University of Maryland
Department of Astronomy
College Park, Maryland 20742

[S0002-7537(99)06701-3]

This report covers astronomical activities primarily within Maryland's Department of Astronomy but also includes some astronomical work carried out in other departments, such as the Department of Physics. The period covered is from 1 October 1997 to 30 September 1998.

1. PERSONNEL

The continuing personnel in the Department of Astronomy during the period were Professors M. Leventhal (Chair), M. F. A'Hearn, J. Earl, J. P. Harrington, M. R. Kundu, K. Papadopoulos, W. K. Rose, V. Trimble, S. Vogel, and A. S. Wilson; Emeritus Professors W. C. Erickson, F. J. Kerr, and D. G. Wentzel; Adjunct Professors M. Hauser and S. Holt; Associate Professors A. Harris, L. G. Mundy, and J. M. Stone; Assistant Professors D. Hamilton, E. Ostriker, and S. Veilleux; Associate Research Scientists K. Arnaud, C. C. Goodrich, R. Lopez, L. McFadden, G. Milikh, E. Schmahl, S. Sharma and S. White; Assistant Research Scientists S. Balachandran and T. Golla; Research Associates M. Bautista, S. Dinyes, P. Ferruit, F. Finkbeiner, D. Chornay, K. Fast, K. Gendreau, E. Grayzeck, U. Hwang, T. Livengood, C. Mundell, F. Porter, K. Rauch, A. Raugh, I. Richardson, P. Safier, J. Staguhn, M. Stark, P. Teuben, D. Wellnitz and M. Wolfire; Instructors G. Deming and D. Theison; and Associate Director J. D. Trasco.

Assistant Professor John Wang died tragically in an accident in the Summer. His many contributions to the department and the community will be fondly remembered.

R. A. Bell retired in 1998 and was appointed as Emeritus Professor. S. S. McGaugh was appointed as Assistant Professor. W. Chen, C. Lisse, M. Loewenstein and G. Madjeski, were promoted to Assistant Research Scientist. D. Audley, M. Choi, W. Focke, V. Kunde, T. Lanz, C. Ng, A. Nindos, P. Shopbell, A. Valinia and F. Wyrowski were appointed as Research Associates. L. Cheng, O. Columbo, M. Houdashelt, K. Issak, N. Lame, J. Lee, J. Morgan, N. Pereyra, K. Roettiger and C. Sharf completed short term appointments and left the department.

Ph.D. degrees were awarded to R. Cavallo and B. Piner. M.S. degrees were awarded to P. Daukantas, K. Kuntz, C.-F. Lee, K. Miller, A. Sherwin, K. Sheth, K. Watt, S. Watt, and J. Zhang.

V. Trimble was elected to serve as chair of the Astronomy Section of the American Association for the Advancement of Science for the period 1998-99.

D. G. Wentzel continues as secretary (organizer) for the IAU project Teaching for Astronomy Development, now operating in Vietnam, Central America and Morocco.

Graduate student J. A. Valdivia was the recipient of the AGU 1998 Fred Scarf Award for the most outstanding PhD dissertation in the disciplines of space physics and aeronomy.

2. MEETINGS

The series of Washington Area Astronomers meetings initiated in September 1981 has continued. The Fall 1998 meeting was held at the Johns Hopkins Applied Physics Laboratory in Laurel, Maryland. Typical attendance has been 100 persons per meeting. The Maryland-Goddard Astrophysics series which started in Fall 1990 has continued. The most recent meeting ''After the Dark Ages: When Galaxies Were Young'' was held at the University of Maryland in October 1998. Total attendance was approximately 200 persons.

A new program within the University's College Park Scholars Program, a residential, living-learning program for academically talented students, was initiated last year from the Astronomy Department and the College of Computer, Mathematical and Physical Sciences. The program in Science, Discovery and the Universe, is headed by faculty director, L. McFadden. Now in its second year, it has proven very popular with a total enrollment of over 100 students.

3. FACILITIES AND INSTRUMENTATION

3.1 Laboratory for Millimeter-Wave Astronomy

The Laboratory for Millimeter-wave Astronomy (LMA) is the organization set up by the University of Maryland to manage its participation in the Berkeley-Illinois-Maryland Association (BIMA) project, which has led to the construction of a ten radio-dish millimeter array located in Hat Creek, California. The lab is part of the Astronomy Department and has associated with it five faculty members, one research scientist, three scientific staff, four postdoctoral fellows, and five graduate students. The faculty are S. Vogel (director), W. Erickson (emeritus), A. Harris, M. Kundu, and L. Mundy. The Associate Research Scientist is S. White. Postdoctoral fellows include P. Safier, M. Choi, J. Staguhn, and F. Wyrowski. The scientific staff includes M. Pound, J. Morgan and P. Teuben. Graduate students doing degree work with the array include S. Donaldson, C. Lee, L. Looney, K. Sheth, and L. Woodney. During the year, J. Morgan and K. Isaak departed Maryland, and F. Wyrowski joined the group.

The scientific work done with the BIMA array is outlined in the relevant sections of this report. The array is now fully operational with 10 antennas, and 1.3 mm capability was added during the past year. A new station was added to extend the array to provide maximum baselines of 1.3 km and a resolution at 3 mm of 0.4'', the longest baselines available with any connected-element millimeter array. Mundy, Looney, and Erickson from Maryland designed and built the optical fiber links to carry local oscillator signals to and return the astronomical signals from the long-baseline antenna pads. In addition, optical fiber fixed and variable delay systems were built to enable real time correlation of astronomical signals.

The emphasis of experimental work in the LMA continued to be in the area of wide bandwidth correlation spectrometers. Harris and Isaak (U. Cambridge) completed the

prototype WASP spectrometer (Harris, Isaak, and Zmuidzinas 1998) and used it at the Caltech Submillimter Observatory in a collaborative project with Zmudizinas (Caltch). The spectrometer has a 3.25 GHz bandwidth, optimized for submillimeter heterodyne observations of external galaxies. A number of galaxies were detected in the CO $J = 6 - 5$ (691.5 GHz) lines for the first time, demonstrating the scientific and technical feasibility of the project. The prototype receiver and spectrometer are being upgraded to enable routine observations with this new system, which is also a precursor to the heterodyne spectrometer for the SOFIA airborne observatory. Holler and Harris collaborated with Townes (UC Berkeley) on an initial test of the wideband spectrometer for mid-IR stellar heterodyne spectroscopy.

A single board of the upgraded version of the spectrometer is also the hardware core of a new system for atmospheric phase correction for the BIMA and MMA millimeter-wave synthesis arrays. Staguhn completed work on Monte-Carlo simulations of phase errors introduced by atmospheric water vapor fluctuations at a range of altitudes to find the optimum set of channels and widths for a spectrometer that will measure the column of water above each antenna in the array. Staguhn, Harris, and Mundy are continuing to refine the design of the hardware and software for initial experiments in collaboration with Woody (OVRO, Caltech), an upgrade to the quasi-spectroscopic system now in operation at the Owens Valley Millimeter Array. This work is supported in part by the Millimeter Array (MMA) as a end-to-end test of phase correction techniques.

Maryland is jointly responsible with Illinois for the calibration, analysis, and image reconstruction software for the BIMA consortium. Teuben and Pound continued the joint BIMA development of the MIRIAD data reduction package. The Maryland group focuses on antenna-based calibration routines for use with the 10-element array; reduction and analysis of long-baseline interferometric data including atmospheric phase correction; rapid time integration routines for solar flares and eclipses; holography techniques for the new antennas; observing software; analysis applications in the UV-plane; the WIP interactive graphics tool; various X-window oriented applications; and Java applications for remote and on-site users to monitor the real-time status of the BIMA array.

Pound has developed JStatus, a Java program that allows remote and on-site users to monitor the real-time status of the BIMA array via a web browser (applet) or as a standalone Java application. Users can monitor conditions of antennas, receivers, cryogenics, the current observing program, weather, and electronics. Future additions will include real-time atmospheric phase monitoring and uv-data display. Users may examine the recent history of systems with a graphical plot or list. Audible and visual warnings are issued if critical values fall outside pre-set ranges. Users may also set the ranges and the type of warning issued. JStatus also supports printing and file i/o. The latest version of JStatus incorporates the GUI from a similar program used at OVRO. Work is underway in collaboration with OVRO to merge the two programs.

The LMA has continued to develop its local World Wide Web WWW server to provide world wide access to information related to the BIMA project, observing at the Hat Creek telescope, the MIRIAD software package, and the University of Maryland Astronomy Department. The LMA has also continued its involvement with the AIPS++ software development, working on a filler for BIMA visibility data.

Maryland is designated as the East Coast observing site for the array. Thirty percent of the observing time on the array is generally available to outside users (outside of the time designated for system development and tests).

The next step in the expansion of the BIMA array baselines was completed in December 1997 with the construction of an antenna pad located 1.5 km northwest of the main array center. The maximum baseline of the array is now nearly 2 km; the maximum array configuration, the A-array, can image with 0.5″ resolution at 2.7 mm wavelength, and 0.25″ resolution at 1.3 mm wavelength. Mundy and Looney played a principle role in the expansion, designing and building the optical fiber communication links and variable delay system. The system was operated in December 1997 and January 1998 yielding excellent results. In the future, the A-array will be utilized regularly during the winter months.

Mundy conducted an extensive study of array configurations for 8 and 18 element arrays. The traditional T-configurations of millimeter arrays, which were adopted when the arrays were envisioned as only having 3-5 antennas, are not appropriate for large number of elements. The National Radio Astronomy Observatory is recommending nested circles for their 40-60 element array to be built in Chile. The study puts forward a 5-arm star configuration as the best compromise between the two. The 5-arm star provides many of the imaging advantages of the nested circle with lower cost and lower environmental impact due to the lesser number of antenna stations and connecting roads.

3.2 Advanced Visualization Laboratory

To meet the widely perceived need for data visualization support on campus, the Department of Astronomy and the Computer Science Center jointly established the Advanced Visualization Laboratory (AVL), under the direction of C. Goodrich (Astronomy). This laboratory serves as the focal point for visualization expertise on campus providing information and demonstrations of state of the art visualization software and hardware. Their goal is to provide graphics support and innovation focusing on the types of computers generally available to researchers and students on campus. The functions of the laboratory are at three levels. At the most basic level, the AVL provides color input/output facilities on a fee-for-materials and nominal service charge basis, including paper and transparency color printing, 35mm film recording, color scanning, and SVHS/VHS videotape production and editing. At a higher level, the AVL provides faculty and students the opportunity for hands-on evaluation of a variety of visualization software on a range of computers in a friendly environment. Basic assistance in the use of visualization software and devices is available from the laboratory staff, and classes in scientific visualization are under development. Finally, the AVL actively pursues joint projects with researchers to develop custom visualization

tools and works with hardware and software vendors to evaluate, test, and enhance available commercial solutions. The AVL has current research collaborations in the space sciences, mathematics, and fishery management.

3.3 Planetary Data System

The Small Bodies Node (SBN) of the Planetary Data System (PDS) continues in the department under the direction of M. A'Hearn and E. Grayzeck. A. Raugh provides programming support; S. Dinyes is a half-time data engineer. Subnodes are operated at the U. Hawaii, U. Arizona Planetary Science Institute, and Konkoly Observatory (the European Sub-node) in Budapest, Hungary. The Sub-nodes archive relevant data for comets, asteroids, and interplanetary dust; they also distribute data once it has been reviewed by the PDS. Five major sets of data have now been reviewed and ingested into PDS: the Galileo and Ulysses Dust Detection System (DDS) data through 1996, the Giotto Extended Mission to comet 26P/ Grigg-Skjellerup in 1992 including ground based imaging; the Comet Halley CD-ROM Archive of 26 disks completed to include relevant spacecraft data; data sets of derived cometary properties and fundamental asteroid data; and IRAS data determined to be useful for studying interplanetary dust. Most data are available through the SBN home page on the World Wide Web, which provides on-line browsing and a form-based utility to accept off-line data orders and special requests. Sub-nodes are actively involved in archiving spacecraft data from various missions: the NEAR mission to Eros and Mathilde; the Galileo experiments which collected data from asteroids Gaspra and Ida; and further interplanetary dust measurements from Ulysses and Galileo. The comet subnode is supporting archive planning for the current mission Deep Space 1 as well as three future missions (Stardust, Rosetta, Contour) which are in phases of instrument definition and cometary target selection.

The PDS-SBN played a major role in the campaign to study the collision of comet D/Shoemaker-Levy 9 with Jupiter and has now assembled a CD-ROM archive of relevant data to be produced in coordination with groups at New Mexico State U. and the Jet Propulsion Lab. The first twelve volumes of this collection, which includes the spacecraft measurements, are currently under production.

4. RESEARCH

4.1 Extragalactic Astronomy

Using the BIMA interferometer, K. Sheth and S. Vogel resolved over 20 Giant Molecular Clouds (GMCs) in the nearby spiral galaxy Andromeda (M31). Contrary to expectations, preliminary analysis indicates that the GMCs in Andromeda are similar to those found in the Milky Way Galaxy and the spiral M33, despite the fact that M31 is often considered to be a gas-poor galaxy.

Sheth, Vogel and P. Teuben continued their collaboration with M. Regan (CIW-DTM) in studying the molecular gas, dust and star formation in barred galaxies. In a sample of seven barred spirals observed with the BIMA array, they find that the CO spectra are consistent with predictions of the hydrodynamic models in all cases; there is kinematic evidence for the key components of the model, including gas in circular orbits in a nuclear ring, gas flowing down the dust lane towards the contact point with this ring, and also gas which misses the nuclear ring and sprays past the contact point. One galaxy, NGC 5383, has been studied in greater detail using a multi-wavelength dataset Sheth *et al.* find that while star formation is relatively low in the bar region, stars may be forming from spurs (giant gas complexes) occurring in the bar along the dust lanes.

Sheth, A. Harris, and Vogel are collaborating with T. Wong, D. Bock, L. Blitz (Berkeley), M. Thornley (NRAO), T. Helfer (NRAO) and M. Regan (CIW-DTM) on a BIMA key project which will survey CO emission in 44 nearby spiral galaxies. They have begun mapping the galaxies using the BIMA interferometer at a resolution of $\sim 6''$ ($\sim$ 300 pc), nearly an order of magnitude better than previous surveys. Complimentary data is already being collected at the NRAO 12m telescope in Tucson and they plan to obtain optical, near-infrared and narrow-band Hα data. Initial results indicate that the distribution of molecular gas is very inhomogeneous and varies markedly between galaxies.

Teuben, in collaboration with Blitz (Berkeley), Spergel (Princeton), Hartman (Cambridge/Bonn) and Burton (Leiden), finished their study of High Velocity Clouds. Based on a large number of arguments, both statistical in nature and matching simulations with existing HI surveys, they concluded that HVC must be large (25kpc) clouds, part of and falling onto the Local Group, and contributing about 10**11 solar masses to the local group. Reexamining this Local Group hypothesis they find that properties of the HVC naturally connect to the hierarchical structure formation scenario and to the gas seen in absorption towards quasars.

Vogel, S. Veilleux, and R. Weymann (Carnegie Observatories) are continuing their collaboration to detect and measure the metagalactic ionizing flux at zero redshift using their newly constructed reimager with an FP system at the Las Campanas Dupont 2.5 meter telescope.

B. Weiner (Carnegie Observatories), Vogel, and Veilleux have observed the Magellanic Stream and high velocity clouds in Hα with the FP system on the CO 2.5 m telescope. The Magellanic Stream observations are designed to distinguish between shock and photoionization models for the origin of Hα emission from the Stream. The high velocity cloud observations can test the Blitz *et al.* model for high velocity clouds, which proposes that the HVCs are at characteristic distances of 1 Mpc; at that distance, ionization by the Milky Way and other Local Group galaxies is negligble, and the Hα emission would be expected to be much lower than for clouds near the galaxy.

H. Falcke (MPIfR), A. Wilson and C. J. Simpson (Subaru Telescope) have obtained HST/WFPC2 images and new VLA radio maps of seven Seyfert 2 galaxies in the [OIII] λ5007 and Hα+[NII]$\lambda\lambda$6548, 6583 emission lines. They find detailed correspondences between features in the radio and emission-line images that clearly indicate strong interactions between the radio jets and the interstellar medium. Such interactions play a major role in determining the morphology of the NLR, as the radio jets sweep up and compress ambient gas, producing ordered structures with enhanced

surface brightness in line emission. In at least three galaxies (Mrk 573, ESO 428 − G14, and Mrk 34), off-nuclear radio lobes coincide with regions of low gaseous excitation. In Mrk 573 and NGC 4388, there is a clear trend for low brightness ionized gas to be of higher excitation. These results may be understood if radio lobes and regions of high emission-line surface brightness are associated with high gas densities, reducing the ionization parameter. [OIII]/(Hα+[NII]) excitation maps reveal bi-polar structures which can be interpreted as either the 'ionization cones' expected in the unified scheme or widening, self-excited gaseous outflows.

