the Mercury Orbiter SWT.

X. INSTRUMENT DEVELOPMENT

Superconducting Bolometers. J. Brasunas and B. Lakew have succeeded in making improved performance high Tc superconductor (HTS) bolometers. The advancement came through further reductions in thermal inertia by reducing the sapphire substrate thickness for the HTS thin-film. By reducing the thickness below 10 m by chemical polishing, we have reached a detectivity of over 10^{10} $cmHz^{1/2}/W$. These detectors operate near 85-90 K, readily achievable by passive coolers on planetary missions, and exceed by an order-of-magnitude the signal-to-noise for uncooled thermal detectors such as were used or are being used on Voyager IRIS, Cassini CIRS, and Mars Global Surveyor TES.

Solid State High-Energy Photon Detectors. As a result of accomplishments in the PIDDP, NEAR, and CLARK programs by the combined efforts of P. Clark, L. Evans, S. Floyd, R. Starr, and J. Trombka, standardized designs, calibration procedures, and test protocols have been developed for the next generation of solid state remote and in-situ X-ray and Gamma-ray detectors. Remote X-ray detectors, particularly Si PIN and CZT detectors as single chips or arrays, are being developed for geochemical and solar monitoring applications. Work is now beginning on the development of X-ray *in situ* detectors with similar materials or a new material, HgI2.

IR Imaging. J. Hillman and D. Glenar (in collaboration with the Engineering Directorate) are developing near-IR spectrophotometric imaging cameras based acousto-optic RF-tunable filter (AOTF) technology. AOTF device fabrication techniques are now mature, and commercially available devices made from Tellurium Dioxide (TeO_2) operate to 5 µm wavelength with high efficiency and throughput (etendue). A near-IR AOTF camera, using 256 x 256 NICMOS-3 HgCdTe focal plane arrays has been built at GSFC and operates from 1.6 to 3.4 µm with a spectral resolution of approximately 12 cm^{-1}. Both optics and AOTF are cooled to reduce instrument thermal emission at the focal plane. This camera was recently used for ground-based observations of Venus nightside thermal emissions at the Apache Point Observatory, 3.5 meter telescope (see IV. PLANETARY ATMOSPHERES: Venus). A low-background, mid-wave IR (2.5 to 5.1 µm) camera is also being built which uses a very low power (less than 1 watt) acoustically resonant IR AOTF, developed under the NASA Small Business Innovative Research (SBIR) Program.

Wind measurements. A transportable infrared Heterodyne Instrument for Planetary Wind And Compositional studies (HIPWAC) is being developed (T. Kostiuk, D. Buhl, T. Livengood) to permit direct ground-based measurements of wind velocities on all terrestrial planets, as well as Jupiter, Saturn and Titan. This instrument coupled to current 8-10 meter class telescopes will permit studies of global planetary dynamics with high spatial resolution (~0.3 arcsec) and possible velocity resolution <5 m/sec. It will be usable from observatories throughout the world and could also be used for dynamical studies of comets and astrophysical sources.

XI. OUTREACH

Education Initiatives. A Sun-Earth Connections Education Forum (SECEF) has been established as a partnership between GSFC, the University of California at Berkeley, and several other institutions. R. Vondrak and I. Hawkings (UCB) serve as co-chairs. The Forum is intended to facillitate the dissemination of SEC discoveries to a wide audience, including K-12 students and the general public.

The Laboratory's Education and Outreach Committee, jointly chaired by R. Lepping and F. Ottens, continues to assist teacher and students of nearby schools as well as the general public in better understanding the role of space scientists and our Lab's work in particular. The Committee has made significant progress in developing a Web Homepage that describes the work of the Lab in terms that are comprehensible to the public and especially to young people. The contents are useful tutorials on magnetospheric physics (D. Stern), asteroids (J. Trombka's team), findings from the Antarctic (P. Wasilewski), appreciation of relative sizes in space physics (A. Roberts), and many more topics. Recently added was a button called "Resources for Educators" which was recommended by a visiting middle school teacher (L. Newsome); it lists members of the Lab who have volunteered to mentor area teachers and students, as well as judge fairs and help with Community Day guiding and display booth activities. A comprehensive glossary of space science terms for young people is being added to the Homepage also.

P. Romani collaborated with teachers at Glenarden Woods Elementary School in Glenarden, Maryland this year to incorporate math and science projects involving astronomy into their curriculum. Fifth and sixth grade students at the school studied Europe in the Medieval time period in a thematic unit that involved language arts, social studies, and art. We integrated the science projects into the thematic unit rather than having math and science be divorced from what the students were doing in the other subject areas. For the first project we studied the claims of astrology. This was chosen because during the Medieval time period astronomy and astrology were closely linked. We then took advantage of Comet Hale-Bopp to compare what people in the Medieval time period thought/knew about comets to what we believe now. We then stretched the middle ages to include a demonstration of how Tycho proved that the comet of 1577 was farther from the Earth than the Moon. Details of the work were presented at the 1997 Division of Planetary Sciences meeting.

The Geochemical Exploration Group, with the help of students from the Madeira School, developed a home page. L. Evans and P. Solomon, with high school teachers from the summer program, developed educational packages for the NEAR and Mercury Messenger missions. P. Clark worked with high school teachers on X-ray production and background determination and published an article of general interest (1996) on the launch of the NEAR mission. P. Clark has also been editing a newsletter for the planetary community interested in Mercury for the last ten years.

L. Evans, P. Solomon, R. Starr, S. Floyd, T. McClanahan, and R. Clark supported an exhibit at the 1997 Education Showcase at GSFC on October 23, 1997. The Goddard XGRS group provided two teacher lesson plans, a list of NEAR-related web sites, an interactive computer display featuring different aspects of the NEAR mission, a continuous tape player, and science experts to interact with Showcase participants.

As part of the NASA/Prince George's County Teacher Intern program Mrs. L. Newsome, from Benjamin Tasker Middle School, in Bowie MD, visited the Laboratory for six weeks. She participated in research aimed at understanding the source of errors in the position of the IMP-8 spacecraft, and analytically determining them using magnetic field data in a novel approach. All done in an attempt eventually to correct for these errors. A student (C. Carter; J. Byrnes mentor) participated part time on this project also. The teacher also assisted in various aspects of the Lab's Education and Outreach Homepage, and in particular on "teachers' resources" and she consulted on the proper level to use for its glossary terms. She worked with A. Szabo and her mentor, R. Lepping. The student also contributed to adding instrument calibration information to the Lab's Web Homepage on the WIND magnetometer.

Eclipses. F. Espenak published a NASA Reference Publication on the total solar eclipse of 1999 August 11. This publication contains detailed predictions, tables and maps and is provided as a public service to both the professional and lay communities, including educators, planetariums and the media. Public talks on eclipses and NASA's eclipse bulletins were given by Espenak in New Mexico, Connecticut, Maryland and Toronto. Espenak also created a web site with detailed information about past and future solar and lunar eclipses (http://planets.gsfc.nasa.gov/eclipse/eclipse.html). The site currently receives about 3000 hits per day. Espenak gave interviews about eclipses and Comet Hale-Bopp on a number of television programs including NBC's "The Today Show."

XII. PUBLICATIONS

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