## I. INTRODUCTION

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 1994 through 30 September 1995.

## II. PERSONNEL

The continuing personnel in the Department of Astronomy during the period were Professors M. Leventhal (Chair), M. F. A'Hearn, R. A. Bell, L. Blitz, J. P. Harrington, M. R. Kundu, K. Papadopoulos, W. K. Rose, V. L. Trimble, 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 L. G. Mundy and S. Vogel; Visiting Associate Professors L. McFadden and S. Vrtilek; Assistant Professors J. Stone, J. Wang, and S. Veilleux; Associate Research Scientists C. C. Goodrich, N. Gopalswamy, R. Lopez, E. Schmahl, S. Sharma and S. White; Assistant Research Scientists K. Arnaud, M. Aschwanden, T. Golla, A. Grossman, and M. Schaefer; Research Associates D. Chornay, O. Colombo, K. Fast, E. Grayzeck, D. Lengyel-Frey, P. Leonard, T. Livengood, R. Meier, G. Milikh, J. Morgan, E. Pavlis, R. Rand, A. Raugh, J. Raulin, I. Richardson, D. Smith, M. Stark, P. Teuben, D. Wellnitz, and T. Xie; Visiting Research Associates J. Mattox and L. Sage; Hubble Fellow E. Lada; Instructors G. Deming and D. Theison; and Associate Director J. Trasco.

D. Hamilton and S. Veilleux were appointed as Assistant Professors. T. A. Matthews retired. K. Gendreau, H. Falcke, N. J. Lame, C. Lisse, S. Porter, D. Robinson, K. Roettiger, and P. Safier began appointments as Research Associates. F. Cheng, S. Kim, F. Lemoine, and R. Schulz completed short term appointments and left the department. D. Neufeld and D. Spergel began year long sabbatical visits to the department.

M. F. A'Hearn, L. Blitz and L. Mundy returned from sabbatical. V. Trimble was elected to the Board of Directors of the Astronomical Society of the Pacific. R. A. Bell completed his second (and last) term of office as Secretary of the American Astronomical Society.

Ph.D. degrees were awarded to D. S. Davis, J. P. McMullin, T. Miyaji, J. S. Mulchaey, and M. W. Pound. M.S. degrees were awarded to R. M. Cavallo, P. A. Esterle, M. D. Thornley, and J. Xu.

## III. MEETINGS

The series of Washington Area Astronomers meetings initiated in September 1981 has continued. The Spring 1995 meeting was held at the Space Telescope Science Institute in Baltimore and the Fall 1995 meeting was held at the Naval Research Laboratory. Typical attendance has been 100 persons per meeting.

The Maryland-Goddard Astrophysics series which started in Fall 1990 has continued. The most recent meeting "Cosmic Abundances" was held at the University of Maryland in October 1995. Total attendance was approximately 250 persons.

The Department of Astronomy hosted the 107th annual meeting of the Astronomical Society of the Pacific - "Universe '95" from June 22 through 28. The public program drew over 1000 persons during a weekend of talks and exhibits. This was preceded by a teachers' workshop - "Universe in the Classroom". As part of the overall proceedings, J. Percy (U. of Toronto) organized an Astronomy Education Symposium: "Current Developments, Future Coordination" which was attended by approximately 200 educators. V. Trimble organized the Scientific Symposium: "Clusters, Lensing and the Future of the Universe" which had over 100 scientists participating. Local organizing for the various events was done by D. Wentzel and J. Trasco.