Wilson, in collaboration with A. Roy, J. Ulvestad (NRAO), and E. Colbert (GSFC), has begun a study of Seyfert galaxies at milli arc second resolutions with the VLBA. The goals are to study the morphology of the radio emission at sub-pc resolution and to investigate thermal gas in the putative obscuring disk or torus and in the narrow-line region clouds through free-free absorption of the radio emission. The first objects studied were NGC 1068 and NGC 4151.

In NGC 1068, component S1 is probably associated with the active nucleus, with radio emission originating from the inner edge of the obscuring torus according to Gallimore *et al.* The observed flux densities at 1.7 and 5 GHz are in agreement with their thermal bremsstrahlung emission model, and the nuclear radiation may be strong enough to heat the gas in S1 to the required temperature of $\sim 4 \times 10^6$ K. The bremsstrahlung power would be 0.15 (f_{refl}/0.01) times the bolometric luminosity of the nucleus between $10^{14.6}$ and $10^{18.4}$ Hz (where f_{refl} is the fraction of radiation reflected into our line of sight by the electron scattering mirror) and so the model is energetically reasonable. Two other models for S1 that also match the observed radio spectrum are discussed: electron scattering by the torus of radio emission from a compact synchrotron self-absorbed source, and synchrotron radiation from the torus itself. Components NE and S2 have spectra consistent with optically-thin synchrotron emission, without significant absorption. Both of these components are elongated roughly perpendicular to the larger-scale radio jet, suggesting that their synchrotron emission is related to transverse shocks in the jet or to bow shocks in the external medium. Component C has a non-thermal spectrum absorbed at low frequency. This absorption is consistent with free-free absorption by plasma with conditions typical of narrow-line region clouds.

In NGC 4151, a compact, linear structure of length $\sim$ 13 milli arc secs (0.8 pc) is found associated with the putative nucleus. This source fulfills the classical criteria for a radio jet, but its radio luminosity is only $\sim 10^{38}$ erg s^{-1}, several orders of magnitude less than the pc-scale jets in radio galaxies, and it is misaligned by $\simeq$ 55° from the arc second scale radio jet. Possible reasons for the misalignment include deflection by the inner narrow-line region, buoyancy forces, and a change in the plane of the accretion disk presumably responsible for the jet collimation. The possibility that the putative change in the plane of the accretion disk results from disk precession driven by the pressure of radiation emitted by the central part of the disk is considered. In order to reconcile the much smaller column density of HI towards the nucleus found by Lyman absorption than by 21 cm absorption measurements, it is proposed that a $\simeq$ 0.01 pc thick gas disk surrounds the nucleus and is ionized out to a radius of $\simeq$ 2 pc. The large 21 cm absorption column observed then results from off-nuclear radio components shining through the outer, neutral part of this disk. The flat spectrum of the nuclear radio source may indicate synchrotron self-absorption, electron scattering of a synchrotron self-absorbed source or free-free absorption by the inner, ionized part of the accretion disk. Comparison of the 18-cm image with the EVN image acquired by Harrison *et al.* in 1984 provides upper limits of 0.11*c* and 0.20*c* for the apparent speeds of the radio components at distances of 6 and 29 pc from the galaxy nucleus, respectively.

In collaboration with A. Alonso-Herrero (UAz), C. J. Simpson (Subaru Telescope) and M. J. Ward (U. Leicester), Wilson completed a near-infrared J, H, K and L′ band (1.25–3.80 μm) imaging study of a sample of Seyferts with extended emission line regions. The observed near infrared colors are consistent with a mixture of emissions from an old stellar population and either reddened ($A_V \sim$ 5 - 30 mag) or unreddened hot dust. All of the galaxies exhibit an unresolved source at L′. The circumnuclear colors (in a 0.5 - 1.0 kpc annulus) are similar to those of normal spirals in most cases. We find stellar bars in 16% and ''bars within bars'' in 25% of the sample. There is alignment on small scales between the near-IR continuum and line emission in 33% of the sample, but the results suggest that in some cases the extended gas represents gas within the nuclear stellar bars while in others it is gas escaping along the minor axis of the galaxy.

Falcke (MPIfR), M. J. Rieke, G. H. Rieke (UAz), Simpson (Subaru Telescope) and Wilson have obtained near-infrared spectra to search for Paα and molecular hydrogen lines in edge-darkened (FRI-type) radio galaxies in the redshift range $0.06 < z < 0.15$ and with bright Hα emission. They find that all three galaxies in the sample associated with strong cooling flows (PKS 0745-191, Abell 1795, & Abell 2597) also have strong Paα and H_2 1–0 S(1) through S(5) emission, while other radio galaxies do not. This confirms earlier claims that cooling flow galaxies are copious emitters of molecular hydrogen with H_2 1–0 S(3)/Paα ratios in the range 0.5 to 2. The emission is centrally concentrated within the inner few kiloparsec and could come from material which is being deposited by the cooling flow. By analogy to the situation in Seyfert galaxies, the molecular hydrogen emission could be related to the interaction between the jets and the inflowing molecular gas.

P. Ferruit, E. Pécontal (Lyon), Wilson and L. Binette (UNAM) have studied the Seyfert galaxy NGC 5929 with the integral field spectrograph TIGER. These 3D spectrographic data, with sub-arcsecond spatial resolution, consist of 394 flux-calibrated spectra, covering the [NII]λλ6548, 6583, Hα and [SII]λλ6717, 6731 emission lines associated with the two radio-lobes. Although the line-of-sight velocities of the clouds are consistent with normal rotational motions, their high internal velocity dispersions and spatial association with the radio components clearly indicate an interaction between the radio ejecta and the ambient medium. The authors discuss four specific models describing

this interaction but conclude that none of them is completely satisfactory.

In collaboration with G. Bower (NOAO) and others, Wilson measured the mass of the putative black hole in the Virgo cluster elliptical M84 (NGC 4374) by means of HST STIS observations. The spectra reveal that the nuclear gas disk seen in previous WFPC2 imaging is rotating rapidly. The velocity curve has an S-shape with a peak amplitude of 400 km s^{-1} at 0.1 arc sec = 8 pc from the nucleus. The results indicate that the gas dynamics are driven by a nuclear compact mass of $1.5 \times 10^9 M_\odot$ with an uncertainty range of $(0.9 - 2.6) \times 10^9 M_\odot$ and that the inclination of the disk with respect to the plane of the sky is 75 - 85°. Of this nuclear mass, only $\leqslant 2 \times 10^7 M_\odot$ can possibly be attributed to luminous mass.

M. Claussen, P. Diamond, J. Braatz (NRAO), C. Henkel (MPIfR) and Wilson have imaged the H_2O maser emission in the nucleus of the nearby elliptical NGC 1052. Unlike the narrow maser spikes seen in other active galaxies, this galaxy exhibits a relatively broad ($\approx$ 90 km s^{-1}) and smooth H_2O profile. The masers do not lie in a disk around the central engine in the galaxy. Rather, they appear to lie along the jet emanating from the core on a scale of 400 μas (7000 A.U.). The masers could be associated with the radio jet, and it is shown that the jet is energetically capable of powering the observed maser emission by driving slow, non-dissociative shocks into circumnuclear, dense molecular clouds. Alternatively, the masers could represent amplification of the radio continuum emission of the jet by foreground molecular clouds, perhaps in the accretion disk.

R. González Delgado, T. Heckman, G. Meurer, J. Krolik (JHU), C. Leitherer (STScI) and Wilson have investigated the relationship between nuclear activity and starbursts by means of HST (WFPC2 and FOC) images and UV GHRS spectra plus ground-based near UV through to near IR spectra of three Seyfert 2 nuclei (NGC 7130, NGC 5135 and IC 3639). The data provide direct evidence for the existence of a nuclear starburst in each galaxy that dominates the UV light and seems to be responsible for the so-called featureless continuum. These starbursts are dusty and compact. They have sizes (from less than 100 pc to a few hundred pc) much smaller and closer to the nucleus than that seen in the prototype Seyfert 2 galaxy NGC 1068. Their GHRS spectra show absorption features formed in the photospheres (SV λ1501, CIII λ1426,1428, SiIII λ1417, and SiIII+PIII λ1341-1344) and in the stellar winds (CIV λ1550, SiIV λ1400, and NV λ1240) of massive stars. Evolutionary synthesis models are used to constrain the star formation history from the stellar components of these UV absorption lines. The results indicate that one is witnessing starbursts of short duration with ages between 3 and 5 Myr. Signatures of massive stars are also clearly detected in the optical spectra. The high order Balmer series and He lines are observed in absorption. These lines are formed in the photospheres of O and B stars, and thus they also provide strong evidence of the presence of massive stars in the nuclei of these Seyfert 2 nuclei. The bolometric luminosities of these starbursts are similar to the estimated bolometric luminosities of the associated obscured Seyfert 1 nuclei, and thus they contribute a similar amount to the overall energetics of these galaxies. It is suggested that the luminosities of the Seyfert nuclei and the associated starbursts are correlated and that the central starburst could be triggered in the molecular torus that hides the nucleus.

Ferruit, Wilson, Ferland, Whittle and Simpson have obtained HST/FOS spectra of off-nuclear nebulosities in the two Seyfert 2 galaxies NGC 5929 and NGC 2110. These spectra covering the UV and visible spectral domains include lines providing direct information on the electronic density and temperature in the gas, as well as a large number of lines, the ratios of which can be used to discriminate between nuclear and shock-induced photoionization. Although uncertainties in the reddening in these galaxies have prevented them from using the UV carbon lines to rule out one or another of these mechanisms, the various line strengths have been compared to the output of shock and photoionization models, providing constraints on physical parameters like the shock velocity (in the case of the shock-induced photoionization scenario).

Ferruit, Wilson and J. Mulchaey have obtained HST/WFPC2 continuum and line emission images of 13 early-type Seyfert galaxies. These high spatial resolution images have been used to study the line and continuum morphology of these galaxies, in particular in view of the expectations of the unified model for active galaxies. Analysis of the data for the complete sample is on-going and a paper is in preparation. Detailed analysis has been performed for one single object, the Seyfert galaxy NGC 3516, and has provided strong constraints on the geometry of the outflow in this galaxy.

Ferruit, in collaboration with the CRAL-Observatoire de Lyon (France) has also worked on the development and application of a new deconvolution method for 3D data cubes, as can be obtained with integral-field spectrographs like the TIGER instrument. This method has been successfully applied to the Seyfert galaxy Mkn 573, the deconvolved 3D data clearly showing the kinematical disturbances induced in the gas of the emission-line region by the propagation of the radio ejecta. Extensive testing of the method using artificial data cube is now on-going.

N. Nagar, Wilson, Mulchaey and Gallimore have completed a high-resolution 3.6 cm and 20 cm radio survey of about 50 early-type Seyfert galaxies . They find that Seyfert 2 galaxies show a strong trend for alignment between the nuclear radio structures, the emission-line ([OIII] and Hα+[NII]) structures and the host galaxy disk. These alignments are consistent with a picture in which the ionized gas represents ambient gas predominantly coplanar with the galaxy disk which is ionized by nuclear radiation that may escape preferentially along the radio axis, and is compressed by shocks driven by the radio ejecta. The alignment was also used to constrain the period of precession of the inner accretion disk. Nagar and Wilson have analyzed the relative orientation of nuclear accretion and galaxy stellar disks in Seyfert galaxies. They find some evidence that the accretion disk in non-interacting late-type Seyferts tends to align with the stellar disk, while that in early-type galaxies is more randomly oriented, perhaps as a result of accretion following a galaxy merger. The data are also consistent with the expec-

tations of the unified scheme but do not demand it.

K. Rauch finished work examining the dynamical evolution of dense star clusters in galactic nuclei containing massive black holes, in the case that physical collisions between stars dominates the evolution. In contrast to previous studies, it was found that collisions preferentially produce a flat density profile in the cluster core, as opposed to the weak cusp normally associated with collisionally dominated systems. The flat core is maintained by low mass collision remnants that previous studies did not produce, due to their simplified assumptions regarding collision products.

Welch, Sage, and Mitchell are studying the molecular gas content of the dwarf companions of M31. They have found molecular gas in two (NGC 185 and NGC205), but there is apparently no gas in either NGC 147 or M32, which are comparable in overall mass and morphological type. In addition, they have begun an unbiased search for molecular and atomic gas in S0 galaxies, using a distance-limited sample. This involves observations with the NRAO 12-m, the IRAM 30-m and Arecibo telescopes, and the VLA.

Sage, Welch, and Lanzetta have begun a search for molecular absorption along the line of sight to a blank-field radio quasar (NRAO 150); no previous search for molecular emission or absorption associated with known Lyman-α clouds has been successful. They have one tentative line. They have also obtained red and near-infrared images of the quasar, which have revealed the host galaxy.

The stellar mass object SS433 is often described as a stellar prototype for the massive black holes associated with active galactic nuclei. In previously reported results, W. Rose has modeled the radio and X-ray emission from this object. During the last year he has extended these calculations to massive black holes undergoing super-Eddington mass accretion.

New HI synthesis studies of Seyfert hosts (Mundell, 1997) show that, despite the presence of sometimes dramatic tidal tails (extending $\sim$ 100 kpc) in interacting Seyferts, and signatures of tidal disturbance in Seyferts classified optically as isolated, nothing catastrophoic appears to be happening in the disks of these active galaxies; direct dumping of tidally stripped gas onto the nucleus is not seen, and kinematically, the galactic hydrogen disks are remarkably undisturbed.

Thean (NRAL), Mundell, Pedlar (NRAL) and Nicholson (NRAL) carried out a detailed HI emission study of the isolated Seyfert NGC5033, and showed that a galaxy very similar to the Milky Way can possess a Seyfert nucleus. The disk possesses a large-scale kinematic warp and large concentrations of hydrogen in the central kpc. Nevertheless the disk kinematics are very well-ordered and show no evidence for a bar or significant non-circular motions in the central region. Four gas-rich dwarf galaxies were also detected in the field.

A comparison of optical colour maps and neutral hydrogen emission maps of the inner regions of the gas-rich bar in NGC4151 reveals a close correspondence between the dusty circumnuclear ellipse and two arcs of HI which lie on the inner edges of the bar (Asif, Mundell, *et al.* 1998). Kinematics of the HI suggests that, if the HI is associated with the dust ring, the ring is intrinsically elliptical, lies in the plane of the galaxy and exhibits non-circular orbits which could have implications for the fuelling of the AGN. This forms part of a larger, HI study of NGC4151 currently underway by Mundell.

On smaller scales (tens of parsecs), high resolution ($\sim$ 0.2'') studies of HI absorption towards the radio continuum nuclei of Seyferts have been used to search for evidence of the obscuring torus advocated in Unification Schemes. Using MERLIN, Gallimore (MPE), Holloway (U. Manchester), Pedlar and Mundell detected HI absorption against the arcsecond-scale radio jet in Mkn 6 and proposed a model in which the absorption arises in a dust lane, $\sim$ 380 pc north of the AGN, and, contrary to previous models, places the southern jet on the near side of the inclined galaxy disk. Cole (NRAL), Pedlar, Mundell, Gallimore and Holloway find a similar situation in NGC5929 where absorption is only detected against the NE radio component.

Cole, Mundell and Pedlar used MERLIN to study the HI absorption against individual supernova remnants in central 250 pc of the nearby, edge-on starburst galaxy, NGC3628. Sixteen continuum components were resolved, thirteen of which show spectra consistent with SNRs and the remaining three being weak AGN candidates. The HI shows complex kinematics with two components present; rotation and outflow are both suggested. The large inclination of this galaxy (89°), however, makes 3D interpretation difficult.

Veilleux, D. B. Sanders (U. Hawaii), and D. C. Kim (IPAC/Caltech) have pursued their survey of ultraluminous ($\log[L_{ir}/L_{\odot}] > 12$) IRAS galaxies. As found in previous studies, the fraction of Seyfert galaxies among LIGs increases abruptly above $L_{ir} \approx 10^{12.3} L_{\odot}$ — more than 50% of the galaxies with $L_{ir} > 10^{12.3} L_{\odot}$ present Seyfert characteristics. Many of the optical and infrared spectroscopic properties of the Seyfert galaxies are consistent with the presence of a genuine active galactic nucleus (AGN). About 30% of these galaxies are Seyfert 1s with broad-line regions similar to those of optical quasars. Near-infrared spectroscopy also suggests that many of the Seyfert 2 galaxies (especially those with warm *IRAS* 25-to-60 μm colors) are in fact obscured Seyfert 1 galaxies with broad ($\gtrsim$ 2,000 km s^{-1}) recombination lines at 2 μm, where dust obscuration is less important. Comparisons of the broad-line luminosities of optical and obscured Seyfert 1 ULIGs with those of optically selected quasars of comparable bolometric luminosity suggest that the dominant energy source in most of these ULIGs is the same as in optical quasars, namely mass accretion onto a supermassive black hole, rather than a starburst. These results appear to be consistent with recently published ISO, ASCA, and VLBI data.

In collaboration with J. Bland-Hawthorn (AAO), G. Cecil (U. North Carolina), S. Miller, R. B. Tully (U. Hawaii), and Vogel, Veilleux is carrying out a comprehensive study of the warm ionized medium on the outskirts of nearby disk galaxies. The physical state, distribution, and velocity structure of this material are relevant for understanding large-scale galactic winds (''superwinds) and fountains in active and normal galaxies, quasar absorption-line systems, the baryonic content of the universe, the formation and evolution of galaxies, and measuring the mass and distribution of dark matter in galaxies. The distribution of the line-emitting gas in a com-

plete sample of nearby galaxies is being mapped down to unprecedented flux levels using state-of-the-art optical Fabry-Perot interferometers and recently developed observational techniques.

A complementary study of some of these objects was carried out by E. Colbert (UMD/STScI), S. Baum, C. O'Dea (STScI), and Veilleux using archival PSPC and HRI ROSAT images. Kiloparsec-scale soft X-ray nebulae were detected in three objects (NGC 2992, NGC 4388 and NGC 5506), extending along the galaxy minor axes. The X-ray nebulae are roughly co-spatial with the large-scale radio emission, suggesting that both are produced by large-scale galactic outflows. The large-scale outflows in these objects most likely originate as AGN-driven jets that entrain and heat gas on kpc scales as they make their way out of the galaxy. AGN- and starburst-driven winds are also possible explanations in cases where the winds are oriented along the rotation axis of the galaxy disk.

Shopbell and J. Bland-Hawthorn (AAO) recently completed a detailed Fabry-Perot study of the galactic wind in the nearby starburst galaxy, M82. Kinematic observations of the ionized gas in this system reveal a network of filaments that can be modeled as the surfaces of a pair of outflowing cones. The specific structure of the model agrees well with hydrodynamic simulations of galactic winds. Emission line ratios are indicative of a photoionization mechanism for the filaments, presumably originating with the central starburst.

Shopbell has worked with J. Cohen (Caltech) as part of the Caltech Faint Galaxy Redshift Survey (CFGRS) project, a K-selected, pencil-beam redshift survey of 195 objects in a $2' \times 7'$ field, conducted with the LRIS instrument on the Keck Telescope. This survey has been completed, and the sample and initial analysis published. Cohen *et al.* find that half of the galaxies lie in 5 narrow peaks in the redshift distribution, the most distant at $z = 0.77$. The dynamical masses and sky distribution of the galaxies appear similar to those of poor clusters of galaxies in the local universe, indicating that at least some groups of galaxies form at early epochs, i.e., $z > 1.5$. The galaxies in such groups show little sign of ongoing star formation, while more isolated galaxies frequently exhibit strong emission lines, suggesting that star formation occurs at later epochs in those systems.

Wolfire along with Luhman *et al.* (NRL) reported the measurements of the [C II] 158 μm line in a sample of seven ultraluminous infrared galaxies (ULIGs) with LWS on board ISO. The [C II] line was detected in four of the seven ULIGs, but with a surprisingly low brightness of $\sim 10^{-20}$ W cm^{-2}. Relative to the far-infrared continuum, the [C II] flux observed in ULIGs is only $\sim$ 10% of that seen in nearby normal and starburst galaxies. In normal galaxies the [C II] line is a dominant coolant of the ISM. Several hypothesis were presented to explain the [C II] deficit including (1) self-absorbed or optically thick [C II] emission, (2) saturation of the [C II] emission at high density or (3) the predominance of soft UV radiation produced by a stellar population deficient in massive main-sequence stars.

4.2 Galactic Astronomy

Hollis (NASA/GSFC), Vogel, Van Buren (IPAC), Strong, Lyon, and Dorband (NASA/GSFC) have observed [NII] emission from the symbiotic binary system R Aqr with the Maryland-Palomar Fabry-Perot. The observations are consistent with a jet originating from R Aqr which forms a helical structure.

Teuben is continuing development of the NEMO stellar dynamics package, and collaborating with Hut (Princeton), McMillan (Drexel), Makino and Portegies Zwart (Tokyo) on a C++ programming project to combine stellar dynamics and stellar evolution (STARLAB).

L. Cheng, M. Leventhal, P. Milne and J. Kurfess have continued with mapping the inner Galactic 511 keV positron/electron emission using maximum entropy analysis. The Oriented Scintillation Spectrometer Experiment (OSSE) (field of view: 3.8° × 11.4° FWHM) on the Compton Gamma-Ray Observatory (CGRO) has completed numerous observations of the GC and Galactic plane regions. An unexpect additional component extending approximately 10° above the GC was discovered in 1997 when all the OSSE Cycle 1-6 data are combined for a mapping analysis. This year (Cycle 7), more OSSE scan observations have been proposed to better study the positive latitude enhancement. Cheng and Leventhal have made maps using Cycle 7 data alone and all Cycle 1-7 data combined. These maps confirm the existence of the enhancement.

Collaborating with J. Naya, S. Barthelmy, L. Bartlett, N. Gehrels, A. Parsons, B. Teegarden, and J. Tueller (NASA/GSFC), Leventhal has been working on measuring the galactic ^{60}Fe decay line (1173 and 1332 keV). The data from two 1995 Gamma-Ray Imaging Spectrometer (GRIS) balloon drift scan flights, in which the GC and Galactic plane at l=240° passed through the field-of-view of GRIS, have been analyzed. They found a 2σ upper limit of 1.7 - 3.1 $M_\odot$ for ^{60}Fe.

Collaborating with D. Smith and D. Main (UC Berkeley), F. Marshall and J. Swank (NASA/GSFC), W. A. Heindl (UCSD), and J. Zand and J. Heise (Space Research Organization of the Netherlands), Leventhal has contributed to the discovery of a new x-ray transient, XTE J1739-302 using data from the Proportional Counter Array (PCA) on the Rossi X-ray Timing Explorer (RXTE). The x-ray spectrum and intensity of this source suggest a giant outburst of a Be/neutron star binary, although no pulsations were observed. This source was only detected on one day and totally not detectable in other two observations that have it in the FOVs and are nine days earlier and two days later.

Cheng, Leventhal, Tueller and J. Naya (NASA/GSFC) have revised their atmospheric 511 keV production model. Atmospheric 511 keV photons are produced by the annihilation of positrons, which are generated in the hadronic and electro-magnetic cascades initiated by cosmic particles injected from the top of the atmosphere. They used GEANT 3, the most popular Monte Carlo simulation package in high energy physics. The Monte Carlo atmospheric 511 keV production function, when combined with the real data, imply an upper limit of cosmic diffuse 511 keV line flux of about 2

$\times 10^{-3}$ ph sr^{-1} cm^{-2}, which is much lower than previous measurements.

4.3 Stellar Astronomy

V. Trimble and graduate student A. Kundu have completed analysis of their early-release data from Hipparcos satellite, representing several different classes of stars in short-lived or rare stages of evolution. Some of the conclusions include (a) the nova-like variable AE Aqr is not nearly as bright as one would have expected for a system supposedly stuck at a high level of mass transfer, (b) proper motions for stars in crowded regions with diffuse backgrounds differ from ground-based values by considerably more than the errors of either, especially in the right ascension coordinate, and (c) one star previously identified as an FK Comae variable (rapidly rotating giant) is actually a very young, cool main sequence star.

Lim, Carilli, White *et al.* reported radio observations of Betelgeuse that revealed the temperature structure of its extended atmosphere from two to seven times the photospheric stellar radius. Close to the star the atmosphere had an irregular structure and a temperature consistent with the photospheric temperature but much lower than that of gas in the same region probed by optical and UV observations. This cooler gas decreased steadily in temperature with radius. Their results suggest that a few inhomogeneously distributed convective cells are responsible for lifting the cooler photospheric gas into the atmosphere; radiation pressure on dust grains that condense from this gas may then drive Betelgeuse's outflow.

4.4 Interstellar Medium and Star Formation

M. Pound (1998) has used BIMA to make the first ever images of the molecular gas in Eagle Nebula, a region made famous in 1995 by stunning HST images of its exquisite ''fingers.'' The BIMA maps of CO(1-0), ^{13}CO(1-0), and C^{18}O(1-0) emission, which have about 10″ ($\sim$ 0.1 pc) resolution, reveal a 700 $M_\odot$ molecular cloud being demolished by the intense activity of nearby O stars. Velocity gradients in the molecular gas reach up to 20 km s^{-1} pc^{-1}—enormous in comparison to typical clouds—with position angles that point directly back to the O stars. Through detailed examination of these velocity patterns, Pound has shown that the cloud's large fingers are unlikely to have arisen as a result of a Rayleigh-Taylor instability. In addition, he has measured directly from the data the evaporation and dynamic timescales of the cloud. The former is much longer than lifetime of the O stars, while the latter is much shorter and therefore more important to the cloud's ultimate fate. The cloud may be destroyed in as little as 100,000 years.

L. Looney has completed his thesis work on the circumstellar environment of young stars under the supervision of L. Mundy. The centerpiece of his thesis work is an 0.5'' resolution survey of ten young stellar objects (YSOs) with the BIMA array. The images are fully sampled spatially from 0.4'' to 60'' and represent the highest angular resolution of YSOs to date at this wavelength (Looney, Mundy, and Welch 1998). The survey shows that multiplicity is common among embedded YSO's and this multiplicity is related to the natural scales of fragmentation within the cloud. Modeling of the envelopes and disks associated with individual YSO's yielded estimates of the density distributions and the masses. One specific result is that the circumstellar disks in deeply embedded systems are not generally more massive than the disks around Classical T Tauri stars.

In a study of the young binary system T Tauri (Hogerheijde *et al.* 1997) it was proposed that the system is a coeval binary with one star being viewed through the disk of the other. This is counter to many previous claims that the two stars represent an unexplainable non-coeval binary. A survey of the continuum emission from five low-mass young stellar objects with known water masers (Lebee *et al.* 1998) showed that the masers are not associated with circumstellar disks, but they are generally within 50-200 AU of the central star. It is suspected that the masers arise from wind interactions in the low-mass systems.

Choi and Y. Lee (TRAO, Korea) 1998 observed the driving source of the Herbig-Haro object HH 1-2 using the BIMA and TRAO telescopes in the H^{13}CO$^+$ 1-0 line. Our map revealed that there is a high-density core elongated perpendicular to the outflow axis, but there is a positional displacement between the molecular core and the strongest continuum source, VLA 1, suggesting a complicated nature of the central region.

Choi, Panis (ASIAA), and Evans (Texas) 1998 completed a survey of ten Class 0 objects using the BIMA interferometer in the HCO$^+$ 1-0 and the HCN 1-0 lines. Although the target sources were selected from their infall signature in a single-dish survey, only about half of them show convincing infall signature with a small beam ($\sim$ 10″). The other half showed complicated line profiles either due to confusion from multiple clumps or due to systematic motions other than infall. They are doing radiative transfer simulations to reproduce the observed infall signature using theoretical models.

In collaboration with Farhad Yusef-Zadeh (Northwestern U.), J. Staguhn started a BIMA high resolution observing project in order to further investigate the physical properties of two molecular clouds, presumably interacting with the G359.54+0.18 Nonthermal Filaments and an associated HII region east of the filaments. He also obtained sub-mm 490 GHz [CI] $^3P_1 \rightarrow {}^3P_0$ observations of the Sgr C region in the Galactic center. These data were obtained with the South Pole based sub-mm telescope AST/RO. Since neutral carbon emission is an important tracer for photo-dissociation regions, these observations will contribute to a better understanding of the physical - and chemical - conditions in star formation regions in the Galactic center region.

P. Safier has critically examined the physical basis for current magnetic-accretion models for classical T-Tauri stars. He argues that there is little observational evidence for the strong, dipolar stellar magnetic fields required by these models; also the steady-state assumed by these models is not supported by the models. Safier has completed his study of the BD+41 40 star-forming region with the BIMA millimeter-array. The images reveal the structure of the associated molecular cloud, and confirm the existence of a out-

flow source associated with the complex. Safier and J. Lauroesch (NWU) are using the BIMA array at cm wavelengths in an effort to detect hydrogen recombination lines from quasars.

K. Rauch and J. Wang started an investigation of the accretion of inhomogeneous interstellar gas onto stellar mass black holes. The study utilizes time-dependent hydrodynamics simulations to trace variations in the mass accretion rate and follow the formation of (temporary) accretion disks around the black hole, as it accretes ISM material containing realistic density fluctuations. Such objects may be detected during the course of the upcoming Sloan Digital Sky Survey, but properly classifying them will require a deeper understanding of their physical characteristics than is currently available, which this study aims to provide.

E. Ostriker, in collaboration with J. Stone and C. Gammie (CfA), is continuing to model the evolution of dynamics and structure in star-forming molecular clouds using numerical magnetohydrodynamics in two and three dimensions. Over the past year, results have included (1) evaluation of turbulent decay rates and times for both quasi-steady state forced turbulence and decaying turbulence, showing that these decay times rarely exceed the fluid crossing time even for strongly magnetized clouds, (2) evaluation of the gravitational collapse times for self-gravitating clouds, showing that ''turbulent pressure'' cannot help to support clouds, but instead the (static) MHD Jeans criterion determines stability, (3) analysis of the density contrast in simulated clouds, showing that lognormal distributions occur, with mean contrast comparable to that in observed GMCs only for relatively strong mean magnetic fields ($> 15\mu G$), and (4) analyzing the power spectra of the velocity field to show it approaches the k^{-2} law observed in real clouds, and evidences both inverse and direct energy cascades. From the results (1) and (2), the conclusion is that ongoing turbulent re-excitation, likely associated with the star formation process, is necessary for GMC lifetimes to extend to the values inferred from other age-dating methods.

With P. Teuben and student J. Marshall, Ostriker investigated the problem of mass segregation in present-day star-forming clusters, using direct n-body simulations with realistic IMFs and comparing to the ONC. Their results showed that the observed segregation of the ONC could be achieved by dynamical friction assuming the current cluster properties only if its lifetime were three times observational estimates; a likely alternative is that the original mass of the cluster was larger (due to gas), thereby decreasing its dynamical friction time to acceptable values.

Ostriker has also used linear theory to deduce analytic formulae for the perturbed density distributions, and corresponding gravitational drag, on a massive object moving either subsonically or supersonically through a gaseous medium. The subsonic result corrects earlier statements of other workers which claim no drag in the case of subsonic motion; in fact, the dynamical drag is proportional to the Mach number for very small perturber velocities.

Ostriker has worked with student W.-T. Kim on investigation of the stability of magnetized winds to internal disturbances, for application to understanding the properties of winds and jets that are driven from the surfaces of accretion disks around protostars and compact objects. Findings so far show that global axisymmetric instabilities always exist when the equilibrium magnetic field has a sufficiently steep (< -0.88) logarithmic gradient; analysis of more complex modes is underway.

Ostriker has also reviewed magnetized condensation and collapse models for protostar formation by a number of different authors, and concluded that the similar condensation profiles found under a variety of different assumptions can all be understood as a consequence of magnetically-critical radial condensation with vertical quasistatic equilibrium. Ostriker also found solutions for the accretion rate for the collapse of a cold, power-law density sheet and showed that these agree well with observations of accretion rates and transition times in Class 0 and Class I protostars, when the initial density is normalized by the condensation solutions.

J.P. Harrington continues to work on planetary and proto-planetary nebulae. In collaboration with K. Borkowski (N Carolina State), ISO observations of hydrogen deficient PNe had been obtained. N.J. Lame has completed the reduction of this ISO data. These observations led to the discovery of a 6.4 μm dust feature in two of the three objects observed in this wavelength band. The authors note the absence of the usual ''PAH'' features in all three objects (why? no hydrogen to make PAHs = polycyclic aromatic hydrocarbons) and they interpreted the 6.4μm band as a C-C stretch mode. It is interesting that this feature is shifted from the usual 6.2μm wavelength seen in hydrogen-rich objects. This shift is not yet understood, but it must hold information about the nature of these small carbon grains. This paper explores only a fraction of our ISO and HST data, and modeling is continuing.

The proto-planetary nebula He 3-1475, an object with high-velocity (400-800 km s^{-1}) jets, is the target of a multi-instrument program of HST observations by Harrington and Borkowski. While STIS observations are still pending, narrow-band NICMOS observations have detected 2.12μm H_2 emission. NICMOS polarization observations have shown that the scattered light is up to 40% polarized. Preliminary single-scattering models show the polarization to be consistent with a disk with cavities along the axial (jet) directions. Monte Carlo scattering models are being constructed to verify this picture of the morphology of the neutral gas which is collimating the jets.

Wolfire along with C. Ceccarelli *et al.* (Observatoire de Grenoble) presented mid-IR wavelength observations toward the low mass star forming region IRAS 16293-2422 taken with LWS on board ISO (Ceccarelli *et al.* 1998a). The spectrum was dominated by emission from CO, H_2O, OH, and [O I]. Analysis of the high-J CO lines indicate that the emission arises in a dense ($n \sim 10^4$ cm^{-3}) warm ($T \sim 1500$ K) gas associated with a C-type shock in an outflow region. The derived H_2O and OH abundance was found to be $H_2O/H_2 \sim 2 \times 10^{-5}$ and $OH/H_2 \sim 5 \times 10^{-6}$ respectively. This relatively low water abundance suggests that the time required to convert oxygen into water is longer than the outflow time. The observed [O I] 63 μm emission was found to be consistent with model predictions of the line emission produced in a collapsing envelope.

Wolfire along with C. Ceccarelli *et al.* reported the detection in IRAS 16293-2422 of high-N transitions of CO^+ taken with ISO (Caccarelli *et al.* 1998b). This was the first time that CO^+ was detected in a low luminosity source and the first time that high-N lines were detected in any source. The best fit model suggests that the CO^+ emission originates in a strong, dissociative J-shock at 500 AU from the star with a shock velocity of 100 km s^{-1}. The models also predict a stong magnetic field to be present with a field strength as high as $\sim$ 1 mG.

4.5 Planetary Science

4.5.1 Comets

Y. Fernández, D. Wellnitz, M. A'Hearn, and C. Lisse, with collaborators from Lowell Obs., Lunar and Planetary Laboratory, and MIT, completed an analysis of an observed close appulse ($\leqslant 0.02 arcsec$) of the comet Hale-Bopp with a 9th-magnitude star in Ophiuchus in late 1996. By modeling the size of the nucleus and the structure of the inner coma, they found that the nucleus' radius was likely smaller than about 30 km and that the opacity of the dust was greater than unity within 20 to 70 km of the center of the nucleus. This was the first time such a close appulse had been observed between the nucleus of an active comet and a star, only the second time the coma's opacity had ever been measured so close to the nucleus (the other being done during the spacecraft flybys of comet Halley in 1986), and the highest opacity ever measured for a comet's dust coma. Occultations are one of the best ways to probe the deepest parts of the comet, which are usually beyond the capabilities of traditional observational methods.

Fernández, Lisse, and A'Hearn, with collaborators from Boston U., U. of Arizona, JPL, Harvard-Smithsonian Astrophysical Obs., and U. of Hawaii, continued their survey of the physical properties of the nuclei of active comets. They reported a determination of the radius and visual geometric albedo of comets 81P/Wild 2 and 55P/Tempel-Tuttle, the former being the target of the *STARDUST* spacecraft in the next decade and the latter being the parent to the Leonid meteor stream. They also constrained the size of the nucleus of the long-period comet Utsunomiya (C/1997 T1)—a rare bonus considering the typical logistical uncertainty of observing long-period comets. Their work improves the understanding of the comet-to-comet variation of physical characteristics, and furthers a long-term goal of collecting a statistically-significant sample of the characteristics of cometary nuclei.

Fernández, Lisse, and A'Hearn, with collaborators at European Southern Obs. and Max Planck Institut für Kernphysik, studied comet 2P/Encke. Though observed for nearly 60 apparitions—more than any other comet—the basic properties of its nucleus had remained hidden. Fernández *et al.* took advantage of the closest passage of the comet to Earth ever—$\leqslant$ 0.2 AU in mid-1997—using high-resolution ground-based mid-infrared imaging and photometry from the *ISO* spacecraft to constrain the size and reflectivity of the nucleus, its rotation rate, and the albedo and production rate of the very large ($\sim 100\mu$) dust grains being emitted by the comet.

Lisse, Fernández and A'Hearn finished their long-term monitoring at NRAO, CSO, KPNO, ESO, and NASA/IRTF of comet Hale-Bopp during its spectacular apparition of 1995 - 1998. Reports describing the results of the campaign were presented at the 1st International Conference on Comet Hale-Bopp, and published in the journal Earth, Moon, and Planets. Results include an infrared determination of the nucleus size of $\sim$25 km, a huge outflow of normal composition but small, hot, and dense dust, and a low rate of x-ray generation from the comet compared to its optical luminosity and gas and dust production rates.

Lisse and collaborators at MPE and NASA/GSFC continued their study of x-ray emission from comets. Comets P/Encke and P/Tempel-Tuttle were observed using the ROSAT, EUVE, and ASCA spacecraft in July 1997 and January 1998, respectively. X-ray luminosities $\sim$0.10 that of Hyakutake were found, broad-band photometry was extended in energy from 0.03 keV to 2.0 keV using the multiple spacecraft, and long-term monitoring produced detailed light curves of these two comets. No correlation was found between the x-ray emission and solar x-ray emission, but a strong correlation was found between the cometary x-ray emission and the solar wind flux. The spectromphotometry of the emission was found to be soft and continuum dominated down to the lowest energies. Comparison to other comets shows that dust based emission mechanisms can be ruled out. Efforts continued to model possible mechanisms and compare the results to observations. Three possible mechanisms, charge-exchange between solar wind minor ions and cometary neutrals, electron-neutral bremsstrahlung, and reconnection of solar wind magnetic field lines remain viable.

Lisse, A'Hearn, and Fernández, with collaborators at GSFC and MPIK, continued their long term study of cometary dust emission trends, publishing the 1-300 μm observations of the 4 comets detected by the absolutely calibrated COBE/DIRBE telescope, ground based and space based observations of comet C/Hale-Bopp at 1-20 μm (see above section on Hale-Bopp campaign), preparing for submission a paper comparing the very different dust emission from comet P/IRAS (many small hot grains) and P/Encke (few large cold particles) as determined from ISO 1-100 μm measurements, and beginning a 1-20 μm ground-based study of the dust in Saturn's rings, searching for clues to the icy particles' size, composition, and thermal behavior from our knowledge of cometary dust.

L. Woodney, A'Hearn and colleagues at NRAO and NOAO completed their long term monitoring of sulfur species in C/Hale-Bopp. Regular observations of the millimeter wave transitions of CS, H_2S and OCS were made at the National Radio Astronomy Observatory, 12-m telescope over the course of two years. Significant results include the discovery of H_2CS in a comet, and the long term behavior of OCS. The abundance of H_2CS is low enough that it was found not to play a major role in the overall sulfur budget of comets. The production rates of the major sulfur species were tracked with heliocentric distance, and it was found that

the production rate of OCS increased much more quickly with decreasing heliocentric distance than any other species. This indicates there is something fundamentally different about the OCS in cometary ice. These results were presented at the first international conference on Hale-Bopp held in Tenerife, Canary Islands.

Additionally, Woodney, A'Hearn, colleagues at Lowell Observatory, and the Berkeley-Illinois-Maryland comet observing team undertook a comparison of the morphology of HCN and CN. Hale-Bopp is the first comet for which there has been simultaneous high resolution imaging of this parent and daughter pair, so that this is the first time the morphology of their relationship can be examined. A greater understanding of the HCN/CN relationship will place constraints on the much disputed nature of other proposed CN parents. Of particular interest is what these HCN images can reveal about the nature of the association of the nuclear HCN source with the CN jets since there is enough spatial resolution to detect HCN jets.

The HCN maps of the $J=1\rightarrow 0$ transition at 3mm were made with the Berkeley-Illinois-Maryland Association (BIMA) Array in Northern California, with a beam size of $\sim 9''$. The maps have been created so that they are phased with the rotational period of the comet to reduce the smearing of any spatial features seen in the maps. At each phase examined, data spanning several days has been summed both to increase the signal to noise ratio and give more complete uv coverage than a 1 to 2 hour observation would provide on its own. When these maps are compared to similarly phased narrowband CN images obtained at Lowell Observatory taken near or at the same time as the HCN images it is clear that at least some of the CN jets are a product of HCN jets, but that there is probably a secondary source. A likely candidate for this secondary source is dust, however more exotic parent molecules such as C_2N_2 as suggested by Festou *et al.* (1998) are also possible. These results were reported at the Division of Planetary Sciences meeting in Madison, WI.

4.5.2 Asteroids

The initial analysis of images of asteroid 253 Mathilde acquired when the NEAR spacecraft flew passed this C-type asteroid at a distance of 1212 km in June, 1997 were published by the NEAR MSI team of which McFadden is a member Veverka *et al.* 1997, Science, 278, 2109). The surface of this irregularly shaped asteroid measures 66 x 48 x 46 km, principal axes diameters, as determined from stereogrammetry and limb fitting models. Its surface is heavily cratered with a range of crater diameters. Five craters are observed in the 50% coverage of the asteroid with diameters between 19 and 33 km, close to the value of the radius of the asteroid. This is consistent with a cratering function that is similar to that forming craters on the Moon. There are no measurable albedo or color variations across the observed surface suggesting a homogeneous composition throughout the asteroid. No satellites were detected, and no evidence to explain Mathilde's slow rotation period of 17.4 days was revealed. The volume derived from the images, 78,000 km, combined with the mass derived from Doppler tracking of the spacecraft, 1.033×10^{20} g, yield a density from 1.1-1.5 g/cm^3. This value is half that of carbonaceous chondrite meteorites, implying that the internal structure of the asteroid is extremely porous, supporting the rubble pile theory of asteroid interiors. This is the first experimental data addressing such theory.

Data Acquisition plans for the nominal mission to 433 Eros have continued throughout the year. D. Wellnitz has joined the NEAR science team as an associate. Wellnitz and McFadden are preparing for data verification and calibration for the upcoming year-long data acquisition phase of the NEAR mission to asteroid 433 Eros, an Earth-approaching, Amor asteroid.

Analysis of the surface of olivine after bombardment by low energy 1 keV electrons for evidence of chemical or structural change was reported by Dukes *et al.* (1998). This work was designed to study the effect of the solar wind on the optical properties of asteroid surfaces. There was evidence of short term (unstable) reduction of the surface material. The state of iron changed from 2+ to 3+. But under STP, the condition reverted to the 2+ state. The next step is to evaluate the magnitude of this change under sustained bombardment equivalent to longer time frames (greater than 300-500 years) and to determine whether the effect is cumulative to the point of affecting the surface reflectance properties of solid bodies in the solar system.

With Ogilvie and Coplan, the ion composition instrument (ICI) data from the ICE mission through the tail of Comet Giacobini-Zinner was reanalyzed in light of the presence of a sodium tail seen in Comet Hale-Bopp. If the M/q of 22-23 is interpreted as Na+ then sodium exists in comets in more than one state and in different parts of the comet. The ICE spacecraft flew through the comets coma where the sodium was already ionized. The sodium in Hale-Bopp was not ionized and formed a tail.

4.5.3 Dust and Dynamics

K. Rauch, in collaboration with M. Holman (SAO), completed a study exploring new ways to extend the reliability and range of applicability of a class of symplectic integration methods that is widely used in simulating the dynamics of the Solar System and similar physical systems. With the recent discovery of extrasolar planets and the associated surge of interest in the physics of planet formation, the need for robust, efficient methods for investigating the dynamics of many-body systems dominated by a single central mass has become acute. The study of Rauch and Holman provided new clues (and a good deal of practical knowledge) on how this goal can be achieved.

Rauch and D. P. Hamilton began a study of planet migration and the likelihood of orbital resonance trapping during the formation of the Solar System. Through the use of large scale simulations of planetesimal scattering by the outer giant planets, both the radial migration of the planets and the evolving orbital distribution of the planetesimals themselves are being examined. The results should constrain the formation locations of the giant planets as well as provide improved data on the initial configuration of the Oort Cloud, thought to consist of icy planetesimals ejected from the inner

Solar System during planetary close encounters (primarily with Jupiter).

Hamilton undertook a major upgrade of his numerical integrator that follows the orbital evolution of dust grains around planets. New options were added to the code including: 1) the ability to include the gravitational perturbations from multiple planetary satellites and 2) the ability to include a better approximation to the higher order gravity fields of the terrestrial planets. He also added an important package which performs symplectic integrations to the code. This package includes subroutines developed by Rauch, which correctly treat the difficult velocity-dependent electromagnetic force. The symplectic integrator improves the overall speed of integration substantially in many cases; Hamilton also optimized many of the code's internal routines for additional increases in speed. Currently, Hamilton is evaluating the performance of symplectic and standard integrators on typical dust dynamics problems to determine the strengths and weaknesses of each integration method.

Hamilton is collaborating with J. Burns, M. Showalter, and I. de Pater on a study of the jovian rings. Spectacular new data from Keck and Galileo have allowed us to substantially advance our understanding of the physics of the jovian ring. Hamilton employed his numerical integration schemes to interpret the new observations. Two data papers were submitted this year, with more detailed theory efforts to follow.

With E. Grün and the Galileo dust team, Hamilton has continued his study of dust in the jovian system. New concentrations of dust were detected near several of the Galilean satellites. This dust seems to be consistent with fragments ejected during hypervelocity interplanetary impacts of interplanetary material with the moons. Data analysis and numerical modeling efforts are underway.

With graduate student H. Fleming, Hamilton is investigating the consequences of early solar system processes – the growth of Jupiter by mass accretion and its subsequent radial migration – on the Trojan asteroids. These dark distant objects are dynamically locked in 1:1 resonance with Jupiter. We find that Jupiter's mass accretion is very effective at capturing and stabilizing objects in the 1:1 resonance and are currently preparing our analytic and numerical results for publication. An understanding of the processes that affected the Trojans will help us decipher clues about conditions in the early Solar System from the current population of these distant asteroids.

4.6 Space Plasma Physics

The Space Plasma Physics Group (K. Papadopoulos, C. Goodrich, A. Sharma, G. Milikh, M. Wiltberger and R. Lopez) had the NASA group achievement award in recognition of their contribution to the highly successful exploration of geospace by the Global Geospace Science program.

K. Papadopoulos, C. Goodrich, R. Lopez and M. Wiltberger (graduate student) have continued their work on the global modeling research. Over the last few years, they have made very significant advances in the understanding of the Earth's magnetosphere and those of the outer planets. These advances have resulted from three fundamental improvements in their global MHD code, written by their collaborator, J. Lyon (Dartmouth), including extension of the range of the code to several hundred Re downstream of the Earth, incorporation of time dependent conditions on ALL of the boundaries, and implementation of a rotating dipole and semiconducting ionosphere. This work was made in collaboration with Lyon and R. McNutt (Johns Hopkins/APL).

This group has performed a series of global MHD simulations that may provide the key to understanding isolated magnetospheric substorms. This study has mostly focused on the substorm event occurring at 0500 UT on March 9, 1995, which is particularly well documented by both ground based and spacecraft observations. It uses an impressive collection of ground radar, magnetometer, and other data which give a thorough ionospheric view of the substorm. Data are also available from the ISTP spacecraft, which are well placed for in situ observations.

The simulation results give a global description of the substorm that is in good agreement with both the ground based and in situ measurements. They find onset occurs about 0500 UT, following a growth phase marked by thinning of the plasma sheet (PS) and heating of the PS plasma which starts around -8 Re and then progresses tailward. These results indicate onset is marked by an impulsive penetration of electric field into the central plasma sheet, and a diversion of the cross tail current, at about −10 Re. These features thereafter propagate down the tail to about −25 Re, where they engender strong reconnection, and the global magnetic topology reconfiguration characteristic of the substorm expansion phase. These results suggest a realistic model that combines the major aspects of the current leading substorm models, the Near Earth Neutral Line and Current Disruption models.

The global conditions during a moderate geomagnetic disturbance event on May 15, 1996 were also examined by comparing data from several ground-based instruments and inner tail satellites with global MHD simulations of the same event. The ground-based data show two substorm intensification about 40 min apart, the first one being small and localized (a pseudobreakup) and the second leading to a major rearrangement of both the ionospheric auroral distribution and the magnetotail configuration. The simulation shows that during the pseudobreakup, open field lines were reconnecting in the midtail, but the flows were mainly tailward and very few effects were observable in the inner magnetosphere. The result that pseudobreakups can be associated with activity producing topological changes in the tail is an important new aspect that has not been discussed in earlier studies. Both the observations and the simulation show two distinct regions of activity: a thin current sheet in the inner tail magnetically connected with the auroral bulge and a reconnection region in the midtail associated with the most intense electrojet currents.

Furthermore the results of a 3D MHD simulation of the January 10–11, 1997 geomagnetic storm were presented. The simulation results agree well with ground-based and geosynchronous observations. The 28 hours modeled by the simulation include the magnetic cloud responsible for the storm, the shock preceding the cloud, and the dense plasma filament following it. The simulation shows that during the

period of southward IMF ionospheric activity was strongly correlated to the solar wind density. The arrival of the plasma filament during northward IMF pushed the dayside magnetopause well within geosynchronous orbit, but generated little ionospheric activity. It appears that nsw as well as the orientation of Bsw plays a role in controlling the intensity of ionospheric and magnetospheric activity.

A. S. Sharma and K Papadopoulos have continued their investigation of the magnetosphere and space weather using nonlinear dynamical technique.

The solar wind-magnetosphere system exhibits coherence on the global scale and such behavior can arise from nonlinearity in the dynamics. The observational time series data have been used extensively to analyze the magnetospheric dynamics by using the techniques of phase space reconstruction. Analyses of the solar wind and auroral electrojet and Dst indicates have shown low dimensionality of the dynamics and accurate prediction can be made with an input-output model. The predictability of the magnetosphere in spite of the apparent complexity arises from its being synchronized, in the dynamical sense, to the solar wind. The strong electrodynamic coupling between the different regions of the magnetosphere yields its coherent, and thus low dimensional, behavior. The data from multiple satellites and ground stations can be used to develop a spatio-temporal model that identifies the coupling between the different regions. These nonlinear dynamical models yield accurate and reliable forecasting tools for space weather.

J. Valdivia (NASA/GSFC), Sharma and Papadopoulos worked on the prediction of magnetic storms using nonlinear dynamical models. The nonlinear dynamical technique of phase space reconstruction is applied to develop nonlinear models of storms and their predictability using the NGDC database for 1964–1990. Nonlinear predictive models based on the Dst data alone were developed. These models can predict the storm evolution consistently, and can identify intense storms from moderate ones. The models based on IMF and Dst data, as well as those based on Dst alone, can be used for forecasting tools for space weather.

Sharma, Valdivia, S R. Rosa and H. S. Sawant (INPE, San Paolo, Brazil) studied dissipative structures and weak turbulence in the solar corona. In this work for the first time the high resolution X-ray images of the solar corona, obtained by the Yohkoh Mission, as non-linear extended systems have been analyzed. To qualify the spatio-temporal complexity in this extended system, they have introduced an asymmetric spatial fragmentation parameter computed from a matrix representing an image. Choosing different spatial scales on the same image, wave numbers are computed from the intensity contours and this yields a fragmentation spectra. This spectra is used to analyze the images of the complex transient phenomena obtained by the Soft X-ray Telescope board the Yohkoh satellite. The dynamics of the fine structures of the contours suggest the origin of the observed fragmentation to be the localized weak turbulence processes occurring in regions with complex plasma loop configuration.

Sharma and D. N. Baker (U. Colorado) studied what triggers substorm expansion onset, which is a main objective of substorm research. Many mechanisms have been proposed and there has been improved understanding of the role of different processes. However there is no unequivocal agreement on one mechanism of the expansion onset and new or modified mechanisms have recently been proposed. On the other hand there is a new recognition of the global nature of the substorm dynamics. While the search for the initiation mechanism continues, there is significant progress in the efforts to understand the global dynamics. This approach is based on the recognition that in spite of its complexity, the strong coupling between the different parts of the magnetosphere makes global coherence the dominant dynamical feature. Among the new developments in this area is the understanding of the overall substorm dynamics in terms of simple models such as catastrophe and self-organization.

Sharma and M. I. Sitnov (Moscow U.) studied the role of the temperature ratio in the linear stability of quasi-neutral sheet tearing mode. Well-known linear stability criterion of the tearing mode in the magnetotail current sheet with nonzero normal component of the equilibrium magnetic field considers the electrons to be trapped in the current sheet. This condition is significantly modified when electron-to-ion temperature ratio is small, due to the contribution of transient orbits to the perturbed electron density integrated over the flux tube. In contrast to the previous criterion marginal stability may be reached under realistic conditions in the near-Earth tail current sheet during late substorm growth phase.

Sharma, Valdivia, D. Vasiliadis and A. Klimas (NASA/GSFC) studied the spatio-temporal multivariate properties of the electrojet current. They have generalized the input-output analysis of the electrojet indices to a spatio-temporal dynamical model of the high latitude magnetic perturbation, by using multiple ground magnetometer measurements from the Canopus array, as outputs. The spatio-temporal solar wind–magnetosphere coupling during substorms is modeled as a solar wind driven nonlinear system where the different parts of the system are allowed to interact with each other and with the solar wind. A novel technique is used to construct a fully 2 dimensional representation of the high latitude magnetic perturbations.

K. Papadopoulos in cooperation with P. Guzdar and P. Chaturvedi and S. Ossakow (NRL) studied the thermal focusing instability of high power radio waves in the ionosphere near the critical surface. In the simulation model studied, a high power radio wave with 1modulated wave undergoes strong self-focusing at the critical surface where the group velocity of the wave goes to zero. The large parallel thermal conduction leads to the diffusion of these irregularities into the underdense and overdense plasma in narrow filaments. The depletion in the density in the overdense plasma allows propagation of the wave to higher altitude above the original critical surface and hence into the overdense plasma.

Papadopoulos, G. Milikh and Valdivia (NASA/GSFC) have continued their studies of high altitude lightning in cooperation with Y. P. Raizer (Institute of Applied Mechanics, Russia). Valdivia has worked on the problems related to this topic till spring 1997, when he graduated from the Maryland Ph. D. program. Key issues addressed were modeling of so called red sprites, optical flashes located at 60–90 km above

the thunderstorm, with emphasis on their fine structure, and study of the runaway discharge in the presence of the geomagnetic field. Based on the fact that lightning discharges follow a tortuous path which have been identified as a fractal structures, they developed a model of transient electric field from lightning as a fractal antenna. This model allows to obtain a spatio-temporal distribution of the optical flashes due to the lightning.

Recent observations suggest that the sprites are caused by streamers. Those streamers are initiated in the lower ionosphere by electron patches caused by the electromagnetic radiation from the horizontal intracloud lightning, and are then developing downward in the static electric field due to the thundercloud. Raizer, Milikh and Novakovski (UMD) analyzed triggering conditions of streamer development. Using similarity relations known characteristics of streamer tip earlier obtained for the laboratory conditions were extended to the description of streamers in the rare air. Then the streamer growth in the nonuniform atmosphere was calculated. It was shown that streamers first appear at the height of about 80 km, and are then growing downward slightly below 50 km, where they are terminated. This is in agreement with the red sprites observations. The altitude distribution of the streamer generated plasma was obtained. The obtained simple models of streamer development could be applied for the computations of streamers growing at various conditions.

K. Papadopoulos with A. Drobot and C. Chang (Science Application International Corp.) studied the physics of current collection by the tethered satellite system which was deployed from the space shuttle ''Columbia'' on February 24, 1996. Data collected revealed a host of new physics phenomena concerning the current collection was much more efficient than predicted on the basis of theoretical models, and previous laboratory and rocket experiments. Furthermore a sharp transition in the interaction physics occurred at threshold potentials between 5–10 V. In addition a significant population of suprathermal electrons, heated ionospheric ions, and enhanced plasma waves were observed in the ram direction. The ongoing physics analysis of the observed phenomena was presented.

Sharma with P. Guzdar and S. Guhary presented a simple dynamical model for studying the charging of substrates irradiated by particle beams. The charging potential for positive ion beams can be as large as the beam voltage. For negative ions beams, the charging potential is significantly lower and is governed by the secondary electrons. A closed form expression derived for the charging voltage in the case of negative ion beams agrees well with the numerical model. The results are consistent with observations on charging of isolated substrates during ion implantation with positive and negative ion beams.

4.7 Solar Radio Physics

Kundu and Raulin along with Nitta, Shibata and Shimojo searched for nonthermal radio signatures in the form of metric type III bursts in conjunction with two-sided-loop-type X-ray jets observed by the soft X-ray telescope aboard Yohkoh satellite. They found no evidence of type III bursts associated with this particular type of X-ray jets in contrast to the positive evidence of type IIIs associated with anemone-type jets. This result is consistent with simulations which show that anemone-type jets are produced by vertical/oblique plasma flow whereas the two-sided-loop-type jets are produced by horizontal plasma flow.

Lee, White, Kundu along with McClymont and Mikić compared VLA microwave images of a solar active region with state-of-the-art fully nonlinear force-free extrapolations of the photospheric magnetic fields and studied the link between coronal currents and heating of the corona. The extrapolation fully took into account the nonuniform distribution of electric currents observed in the photosphere and its role in the coronal magnetic structure. Under the assumption that the microwave emission is dominated by optically thick gyroresonance radiation, they used the radio images to infer the temperature of the corona at different heights and locations. This was then compared with heating models based on the observed current distribution. They reproduced the radio images remarkably well with a model in which temperature is structured along magnetic field lines, depends on the current on the field line, and increases with height in a manner similar to that inferred from static heated loop models. This result implies a direct link between electric currents and coronal heating.

Lee, White, Kundu along with Mikić and McClymont studied the phenomenon of depolarization of microwaves over solar active regions which can be used to infer the coronal electron density once the coronal magnetic field is known. They explored this technique using excellent VLA maps showing depolarization at two frequencies and for which an excellent magnetic field model was available. They showed that this technique for obtaining coronal densities is very sensitive to the quality of the of the coronal magnetic field model which, in turn, depends significantly on the electric currents used as boundary condition for the field extrapolation. Such extreme sensitivity to the magnetic field model explains in part why the inference of a low density has been a common complaint of studies which have employed the potential field model to determine the density from the depolarization condition.

Lee, White, Kundu along with Mikić and McClymont applied a test to a magnetic field model for an active region. The test was based on the expectation that the temperatures at different points of a magnetic field line should be well correlated. They used radio observations of an active region to measure the temperatures on field lines as they cross two isogauss surfaces in the corona. The magnetic field model was obtained via a nonlinear force-free field extrapolation of the photospheric vector magnetogram. In a region where strongly sheared fields were present, the force-free field model did indeed showed a good correlation between the temperatures in the two surfaces at points on the same field line, while the potential-field model did not.

Nindos with Zirin (Caltech) studied the properties and proper motions of Ellerman Bombs around a sunspot in a mature active region using off-band H_α filtergrams and simultaneous magnetograms. 64% of the Ellerman Bombs did not correspond accurately to enhanced magnetic field elements and did not move while the rest corresponded well to

such elements which all were moving magnetic features. The velocity of this class of Ellerman Bombs was about 1 km/s and their velocity pattern was similar to the velocity pattern of the moving magnetic features.

Nindos, Kundu and White presented the results of a search for radio-selected transient brightenings (TBs) in the solar atmosphere as a complement to the more common X-ray selected surveys. Five small impulsive events were identified in a set of VLA observations at 4.5, 1.5 and 0.33 GHz and compared with soft X-ray images from Yohkoh and EUV images from SOHO/EIT. Four of the events were located at the edges of an active region but one was located 100″ away in a quiet region of the atmosphere. Their data favor an interpretation in terms of gyrosynchrotron radiation from mildly relativistic electrons. A small number of nonthermal electrons with spectral index 3 explained the observed properties of the TBs. Two of the microwave TBs also showed evidence for type III radio emission at 327 MHz.

Silva, Lin, de Pater, White *et al.*, presented a comprehensive analysis of the 1994 August 17, flare, the first flare imaged at millimeter wavelengths. The flare was observed simultaneously by BIMA at 86 GHz, by the Nobeyama Radioheliograph at 17 GHz and by the soft X-ray and hard X-ray telescopes and the Bragg Crystal Spectrometer on board Yohkoh. The energy spectrum from the nonthermal emissions at microwave and hard X-ray wavelengths suggested that these emissions were created by the same electron population. The soft X-rays and millimeter flux density were only consistent with the presence of a multitemperature plasma.

Zhang, White and Kundu investigated the height structure of the solar chromosphere and transition region using images obtained from the Extreme-Ultraviolet Imaging Telescope aboard SOHO. They found that the limb is higher at the poles than at the equator both in the coronal images (chromosphere limb by 1300 km) and the He II 304 Å images (transition region limb by 3500 km). The 304 Å limb is significantly higher than the limb in the coronal images. The height difference is 3100 km at the equator and 6600 km at the poles.

Zhang, Kundu and Schmahl along with Gopalswamy and Lemen presented measurements of the magnetic field gradient in coronal loops based on observations of two transient microwave brightenings. The events were observed at 2 cm and 6 cm with the VLA. Soft X-ray images from Yohkoh satellite were also available. The 2 cm and 3.6 cm sources were located near the footpoints of the soft X-ray loops and came from thermal gyroresonance emission. The estimated magnetic field gradient near the footpoint of the magnetic loop was 0.09 G km^{-1} and 0.12 G km^{-1} for the two events. These values are smaller than those observed in the photosphere and chromosphere by at least a factor of 2.

Aschwanden developed a theoretical model to deconvolve two different electron populations that produce hard X-rays in solar flares. Based on the opposite characteristics of energy-dependent time delays, two electron components can be deconvolved from hard X-ray count rate time profiles: (1) electrons that precipitate directly from the coronal acceleration site to the chromospheric hard X-ray emission site (based on the velocity-dependent electron time-of-flight differences), and (2) electrons that are temporarily trapped in coronal ''magnetic bottles'' and precipitate after they become pitch-angle scattered into the loss-cone by Coulomb collisional scattering. Based on this theoretical model, Aschwanden developed a numerical code that is able to infer from the observed hard X-ray time profiles: (1) the electron time-of-flight distance between the accelerator and the chromosphere, (2) the electron density in the loss-cone, (3) the fraction of trapped electrons, (4) the magnetic mirror ratio in flare loops, and (5) the loss-cone angle. Test simulations revealed a satisfactory inversion of these physical parameters from observed hard X-ray flux profiles.

Aschwanden, Schwartz (GSFC) and Dennis (GSFC) applied then this numerical code to the analysis of some 100 solar flares observed with BATSE on the Compton Gamma Ray Observatory and determined this way the height of electron acceleration sources, densities in flare loops, and the electron trapping efficiency in flare loops. A major result was that electron trapping in solar flares appears to be controlled by collisional scattering (weak-diffusion limit) rather than by wave-induced scattering.

Aschwanden, Kliem (Potsdam), Schwartz (Potsdam), Kurths (Potsdam), Dennis (GSFC) and Schwartz (GSFC) analyzed some 700 solar flares observed with the Compton Gamma Ray Observatory with a wavelet transform method. They developed a mathematical transformation of wavelet scalegrams into a standard distribution function of physical time scales. Applying this method to CGRO data with 64 ms time resolution they found that the shortest detected time scales (100-700 ms) inferred with the wavelet technique showed a correlation with spatial scales of flare loops measured in Yohkoh/SXT and HXT images. This spatio-temporal correlation indicates a scaling law between the time scales of elementary acceleration processes with spatial scales of plasma cells in the acceleration region.

Brown, Conway (Glasgow U.) and Aschwanden studied analytically and numerically the relationship between an energy-dependent electron injection spectrum and the resulting bremsstrahlung photon spectrum with the goal of exploring whether injection functions could explain energy-dependent time delays observed in solar flare hard X-rays without any time-of-flight effects. Although the answer is a ''yes'' from the mathematical point of view, no plausible physical model for the acceleration mechanism is known to date that could predict the hard X-ray delays without time-of-flight effects.

Chernov (Izmiran) *et al.* and Aschwanden analyzed radio dynamic spectra of a flare observed with ARTEMIS (France), Izmiran, and Nancay radioheliograph with ''zebra patterns'' in the frequency-time plane and modeled this remarkable event with theoretical models that involve whistler waves and upper-hybrid waves at the double plasma resonance.

Murawski (Poland), Aschwanden, and Smith (St. Andrews) simulated numerically impulsively generated MHD waves and investigated their detectability in solar coronal loops in soft X-ray, optical, and radio wavelengths.

Vourlidas (NRAO), Bastian (NRAO), and Aschwanden analyzed VLA multi-wavelength observations of an active region simultaneously observed with Yohkoh in soft X-rays and modeled the radio emission above the sunspot with inhomogeneous density and temperature models.

4.8 Instrumentation

Trimble has completed a survey of astronomical drivers for optical interferometry and adaptive optics, including monitoring of activity on Io and potential triggers relevant to triggering of earthquakes; deblending of MACHO events and the nature of halo dark matter; and calibration of various extra-galactic distance indicators.

4.9 Other

Trimble has traced out the development of accretion as an astrophysical phenomenon, including epochs when even accretion of meteorites by the earth was denied and other epochs when accretion was credited as a source of solar energy and as primarily responsible for turning long-lived stars into short-lived massive ones. In progress is an investigation of how human concepts of the size of the universe have changed with time and between cultures.

PUBLICATIONS

A'Hearn, M. F., 1999, ''Recent Results in the Study of Comets,'' in Proceedings of ACM 96, Ed. A.-C. Levasseur-Regourd, in press.

A'Hearn, M. F., and Livengood, T.A., 1998, ''Multi-Wavelength Campaigns in the Solar System,'' in ''Ultraviolet Astrophysics: Beyond the IUE Final Archive,'' ESA SP-413, Ed. W. Wamsteker and R. González Riestra, (ESA Pub. Div., Noordwijk), pp. 625-632.

Alonso-Herrero, A., Simpson, C., Ward, M.J., and Wilson, A.S., 1998, ''A Near-Infrared Imaging Study of Seyfert Galaxies with Extended Emission Line Regions,'' AJ, 495, 196.

Aoki, K., Kosugi, G., Wilson, A.S., and Yoshida, M., 1998, 'The Radio Emission of the Seyfert Galaxy NGC 7319,'' ApJ, in press.

Aoki, K., Kosugi, G, Yoshida, M., Ohtani, H., and Wilson, A.S., 1998, ''Outflow in the Seyfert Galaxy NGC 7319,'' in IAU Symposium Nr. 184, in press.

Arballo, J.K., Tsurutani, B.T., Zhou, X.-Y., Lakhina, G.S., Ho, C.M., Kamide, Y., Shue, J.-H., Akasofu, S.-I., Lepping, R.P., Sharma, A.S., Goodrich, C.C., Papadopoulos, K., and Lyon, J.G., 1998, ''Pseudobreakups During January 10, 1997,'' Proc. Fourth Int. Conference on Substorms, ed. Y. Kamide, Terra. Sci., Tokyo, in press.

Aschwanden, M.J., Bynum, R.M., Kosugi, T., Hudson, H.S., and Schwartz, R.A., 1997, ''Electron Trapping Times and Trap Densities in Solar Flare Loops Measured with CGRO and Yohkoh,'' ApJ, 487, 936-955.

Aschwanden, M.J., Dennis, B.R., and Benz, A.O., 1998, ''Logistic Avalanche Processes, Elementary Time Structures, and Frequency Distributions in Solar Flares,'' ApJ, 497, 972-993.

Aschwanden, M.J., 1998, ''Deconvolution of Directly-Precipitating and Trapped-Precipitating Electrons in Solar Flare Hard X-Rays. I. Method and Tests,'' ApJ, 502, (July 20 issue), in press.

Aschwanden, M.J., Schwartz, R.A., and Dennis, B.R., 1998, ''Deconvolution of Directly-Precipitating and Trapped-Precipitating Electrons in Solar Flare Hard X-Rays. II. Compton GRO Data Analysis,'' ApJ, 502, (July 20 issue), in press.

Aschwanden, M.J., Kliem, B., Schwarz, U., Kurths, J., Dennis, B.R., and Schwartz, R.A., 1998, ''Wavelet Analysis of Solar Flare Hard X-Rays,'' ApJ, 506, (Oct 1 issue), in press.

Aschwanden, M.J., 1998, ''What did Yohkoh and Comtpon Change in our Perception of Particle Acceleration in Solar Flares?,'' in ''Observational Plasma Astrophysics: Five Years of Yohkoh and Beyond,'' (eds. T.Watanabe, T.Kosugi, and A.C.Sterling), Netherlands: Kluwer Academic Publishers, p.285-294.

Aschwanden, M.J., 1998, ''Particle Beams and Acceleration Processes,'' IAU Reports on Astronomy 1993-1996, Transaction of the International Astronomical Union, IAU Commission 10, Section on ''Solar Flares,'' (ed. Oddbjorn Engvold), in press.

Aschwanden, M.J., 1998, ''Nonthermal Flare Emission,'' Chapter 8 in ''The Many Faces of the Sun,'' A Summary of the Results from NASA's Solar Maximum Mission, (eds. K.T.Strong, J.L.R. Saba, B.M. Haisch, and J.T. Schmelz), Springer-Verlag, p.265-292, in press.

Aschwanden,M.J., Neupert, W.N., Newmark, J., Thompson, B.J., Brosius, J.W., Holman, G.D., Harrison, R.A., Bastian, T.S., Nitta, N., Hudson, H.S., and Zucker, A., 1998, ''3-Dimensional Models of Active Region Loops,'' in Proc. 2^{nd}, ''Advances in Solar Physics Euroconference (ASPE), Three-Dimensional Structure of Solar Active Regions,'' held in Preveza, Greece, 1997 Oct 7-11, to appear in PASP, (eds. C. Alissandrakis and B. Schmieder), in press.

Aschwanden, M.J., Bastian, T.S., Nitta, N., Newmark, J., Thompson, B.J., and Harrison, R.A., 1998, ''Coordinated Observations with SOHO, Yohkoh, and VLA,'' in Proc. 2^{nd}, ''Advances in Solar Physics Euroconference (ASPE), Three-Dimensional Structure of Solar Active Regions,'' held in Preveza, Greece, 1997 Oct 7-11, to appear in PASP, (eds. C. Alissandrakis and B. Schmieder), in press.

Aschwanden,M.J., 1988, ''Solar Flares: Energetic Particles,'' in Encyclopedia of Astronomy, (4 volumes), (ed. E. Priest), Institute of Physics and Macmillan Publishing, in press.

Asif, M.W., Mundell., C.G., Pedlar, A., Unger, S.W., Robinson, A., Vila-Vilaro, B., and Lewis, J.R., 1998, ''Kinematics of the Dusty Circumnuclear Ring in the Barred Seyfert Galaxy, NGC4151,'' A&A, 333, 466.

Balachandran, S., and Bell, R.A., 1998, ''Shallow Mixing in the Solar Photosphere Inferred from Revised Beryllium Abundances,'' Nature, 392, 791.

Binette, L., Wilson, A.S., Raga, A., and Storchi-Bergmann, T., 1997, ''Photoionization of Very High Excitation Gas

in the Circinus Galaxy and Other Active Galactic Nuclei,'' A&A, 327, 909.

Bland-Hawthorn, J., Veilleux, S., Cecil, G.N., Putman, M.E., Gibson, B.K., and Maloney, P.R., 1998, ''The Smith Cloud: HI Associated With the Sgr Dwarf?,'' MNRAS, 299, 611.

Borkowski, K.J., Blondin, J.M., and Harrington, J.P., 1997, ''Collimation of Astrophysical Jets: The Proto-Planetary Nebula He 3-1475,'' ApJ, 482, L97-L100.

Bower, G.A., Heckman, T.M., Wilson, A.S., and Richstone, D.O., 1997, ''The Nuclear Ionized Gas in the Radio Galaxy M84 (NGC 4374),'' ApJL, 483, L33.

Bower, G.A., and 19 co-authors (inc. Wilson, A.S.), 1998, ''Kinematics of the Nuclear Ionized Gas in the Radio Galaxy M84 (NGC 4374),'' ApJL, 492, L111.

Braatz, J.A., Wilson, A.S., and Henkel, C., 1997, ''A Survey for H_2O Megamasers in Active Galactic Nuclei – II. A Comparison of Detected and Undetected Galaxies,'' ApJS, 110, 321

Brown, J.C., Conway, A.J., and Aschwanden,M.J. , 1998, ''The Electron Injection Function and Energy-Dependent Delays in Thick-Target Hard X-rays,'' ApJ, in press.

Burns, J.A., Hamilton, D.P., Showalter, M.R., Nicholson, Nicholson, P.D., de Pater, I., and Thomas, P.C., 1998. ''The Formation of Jupiter's Faint Ring,'' Science, submitted.

Cabrera-Guerra, F., Pérez-Fournon, I., Acosta-Pulido, J.A., Wilson, A.S., and Tsvetanov, Z.I., 1998, ''Cygnus A: Host Galaxy of a Nearby Quasar?,'' ESO/IAC Conference on 'Quasar Hosts', Tenerife, in press.

Cannon, R.D., Croke, B.F.W., Bell, R.A., Hesser, J.E., and Stathakis, R.A., 1998, ''Carbon and nitrogen abundance variations on the mains sequence of 47 Tucanae,'' MNRAS, 298, 601.

Cavallo, R., Sweigart, A.V., and Bell, R.A., 1998, ''Proton Capture Nucleosynthesis in Globular Cluster Red Giant Stars,'' ApJ, 492, 575.

Ceccarelli, C., Caux, E., White, G. J., Molinari, S., Furniss, I. Liseau, R. Nisini, B., Saraceno, P., Spinoglio, L., and Wolfire, M., 1998a, A&A, 331, 372.

Ceccarelli, C., Caux, E., Wolfire, M., Rudolph, A., Nisini, B., Saraceno, P. and White, G. J., 1998b, A&A, 331, L17.

Chan, K.-W., Moseley, S.H., Casey, S., Harrington, J.P, Dwek, E., Loewenstein, R., Varosi, F., and Glaccum, W., 1997, ''Dust Composition, Energetics, and Morphology of the Galactic Center, ApJ, 483, 798-810.

Chang, C.L., Drobot, A.T., Papadopoulos, K., Wright, K.H., Stone, N.H., Gurgiolo, Winningham, C.J.D., and Bonifazi, C., 1998, ''Current-voltage Characteristics of the Tethered Satellite System: Measurements and Uncertainties Due to Temperature Variations,'' Geophys. Res. Lett., 25, 713-716.

Cheng, L.X., Leventhal, M., Smith, D.M., Gehrels, N., Tueller, J., and Fishman, G., 1998, ''Batse All Sky Search for Transient Gamma-Ray Lines Between 300 and 550 keV,'' ApJ, in press.

Cheng, L.X., Leventhal, M., Barthelmy, S., Bartlett, M., Gehrels, N., Naya, J.E., Parsons, A., Teegarden, B., and Tueller, J., 1998, ''GRIS Detections of Positron Annihilation Radiation from the Galactic Center,'' ApJ, submitted.

Chernov, G.P., Markeev, A.K., Poquerusse, M., Bougeret, J.L., Klein, K.L., Mann, G., Aurass, H., and Aschwanden, M.J., 1998, ''New Features in Type IV Solar Radio Emission: Combined Effects of Plasma Wave Resonances and MHD Waves,'' A&A, 334, 314-324.

Choi, M., and Lee, Y., 1998, ''High-Resolution H13CO+ Observations Toward the Driving Source of the HH 1-2 System,'' ApJL, 498, L71.

Choi, M., Panis, J.-F., and Evans, N. J., II, 1998, ''BIMA Survey of Protostellar Collapse Candidates in HCO+ and HCN Lines,'' submitted.

Claussen, M.J., Diamond, P.J., Braatz, J.A., Wilson, A.S., and Henkel, C.A., 1998, ''The Water Masers in the Elliptical Galaxy NGC 1052,'' ApJL, 500, L129.

Cohen, J.G., Hogg, D.W., Pahre, M.A., Blandford, R., Shopbell, P.L., and Richberg, K., 1998, ''Caltech Faint Galaxy Redshift Survey VII: Data Analysis Techniques and Redshifts in the Field J0053+1234,'' ApJS, accepted.

Cohen, J.G., Blandford, R., Hogg, D.W., Pahre, M.A., and Shopbell, P.L., 1998, ''Caltech Faint Galaxy Redshift Survey VIII: Analysis for the Field J0053+1234,'' ApJ, accepted.

Colbert, E.J.M., Baum, S.A., O'Dea, C.P., and Veilleux, S., 1998, ''Large-Scale Outflows in Edge-On Seyfert Galaxies. III. Kiloparsec-Scale Soft X-ray Emission,'' ApJ, 496, 786.

Cole, G., Pedlar, A., Mundell, C.G., Gallimore, J.F., and Holloway, A.J., 1998, ''Neutral Hydrogen Absorption Observations of the Central Region of NGC5929,'' MNRAS, 301, 782.

Cole, G., Mundell, C.G., Pedlar, A., 1998, ''Neutral Hydrogen Absorption Observations of NGC3628,'' MNRAS, 300, 656.

Cooke, A., Baldwin, J.A., Ferland, G.J., Netzer, H., Wills, B., and Wilson, A.S., 1998, ''NGC 3393 – Broad Lines in a Nearby Seyfert 2 Galaxy,'' ESO/IAC Conference on 'Quasar Hosts', Tenerife, in press.

Corcoran, M.F., Petre, R., Swank, J.H., Drake, S.A., Koyama, K., Tsuboi, Y., Viotti, R., Damineli, A., Davidson, K., Ishibashi, K., White, S., and Currie, D., 1998, ''The ASCA X-Ray Spectrum of η Carinae,'' ApJ, 494, 381.

de Pater, I., Forster, J.R., Wright, M., Butler, B.J., Palmer, P., Veal, J.M., A'Hearn, M.F., and Snyder, L.E., 1998, ''BIMA and VLA Observations of Comet Hale-Bopp at 22-115 GHz,'' AJ, 116, 987-996.

de Pater, I., Showalter, M.R., Burns, J.A., Nicholson, P.D., Liu, M.C., Hamilton, D.P., and Graham, J.R., 1998, ''Keck Observations of Jupiter's Ring System Near Earth's 1997 Ring Plane Crossing,'' Icarus, submitted.

Diamond, P.J., Claussen, M.J., Braatz, J.A., Wilson, A.S., and Henkel, C., 1998, ''NGC 1052: A Different Class of H_2O Megamaser,'' IAU Colloquium 164, ''Compact Radio Sources,'' Eds. A. Zensus, G. Taylor & J. Wrobel, PASP Conf Proceedings, 144, 223.

Di Francisco, J., Evan, N.J., Harvey, P.M., Mundy, L.G., and Butner, H., 1998, ''Far-Infrared Observations of

Intermediate-Mass Pre-Main-Sequence Objects,'' ApJ, accepted.

Dukes, C., Baragiola, R.A., McFadden, L.A., 1998, ''Surface Modification of Olivine by H+ and He+ Bombardment,'' J. Geophys. Res., in press.

Falcke, H., Rieke, M.J., Rieke, G.H., Simpson, C., and Wilson, A.S., 1998, ''Molecular Hydrogen and Paschen-alpha Emission in Cooling Flow Galaxies,'' ApJL, 494, L155.

Falcke, H., Wilson, A.S., and Simpson, C., 1998, ''HST and VLA Observations of Seyfert 2 Galaxies: The Relationship between Radio Ejecta and the Narrow Line Region,'' ApJ, 502, 199.

Falcke, H., Goss, W.M., Ho, L.C., Matsuo, H., Teuben, P., Wilson, A.S., Zhao, J.-H., and Zylka, R., 1998, ''Sgra A* and Company - Multiwavelength Observations of Sgra A* and VLA Search of ''Sgra A*'s'' in LINERs,'' IAU Colloquium 164, ''Compact Radio Sources,'' Eds. A. Zensus, G. Taylor & J. Wrobel, PASP Conf. Proceedings, 144, 323.

Falcke, H., Wilson, A.S., and Ho, L.C., 1997, ''Relativistic Jets in Radio-Weak Quasars and LINER Galaxies,'' In *Relativistic Jets in AGN*, Eds. M. Sikora & M. Ostrowski, in press.

Fernández, Y.R., and 11 colleagues (including A'Hearn, M.F., and Lisse, C.M.), 1999, ''Survey of the Physical Properties of Cometary Nuclei: Recent Progress,'' in ''Cometary Nuclei in Space and Time,'' (ed. M. F. A'Hearn) ASP Conference Series, in press.

Fernández, Y.R., and 12 colleagues (including Wellnitz, D.D., A'Hearn, M.F., and Lisse, C.M.), 1999, ''The Inner Coma and Nucleus of Comet Hale-Bopp: Results From a Stellar Occultation, ''Icarus, in press.

Ferruit, P., Pécontal, E., Wilson, A.S., and Binette, L., 1997, ''Sub-arcsecond Resolution 3D Spectrography of the Emission Line Regions of NGC 5929 with TIGER,'' A&A, 328, 493.

Ferruit, P., Wilson, A.S., and Mulchaey, J.S., 1998, ''HST/WFPC2 Imaging of the Seyfert Galaxy NGC 3516,'' ApJ, (in press for vol 509, nr. 2 December 20, 1998).

Gallimore, J.F., Holloway, A.J., Pedlar, A., and Mundell, C.G., 1998, ''Localised Neutral Hydrogen Absorption Towards the Radio Jet of Markarian 6,'' A&A, 333, 13.

González Delgado, R.M., Heckman, T.M., Leitherer, C., Meurer, G., Krolik, J.H., Wilson, A.S., Kinney, A.L., and Koratkar, A., 1998, ''Seyfert 2 Galaxies: Laboratories to Study the Starburst-AGN Connection,'' ApJ, in press.

Goodrich, C.C., Lyon, J.G., Wiltberger, M,. Lopez, R.E., and Papadopoulos, K., 1998, ''An Overview of the Impact of the January 10–11, 1997 Magnetic Cloud on the Magnetosphere via Global Mhd Simulation,'' Geophys. Res. Lett., 24, 2537-2540.

Groot, P. J., *et al.*, 1998, ''The Rapid Decay of the Optical Emission from GRB 980326 and its Possible Implications,'' ApJL, in press.

Grün, E., Krüger, H., Graps, A.L., Hamilton, D.P., Heck, A., Linkert, G., Zook, H.A., Dermott, S., Fechtig, H., Gustafson, B.A., Hanner, M.S., Horanyi, M., Kissel, J., Lindblad, B.A., Linkert, D., Mann, I., McDonnell, J.A.M., Morfill, G.E., Polanskey, C., Schwehm, G., Srama, R., 1998, ''Galileo Observes Electromagnetically Coupled Dust in the Jovian Magnetosphere,'' J. Geophys. Res., 103, 20,011-20,022.

Guzdar P.N., Chaturvedi, P.K., Papadopoulos, K., and Ossakow, S.L., 1998, ''The Thermal Self-focusing Instability near the Critical Surface In the High-latitude Ionosphere,'' J. Geophys. Res., 103A, 2231-2237.

Guzdar, P.N., Sharma, A.S., and Guharay, S.K., 1997, ''Charging of Substrates Irradiated by Particle Beams,'' Appl. Phys. Lett., 71, 3302-3304.

Hamilton, D.P., 1998, ''Circular Problems,'' Nature, 396, 413.

Harrington, J.P., Borkowski, K.J., and Tsvetanov, Z.I., 1997, ''Modeling Hydrogen-Deficient Planetary Nebulae,'' in IAU Symposium No. 180, ''Planetary Nebulae,'' ed. by H.J. Habing and H.J.G.L.M. Lamers, p 235 (Kluwer Academic Pub.).

Harrington, J.P., Lame, N.J., Borkowski, K.J., Bregman, J.D., and Tsvetanov, Z.I., 1998, ''Discovery of a 6.4 Micron Dust Feature in Hydrogen-Poor Planetary Nebulae,'' ApJ, 501, L123-L126.

Harrington, J.P., Lame, N.J., White, S.M., and Borkowski, K.J., 1997, ''High Resolution Imagery of BD+30 3639 and Its Dusty Halo,'' AJ, 113, 2147-2157, 2344-2349.

Harris, A.I., Isaak, K.G., and Zmuidzinas, J., 1998, ''WASP: A Wideband Spectrometer for Heterodyne Spectroscopy,'' Proc. SPIE 3357, 384-394.

Harris, W.E., Bell, R.A., VandenBerg, D.A., Bolte, M., Stetson, P.B., Hesser, J.E., van den Bergh, S., Bond, H.E., Fahlman, G.G., and Richer, H.B., 1997, ''NGC 2419, M92, and the Age Gradient in the Galactic Halo,'' AJ, 114,1030.

Heckman, T.M., González-Delgado, R.M., Leitherer, C., Meurer, G.R., Krolik, J.H., Wilson, A.S., Koratkar, A., and Kinney, A., 1997, ''A Powerful Nuclear Starburst in the Seyfert Galaxy Mrk 477: Implications for The Starburst–AGN Connection,'' ApJ, 482, 114.

Henkel, C., Wang, Y.P., Falcke, H., Wilson, A.S., and Braatz, J.A., 1998, ''H_2O Megamaser Emission from FR I Radio Galaxies,'' A&A, 335, 463.

Hogerheijde, M.R., Van Langevelde, H.J., Mundy, L.G., Blake, G.A., and Van Dishoeck, E.F., 1997, ''Sub arcsecond Imaging at 267 GHz of a Young Binary System: Detection of a Dust Disk of Radius Less than 70 AU around T Tauri N,'' ApJL, 490, L99.

Kamide, Y., Baumjohann, W., Daglis, I.A., Gonzalez, W.D., Grande, M., Joselyn, J.A., McPherron, R.L., Phillips, J.L., Reeves, E.G.D., Rostoker, G., Sharma, A.S., Singer, H.J., Tsurutani, B.T., and Vasyliunas, V.M.,1998, ''Current Understanding of Magnetic Storms: Storm-substorm Relations,'' J. Geoph. Res., 103A, 17,705-17,728.

Kim, D.-C., Veilleux, S., and Sanders, D.B., 1998, ''The IRAS 1 Jy Sample of Ultraluminous Infrared Galaxies: II. Optical Spectroscopy,'' ApJ, Dec. 1 issue.

Kramer C., Staguhn, J., Ungerechts H., Sievers A., 1998, ''The Sagittarius C Region Mapped in CS(2-1), CS(3-2), and 13CO(2-1) With the IRAM 30m Telescope,'' in: IAU Symposium 184 (Aug 17-30 1997, Kyoto, Japan), Sofue

Y.(ed.), The Central Regions of the Galaxy.

Krüger, H., Grün, E., Hamilton, D.P., Baguhl, M., Dermott, S., Fechtig, H., Gustafson, B.A., Hanner, M.S., Heck, A., Horanyi, M., Kissel1, B.A. Lindblad, D. Linkert, G. Linkert, I. Mann, J.A.M. McDonnell, J., Morfill, G.E., Polanskey, C., Riemann, R., Schwehm, G., Srama, R., and Zook, H.A., 1999, ''Three Years of Galileo Dust Data: II. 1993 to 1995,'' Planet. Space Sci., in press.

Krüger, H., Grün, E., Landgraf, M., Baguhl, M., Dermott, S., Fechtig, H., Gustafson, B.A., Hamilton, D.P., Hanner, M.S., Horanyi, M., Kissel1, J., Lindblad, B.A., Linkert, D., Linkert, G., Mann, I., McDonnell, J.A.M., Morfill, G.E., Polanskey, C., Schwehm, G., Srama, R., and Zook, H.A., 1999, ''Three Years of Ulysses Dust Data: II. 1993 to 1995,'' Planet. Space Sci., in press.

Kundu, M.R., 1998, ''Metric Type III and Microwave Burst Observations of Coronal X-ray Jets,'' in ''Solar Jets and Coronal Plumes,'' ed. T.-D. Guyenne (ESA SP 412; Nordwijk: ESA), 179.

Kundu, M.R., Raulin, J.-P., Nitta, N., Shibata, K., and Shimojo, M., 1998, ''Two-Sided-Loop-Type X-Ray Jets and Metric Radio Bursts,'' Sol. Phys., 178, 173.

Lame, N.J., Harrington, J.P., and Borkowski, K.J., 1997, ''Physical Conditions in NGC 6543,'' in IAU Symposium No. 180, ''Planetary Nebulae,'' ed. by H.J. Habing and H.J.G.L.M. Lamers, pp 252-253 (Kluwer Academic Pub.).

Lamy, P. L., Toth, I., Jorda, L., Weaver, H.A., and A'Hearn, M., 1998, ''The Nucleus and Inner Coma of Comet 46P/Wirtanen,'' A&A, 335, L25-L29.

Lara, A., Gopalswamy, N., Kundu, M.R., Perez-Enriquez, R., Koshiishii, H., Enome, S., 1998, ''Microwave and Soft X-ray Study of Solar Active Region Evolution,'' Sol. Phys., 178, 353.

Lee, J., White, S.M., Kundu, M.R., Mikić, Z., and McClymont, A.N., 1998, ''Microwave Mode Coupling Above Active Regions as a Coronal Density Diagnostic,'' Sol. Phys., 180, 193.

Lee, J., McClymont, A.N., Mikić, Z., White, S.M., and Kundu, M.R., 1998, ''Coronal Currents, Magnetic Fields and Heating in a Solar Active Region,'' ApJ, 501, 853.

Lee, J., White, S.M., Kundu, M.R., Mikić, and McClymont, A.N., 1998, ''A Test of Coronal Magnetic Field Extrapolations,'' ApJ, in press.

Lim, J., Carilli, C.L., White, S.M., Beasley, A.J., and Marson, R.G., 1998, ''Large Convection Cells as the Source of Betelgeuse's Extended Atmosphere,'' Nature, 392, 575.

Lisse, C.M., A'Hearn, M.F., Hauser, M.G., Kelsall, T., Lien, D.J., Mosely, S.H., Reach, W.T., and Silverberg, R.F., 1998, ''Infrared Observations of Comets by *COBE*,'' ApJ, 496, 971.

Lisse, C.M., and 14 colleagues (including Fernández, Y.R., and A'Hearn, M.F.), 1999, ''Infrared Observations of the Dust Emitted By Comet Hale-Bopp,'' Earth Moon & Planets, in press.

Lisse, C.M., A'Hearn, M.F., Fernández, Y.R., Grün, E., Käufl, H.U., Kostiuk, T., Lien, D.J., Osip, D.J., Peschke, S.B., and Walker, R.G., 1999, ''ISOPHOT Measurements of Dust Emitted From Periodic Comets 126P/IRAS (1996) and 2P/Encke (1997),'' Icarus, submitted.

Lisse, C.M., Christian, D., Dennerl, K., Desch, M., Englhauser, J., Marshall, F.E., Petre, R., Snowden, S., Trümper, J., 1999, ''X-ray and Extreme Ultraviolet Emission from Comet P/Encke 1997,'' Icarus, in press.

Lisse, C.M., Fernández, Y.R., A'Hearn, M.F., Dayal, A., Deutsch, L.K., Fazio, G.G., Hora, J.L., Kundu, A., Hoffmann, W.F., 1999, ''The Nucleus of Comet C/1996 B2 (Hyakutake),'' Icarus, in press.

Lisse, C.M., Dennerl, K., Englhauer, J., Marshall, F.E., Petre, R., Trümper, J., ''X-Ray Emission From Comet Hale-Bopp,'' Earth Moon & Planets, in press.

Looney, L.W., Mundy, L.G., and Welch, W.J., 1997, ''High Resolution $\lambda = 2.7$ mm Observations of L1551 IRS5: A Protobinary System?,'' ApJL, 484, L157.

Looney, L.W., Mundy, L.G., and Welch, W.J., 1998, ''Unveiling the Envelope and Disk: A Sub-arcsecond Survey,'' ApJ, submitted.

Lopez, R.E., Goodrich, C.C., Wiltberger, M., Papadopoulos, K., and Lyon, J.G.,1998, ''Simulation of the March 9, 1995 Substorm and Initial Comparison to Data,'' Geospace Mass and Energy Flow: Results From the International Solar-Terrestrial Physics Program, Geophysical Monograph 104, 237–245, published by AGU.

Luhman, M. L., Satyapal, S., Fischer, J., Wolfire, M. G., Cox, P., Lord, S. D. Smith, H. A., Stacey, G. J., and Unger S. J., 1998, ApJ, 504, L11.

Lyon, J.G., Lopez, R.E,.Goodrich, C.C.,Wiltberger, M., and Papadopoulos, K., 1998, ''Simulation of the March 9, 1995, Substorm: Auroral Brightening and the Onset of Lobe Reconnection,'' Geophys. Res. Lett., 25, 3039-3042.

Meheen, L.S.G., Wilking, B.A., Claussen, M.J., Mundy, L.G., and Wootten, A., 1998, ''Water Masers in the Circumstellar Environments of Young Stellar Objects,'' ApJ, 115, 1599.

Meier, R., Wellnitz, D., Kim, S.J., and A'Hearn, M.F., 1998, ''The NH and CH Bands of Comet C/1996 B2 (Hyakutake), Icarus, in press.

Morse, J.A., Cecil, G., Wilson, A.S., Tsvetanov, Z.I., 1998, ''Inclined Gas Disks in the Lenticular Seyfert Galaxy NGC 5252,'' ApJ, in press.

Mundell, C.G., 1997, ''Using HI to Probe AGN Hosts and their Nuclei,'' in Quasar Hosts, ESO astrophysics symposia, Clements, D.L. & Perez-Fournon, I. (eds.), p156 (Springer-Verlag).

Mundy, L.G., Looney, L.W., and Welch, W.J., 1998, ''The Evolution of Envelopes and Disks in Young Stellar Systems,'' Protostars and Planets IV, chapter contribution.

Mundy, L.G., 1998, ''8-Element Star and T Configurations for an 8-Element Array,'' BIMA-OVRO internal memo.

Mundy, L., Shepherd, D., and Scott, S., 1998, ''A-array Configurations with 16 Elements,'' BIMA-OVRO internal memo.

Mundy, L.G., and Shepherd, D., ''Update on A-Array Configurations for Upper Harkless Flats,'' BIMA-OVRO internal memo.

Murawski, K., Aschwanden, M.J., and Smith, J., 1998, ''Im-

pulsively Generated MHD Waves and Their Detectability in Solar Coronal Loops,'' Sol. Phys., 179, 313-326.

Nagar, N.M., Wilson, A.S., Mulchaey, J.S., and Gallimore, J.F., 1999, ''Radio Structures of Seyfert Galaxies. VIII. A Distance and Magnitude Limited Sample of Early-Type Galaxies,'' to appear in ApJS, Vol 120.

Nagar, N.M., and Wilson, A.S., 1999, ''The Relative Orientation of Nuclear Accretion and Galaxy Stellar Disks in Seyfert Galaxies,'' ApJ, in press.

Naya, J.E., Barthelmy, S., Bartlett, M., Gehrels, N., Parsons, A., Teegarden, B., Tueller, J., and Leventhal, M., 1998, ''Gamma-ray Limits on Galactic ^{60}Fe Nucleosynthesis and Implications on the Origin of the ^{26}Al Emission,'' ApJL, 499, L169.

Nindos, A., and Zirin, H., 1998, ''Properties and Motions of Ellerman Bombs,'' Sol. Phys., in press.

Nindos, A., Kundu, M.R., and White, S.M., 1998, ''A Study of Microwave-selected Coronal Transient Brightenings,'' ApJ, in press.

Ogilvie, K.W., Coplan, M.A., McFadden, L.A., 1998, ''Sodium Near the Tail of Comet Giacobini-Zinner,'' Icarus, 134, 249-252.

Ostriker, E. C., 1998, ''Theory of Protostellar Accretion,'' in ''Accretion Processes in Astrophysical Systems,'' (8th Annual October Astrophysics Conference in Maryland), Eds. S. Holt & T. Kallman, Woodbury NY: AIP Press, 11pp.

Ostriker, E. C., 1998, ''The Evolution of Self-Gravitating, Magnetized, Turbulent Clouds: Numerical Experiments,'' in Interstellar Turbulence, Eds. P. Franco and A. Carraminana, Cambridge: Cambridge U. Press, 8pp.

Ostriker, E. C., Gammie, C. F., & Stone, J. M., 1998, ''Kinetic and Structural Evolution of Self-Gravitating, Magnetized Clouds: 2.5-Dimensional Simulations of Decaying Turbulence,'' ApJ, in press.

Ostriker, E. C., 1998, ''Dynamical Friction in a Gaseous Medium,'' ApJ, in press.

Papadopoulos, K., Chang, C.-L., and Drobot, A., 1998, ''Ion Reflection by The Tss-1r Satellite,'' Geophys. Res. Lett., 25, 745-748.

Papadopoulos, K., Goodrich, C.C., Wiltberger, M., Lopez, R., and Lyon, J.G., 1998, ''The Physics of Substorms as Revealed by the Istp,'' *Physics and Chemistry of the Earth*, in press.

Pécontal, E., Ferruit, P., Binette, L., and Wilson, A.S., 1997, ''Bi-Dimensional Spectrography at HST-like Spatial Resolution: [OIII] Kinematics and Ionization in the NLR of NGC 1068,'' in Proceedings of the Schloss Ringberg NGC 1068 Workshop, eds. J. F. Gallimore and L. J. Tacconi, Astrophys, & Space Sciences, 248, 167.

Peschke, S.B., and 14 colleagues (including Lisse, C.M.), 1999, ''ISOPHOT Observations of Comet Hale-Bopp,'' Earth Moon & Planets, in press.

Portier-Fozzani, F., Neupert, W., Aschwanden, M., Sheeley, N.R., Thompson, B., Maucherat, A.J., Newmark, J., and Klimchuk, J.A., 1998, ''3D Structures of the solar corona observed with SOHO/EIT'' in Proc. 2nd, ''Advances in Solar Physics Euroconference (ASPE), Three-Dimensional Structure of Solar Active Regions,'' held in Preveza, Greece, 1997 Oct 7-11, to appear in PASP, (eds. C. Alissandrakis and B. Schmieder), in press.

Pound, M. W., 1998, ''Molecular Gas in the Eagle Nebula,'' ApJ, 493, L113.

Pulkkinen, T.I., Baker, D.N., Wiltberger, M., Goodrich, C.C., Lopez, R.E., and Lyon, J.G., 1998, ''Pseudobreakup and Substorm Onset: Observations and MHD Simulations Compared,'' J. Geophys. Res., 103A, 14847-14854.

Raizer, Yu.P., Milkh, G.M., Novakovski, S., and Shneider, M., 1998, ''Long Streamers in the Upper Atmosphere Above Thunderclouds,'' J. Phys. D: Appl. Phys., in press.

Rauch, K. P., 1999, ''Collisional Stellar Dynamics Around Massive Black Holes in Active Galactic Nuclei,'' ApJ, in press.

Rauch, K. P., and Holman, M., 1999, ''Dynamical Chaos in the Wisdom-Holman Integrator: Origins and Solutions,'' AJ, in press.

Rauch, K. P., and Ingalls, B., 1998, ''Resonant Tidal Disruption in Galactic Nuclei,'' MNRAS, 299, 1231.

Regan, M.W., Sheth, K., and Vogel, S.N., 1998, ''Molecular Gas Kinematics in Barred Spiral Galaxies,'' submitted.

Richer, H.B., Fahlman, G.G., Ibata, R.A., Pryor, C., Bell, R.A., Bolte, M., Bond, H.E., Harris, W.E., Hesser, J.E., Holland, S., Ivanans, N., Mandushev, G., Stetson, P.B., and Wood, M.A., 1997, ''White Dwarfs in Globular Clusters: HST Observations of M4,'' ApJ, 484, 741.

Rosa, R.R., Sawant, H.S., Valdivia, J.A., and Sharma, A.S., 1997, ''Dissipative Structures and Weak Turbulence in the Solar Corona,'' Advances in Space Research, 20, 2303-2318.

Rose, W. K., 1998, *Advanced Stellar Astrophysics* (Cambridge University Press: Cambridge).

Roy, A.L., Colbert, E.J.M., Ulvestad, J.S., and Wilson, A.S., 1998, ''The Compact Radio Sources in the Nucleus of NGC 1068,'' ApJ, 504, 147.

Roy, A.L., Ulvestad, J.S., Colbert, E.J.M., Wilson, A.S., and Norris, R.P., 1998, ''Survey of Milliarcsec Structure in Eight Seyfert Galaxies: Results on NGC 1068 and NGC 4151,'' IAU Colloquium 164, ''Compact Radio Sources,'' Eds. A. Zensus, G. Taylor & J. Wrobel, PASP Conf. Proceedings, 144, 301.

Safier, P., 1997, ''The Star-forming Region BD+41 40,'' ApJ, in press.

Safier, P., 1997, ''A Critique of Current Magnetic-Accretion Models for Classical T-Tauri Stars,'' ApJL, in press.

Sage, L.J., Weistrop, D., Cruzen, S., and Kömpe, C., 1997, ''Molecular Gas And Star Formation Within Galaxies in the Bootes Void,'' AJ, 114, 1753.

Sage, L.J., Welch, G.A., and Mitchell, G.F., 1998, ''The Missing ISM of NGC 147 and M 32,'' ApJ, in press.

Schachter, J.F., Fiore, F., Elvis, M., Mathur, S., Wilson, A.S., Morse, J.A., Awaki, H., and Iwasawa, K., 1998, ''NGC 7582: The Prototype Narrow-Line X-ray Galaxy,'' ApJL, 503, L123.

Sharma, A.S., and Baker, D.N., 1998, ''What Triggers Substorms Expansion Onset? Current Understanding and Outlook,'' Proc. Fourth Int. Conference on Substorms, ed. Y Kamide, Terra. Sci., Tokyo, in press.

Sharma,.A.S., Valdivia, J.A., and Rosa, R.R., 1998, ''Spatio-

temporal Dynamics Using Time Series Data: Nonlinear Dynamics of the Magnetosphere,'' *Nonlinear Dynamics and Computational Physics*, V.B. Sheorey (ed.), Narosa Pub., New Delhi.

Sharma, A.S., Valdivia, J.A., and Kamide, Y., 1998, ''Dynamical Relationship Between Storms and Substorms,'' Proc. Fourth Int. Conference on Substorms, ed. Y Kamide, Terra. Sci., Tokyo, in press.

Shepherd, D., and Mundy, L., 1998, ''Proposed Wildcard Area for the Combined California Array,'' BIMA-OVRO internal memo.

Sheth, K., Regan, M.W., Vogel, S.N., and Teuben, P.J., 1998, ''Molecular Gas, Dust, and Star Formation in the Barred Spiral NGC 5383,'' submitted.

Shopbell, P.L. and Bland-Hawthorn, J., 1998, ''The Asymmetric Wind in M82,'' ApJ, 493, 129.

Silva, A.V.R., Lin, R.P., de Pater, I., White, S.M., Shibasaki, K., and Nakajima, H., 1998, ''Images of Gradual Millimeter Emission and Multi-Wavelength Observations of the 1994 August 17 Solar Flare,'' Sol. Phys., in press.

Simpson, C., Wilson, A.S., Bower, G., Heckman, T.M., Krolik, J.H., and Miley, G.K., 1997, ''A One-Sided Ionization Cone in the Seyfert 2 Galaxy NGC 5643,'' ApJ, 474, 121.

Sitnov, M.I., Malova, H.V., and Sharma, A.S., 1998, ''Role of the Temperature Ratio in the Linear Stability of the Quasi-neutral Sheet Tearing Mode,'' Geophy. Res. Lett., 25, 269-272.

Sitnov, M.I., and Sharma, A.S., 1998, ''Role of Transient Electrons and Microinstabilities in the Tearing Instability of the Geomagnetotail Current Sheet and the General Scenario of the Substorm as a Catastrophe,'' Proc. Fourth Int. Conference on Substorms, ed. Y Kamide, Terra. Sci., Tokyo, in press.

Slysh, V.I., Wal'tts, I.E., Kalenskii, S.v., Larionov, G.M., Mundy, L.G., 1998, ''0.4'' BIMA Array Mapping of the 107 GHz Methanol Maser in W3(OH),'' ApJ, submitted, 1998.

Smith, D.M., Main, D., Marshall, F., Swank, J., Heindl, W.A., Leventhal, M., Zand, J., and Heise, J., 1998, ''The Transient X-ray Binary XTE J1739-302,'' ApJL, in press.

Staguhn, J., Stutzki, J., Uchida, K.I., Yusef-Zadeh, F., 1998, ''The Interaction of the Galactic Center Filament System G359.54+0.18 With its Ambient Medium,'' A&A, 336, 290.

Staguhn, J. Stutzki, J., Chamberlin, R.A., Balm, S.P., Stark, A.A., Lane, A.P., Schieder, R., Winnewisser, G., ''Sub-mm [CI] and CO Absorption Observations of Cold, Low Density Translucent Cloud Material Towards the Galactic Center Broad Line Emission,'' 1997, ApJ, 491.

Staguhn, J., Harris, A.I. Plambeck, R.L., Welch, W.J., 1998, ''Phase Correction for the BIMA Array: Atmospherical Model Calculations for The Design of a Prototype Correlation Radiometer,'' SPIE 3357, 432.

Staguhn, J., Harris, A.I. Plambeck, R.L., Welch, W.J., 1998, ''Phase Correction for the BIMA Array: Atmospherical Model Calculations for The Design of a Prototype Correlation Radiometer,'' BIMA memo 67.

Staguhn, J., Stutzki, J., Balm, S. P., Stark, A. A., and Lane, A. P., 1998, ''Sub-MM [CI] and CO Observations of Molecular Clouds Presumably Interacting with the G359.54 +0.18 Nonthermal Filaments,'' in: IAU Symposium 184 (Aug 17-30 1997, Kyoto, Japan), Sofue Y. (ed.), The Central Regions of the Galaxy and Galaxies, Kluwer Academic Publishers, Dordrecht/Boston/London.

Stern, S. A., Slater, D. C., Gibson, W., Scherrer, J., A'Hearn, M., Bertaux, J. L., Feldman, P. D., and Festou, M. C. , 1998, ''Alice - An Ultraviolet Imaging Spectrometer for the Rosetta Orbiter,'' Adv. Space Res., 21, 1517-1525.

Stern, S. A., Parker, J.W., Festou, M.C., A'Hearn, M.F., Feldman, P.D., Schwehm, G., Schulz, R., Bertaux, J.L., and Slater, D.C., 1998, ''HST Mid-ultraviolet Spectroscopy of Comet 46P/Wirtanen During its Approach to Perihelion in 1996-1997,'' A&A, 335, L30-L36.

Stetson, P.B., Bolte, M., Harris, W.E., Hesser, J.E., van den Bergh, S., VandenBerg, D.A., Bell, R.A., Johnson, J.A., Bond, H.E., Fullton, L.K., Fahlman, G., Richer, H.B., 1998, ''Ages for Globular Clusters in the Outer Galactic Halo: The Second Parameter Clusters Palomar 3, Palomar 4 and Eridanus,'' AJ, (in press).

Stone, J. M., Ostriker, E. C., and Gammie, C. F., 1998, ''Dissipation in Compressible MHD Turbulence,'' ApJL, in press.

Storchi-Bergmann, Eracleous, M., Ruiz, M.T., Livio, M., Wilson, A.S., and Filippenko, A.V., 1997, ''A Precessing Accretion Disk in the Nucleus of NGC 1097,'' ApJ, 489, 87.

Surace, J., Sanders, D.B., Veilleux, S., and Mazzarella, J.M., 1998, ''HST/WFPC2 Observations of Warm Ultraluminous Infrared Galaxies,'' ApJ, 492, 116.

Thean, A.H.C., Mundell, C.G., Pedlar, A. & Nicholson, R.A., 1997, ''A Neutral Hydrogen Study of the Seyfert Galaxy NGC5033,'' MNRAS, 290, 15.

Thomas, N., A'Hearn, M.F., *et al.*, 1998, ''OSIRIS - The Optical Spectroscopic and Infrared Remote Imaging System for the Rosetta Orbiter,'' Adv. Space Res., 21, 1505-1515.

Thornley, M.D., and Mundy, L.G., 1997, ''Dynamic and Stochastic Influences on Spiral Structure in the Flocculent Spiral NGC 4414,'' ApJ, 490, 682.

Trimble, V., 1997, ''Martin Schwarzschild,'' PASP, 109, 1287-97.

Trimble, V., 1997, ''Where in the Universe are You?,'' BeamLine, 27, No. 3, 52-50.

Trimble, V., 1997, ''What (and Why) is the International Astronomical Union?,'' BeamLine, 27, No. 4, 43-52.

Trimble, V., 1997, ''Epilogue'' in W. Waller *et al.* eds., *The Ultraviolet Universe at Low and High Redshifts*,'' AIP Conf. Series, 408, 501-13.

Trimble, V., 1998, ''La Genèse du Big Bang,'' La Recherche, Hors serie No. 1, 16-19.

Trimble, V., 1998, ''Astrophysics in 1998,'' BeamLine, 28, 1, 22-30.

Trimble, V., 1998, ''This was the Year that was,'' Mercury, 27, No. 2, 14- 19.

Trimble, V., 1998, ''Astrophysical Accretion: The Approach to the Irrationality Horizon,'' in S.S. Holt & T.R. Kallman

eds., *Accretion Processes in Astrophysical Systems*, AIP Conf. Proc. 431, 2-14.

Trimble, V., 1999, ''Origin of the Divisions and History of the High Energy Astrophysics Division,'' in D. DeVorkin, ed., *The American Astronomical Society's First Century*, AIP, in press.

Trimble, V., and Kundu, A., 1997, ''Parallaxes and Proper Motions of Prototypes of Astrophysically Interesting Classes of Stars I. R Coronae Borealis Varibles,'' PASP, 109, 1089-92.

Trimble, V., and Kundu, A., 1998, ''Parallaxes and Proper Motions of Prototypes of Astrophysically Interesting Classes of Stars,'' AJ, 115, 358- 360.

Trimble, V., and McFadden, L.A., 1998, ''Astrophysics in 1997,'' PASP, 110, 223-267.

Ulvestad, J.S., Roy, A., Colbert, E.J.M., and Wilson, A.S., 1998, ''A Sub-Parsec Radio Jet or Disk in NGC 4151,'' ApJ, 496, 196.

Valdivia, J.A., Vassiliadis, D., Klimas, A., and Sharma, A.S., 1998, ''The Electrojet Currents: Understanding Their Spatio-temporal Multivariate Properties,'' Proc. Fourth Int. Conference on Substorms, ed. Y Kamide, Terra. Sci., Tokyo, in press.

Valdivia, J.A., Milikh, G.M., and Papadopoulos, K., 1997, ''Red Sprites: Lightning as a Fractal Antenna,'' Geophys. Res. Lett., 24, 3169-3172.

Valdivia, J.A., Milikh, G.M., and Papadopoulos, K.,1998, ''Model of Red Sprites Due to Intracloud Fractal Lightning Discharges,'' Radio Science, in press.

Vassiliadis, E., Dopita, M.A., Bohlin, R.C., Harrington, J.P., Ford, H.C., Meatheringham, S.J., Wood, P.R., Stecher, T.P., and Maran, S.P., 1998, ''Hubble Space Telescope Observations of Planetary Nebulae in the Magellanic Clouds. VI: Cycles 4 and 5 Ultraviolet Spectroscopy Using the Faint Object Spectrograph,'' ApJS, 114, 237-261.

Vassiliadis, E., Dopita, M.A., Meatheringham, S.J., Bohlin, R.C., Ford, H.C., Harrington, J.P., Wood, P.R., Stecher, T.P., and Maran, S.P., 1998, ''Hubble Space Telescope Observations of Planetary Nebulae in the Magellanic Clouds. VII: Cycles 3 and Archive Narrowband [O III] Imaging,, AJ, 503, 253-277.

Veilleux, S., and Bland-Hawthorn, J., 1997, ''Artillery Shells Over Circinus,'' ApJL, 479, L105.

Veilleux, S., Cecil, G., and Bland-Hawthorn, J., 1998, ''Colossal Galactic Explosions,'' Scientific American Presents, 9, 74.

Veilleux, S., Goodrich, R.W., and Hill, G., 1997, ''Infrared Spectroscopy of Seyfert 2s: A Look Through the Obscuring Torus? Part II,'' ApJ, 477, 631.

Veilleux, S., Sanders, D.B., and Kim, D.-C., 1997, ''A Near-Infrared Search for Hidden Broad-Line Regions in Ultraluminous Infrared Galaxies,'' ApJ, 484, 92.

Veverka, J., Thomas, P., Harch, A., Clark, B., Bell III, J.F., Carcich, B., Joseph, J., Chapman, C., Merline, W., Robinson, M., Malin, M., McFadden, L.A., Murchie, S., Hawkins III, S.E., Farquhar, R., Izenberg, N., and Cheng, A., 1997, ''NEAR's Flyby of 253 Mathilde: Images of a C Asteroid,'' Science, 278, 2109-2114.

Veverka, J., Bell III, J.F., Thomas, P., Harch, A., Murchie, S., Hawkins III, S.E., Warren, J.W., Darlington, H., Peacock, K., Chapman, C.R., McFadden, L.A., Malin, M.C., Robinson, M.S., 1997, ''An Overview of the NEAR Multispectral Imager-Near Infrared Spectrometer Investigation,'' J. Geophys. Res. 102, 23,709-23,727.

Vourlidas, A., Bastian, T.S., and Aschwanden, M.J., 1997, ''The Structure of the Solar Corona Above Sunspots as Inferred from Radio, X-ray, and Magnetic Field Observations,'' AJ, 489, 403-425.

Wegmann, R., Schmidt, H.U., Lisse, C.M., Dennerl, K., Englhauser, J., 1998, ''X-rays From Comets Generated by Energetic Solar Wind Particles,'' Plan.& Sp.Sci., 46, 603.

Weissman, P.R., McFadden, L.A., Johnson, T.V., 1998, ''Encyclopedia of the Solar System,'' Academic Press, San Diego, CA.

Welch, G.A., Sage, L.J., and Mitchell, G.F., 1998, ''The Puzzling Features of the Interstellar Medium in Ngc 205,'' ApJ, 499, 209.

Wentzel, D.G., 1997, ''Type I Radio Bursts Defedeflected by Lower Hybrid Waves,'' Sol. Phys., 175, 175-189.

Wentzel, D.G., 1997, ''On the Polarization of Type I Radio Bursts,'' Sol. Phys., 175, 191-196.

White, S.M., 1998, ''The Contributions of the VLA to the Study of Radio Stars'' in ''Interferometry and Imaging: Barry Clark at 60,'' NRAO, in press.

Wilson, A.S., 1997, ''The Narrow Line Regions of Seyfert and Radio Galaxies,'' in ''Emission Lines in Active Galaxies: New Methods and Techniques,'' IAU Colloquium Nr. 159, Eds B. M. Peterson, F.-Z. Cheng, & A. S. Wilson, ASP Conference Series, 113, 264.

Wilson, A.S., Binette, L., and Storchi-Bergmann, T., 1997, ''The Temperature of Extended Gas in Active Galaxies – Evidence for Matter-Bounded Clouds,'' ApJL, 482, L131

Wilson, A.S., and Weiler, K.W., 1997, ''Relativistic Positrons in Non-Thermal Radio Sources,'' ApJ, 475, 661.

Wilson, A.S., and Elvis, M., 1997, ''The X-ray Emission of NGC 1068,'' in Proceedings of the Schloss Ringberg NGC 1068 Workshop, eds. J. F. Gallimore and L. J. Tacconi Astrophys. & Space Sciences, 248, 141.

Wilson, A.S., Roy, A.L., Ulvestad, J.S., Colbert, E.J.M., Weaver, K.A., Braatz, J.A., Henkel, C., Matsuoka, M., Xue, S., Iyomoto, N., and Okada, K., 1998, ''The Ionization Fraction in the Obscuring 'Torus' of an Active Galactic Nucleus,'' ApJ, in press.

Wilson, A.S., Braatz, J.A., and Henkel, C., 1998, ''Statistical Connections Among Water Vapor Megamasers,'' IAU General Assembly, Joint Discussion 21, in ''Highlights of Astronomy,'' in press.

Wilson, A.S., 1998, ''Water Vapor Megamasers in Galactic Nuclei,'' 8th Annual October Astrophysics Conference in Maryland, ''Accretion Processes in Astrophysical Systems: Some Like it Hot,'' AIP Conference Proceedings 431, Eds. S. S. Holt and T. R. Kallman, p 235.

Woodney, L.M., A'Hearn, M.F., McMullin, J., and Samarasinha, N., 1998, ''Sulfur Chemistry at Millimeter Wavelengths in C/Hale-Bopp,'' Earth, Moon, and Planets, in press.

Wright, M.C.H., de Pater, I., Forster, J.R., Palmer, P., Snyder, L.E., Veal, J.M., A'Hearn, M.F., Woodney, L.M., Jackson, W.M., Kuan, Y.J., and Lovell, A.J., 1998, ''Mosaiced Images and Spectra of J=1-0 HCN and HCO^+ Emission from Comet Hale-Bopp (1995 O1),'' AJ, in press.

Zhang, J., White, S.M., and Kundu, M. R., 1998, ''The Height Structure of the Solar Atmosphere from the Extreme -Ultraviolet Perspective,'' ApJL, 504, L127.

Zhang, J., Gopalswamy, N., Kundu, M.R., Schmahl, E.J., and Lemen, J.R., 1998, ''Spatial Structure of Solar Coronal Magnetic Loops Revealed by Transient Microwave Brightenings,'' Sol. Phys., 180, 285.

M. R. Kundu