## IV. FACILITIES AND INSTRUMENTATION

### A. Laboratory for Millimeter-Wave Astronomy

The LMA is the organization set up by the University of Maryland to manage its participation in the Berkeley-Illinois-Maryland Association (BIMA) project. The lab is part of the Astronomy program and has associated with it five faculty members, five postdoctoral fellows, six graduate students, two scientific staff members, and an administrative aide. The faculty are L. Blitz (director), W. Erickson (professor emeritus), M. Kundu, L. Mundy, and S. Vogel. The postdoctoral fellows are E. Lada (Hubble fellow), R. Rand, P. Safier, S. White, and T. Xie. P. Safier joined the LMA in August, and A. Grossman left in July and has gone to Berkeley. The scientific staff includes J. Morgan and P. Teuben. Graduate students using the array for thesis work are T. Helfer, B. Gruendl, L. Looney, Y. Peng, M. Regan, and M. Thornley. J. Williams completed his thesis this past spring and has taken a postdoctoral position at the Center for Astrophysics. Blitz and Mundy were on sabbatical this year; Blitz split his time between Leiden, Cambridge and the Institut d'Astrophysique in Paris. Mundy split his time between Caltech and Leiden.

The scientific work done with the BIMA array is outlined in the relevant sections of this report. Maryland is jointly responsible with Illinois for the calibration, analysis, and image reconstruction software for the BIMA consortium. Morgan, Mundy, and Teuben continued the joint BIMA development of the MIRIAD data reduction package. The Maryland group focuses on antenna-based calibration routines for use with the newly expanded Hat Creek 6-element array (as well as its expansion to 9 elements); holography techniques to aid in setting panels on the new antenna's virtual telescope routines and related observing script checker programs; analysis applications in the UV-plane; the WIP interactive graphics tool; color PostScript utilities; and various X-window oriented applications. BIMA has also continued its involvement with the AIPS++ software development.

The LMA is continuing work on the development of a fiber optics system which will allow the BIMA Array to be expanded to longer north-south baselines. During the Fall of 1994 the LMA was involved in building and testing outrigger antenna pads for the Hat Creek array. These new pads, located 530 and 820 meters north of the main "T" array, are the first part of an expansion project aiming to achieve 0.4" resolution at 2.7 mm wavelength with the array. In Maryland, Mundy, Looney and Erickson designed and built optical fiber links to carry local oscillator signals to and return the astronomical

signals from the outrigger antenna pads. In addition, optical fiber fixed and variable delay systems were built to enable real time correlation of astronomical signals. The entire system was installed on the array in December 1994 and successfully operated during the months of December and January. The system of outrigger pads and optical fibers is now being expanded further to permit operation of six antennas on outrigger pads yielding baselines up to 1 km north-south and 1 km east-west. Construction of the east-west arms is expected to be completed, and testing of the new system initiated in December 1995.

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 test), and users who come to Maryland have full use of the observatory and data reduction and analysis facilities.

### B. 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.

### C. Planetary Data System

The Small Bodies Node (SBN) of the Planetary Data System (PDS) is being operated in the department under the direction of M. F. A'Hearn and E. Grayzeck. A. Raugh and D. Winterfeld provide programming support. Sub-nodes 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. Three major sets of data have now been reviewed and have been ingested into the PDS: the Comet Halley CD-ROM Archive of 24 disks produced by the International Halley Watch with SBN assistance, data sets of derived asteroid properties as well as fundamental data, and IRAS data determined to be useful for studying interplanetary dust. Most data are available through the SBN computer system interface that allows simple browsing and data requests; SBN also has a home page on WWW. Sub-nodes are actively involved in archiving spacecraft data from various missions. These data sets include data from the group of spacecraft that encountered comet Halley in 1986 and the Giotto Extended Mission to comet Grigg-Skjellerup in 1992, the Galileo experiments that collected data at the asteroid Gaspra encounter, and interplanetary dust measurements from Ulysses and Galileo. Work also continues on certain ground-based data for asteroids which supersedes the Asteroids II database and preserving IRAS data in forms suitable for investigating solar system sources. To support the customized GEM archive for comet Grigg-Skjellerup, SBN has developed techniques for CD Write Once production using networked hardware.

The PDS-SBN is playing a major part in the campaign to study the impact of comet Shoemaker-Levy 9 into Jupiter. Its pivotal role as communications hub during impact week contributed to the success of observing campaigns literally around the globe. The node continues to operate an electronic bulletin board which serves as an official point of contact for release of announcements by funding agencies, facilities, and scientists. PDS will also produce a CD-ROM archive of data acquired during this event.

## V. RESEARCH

### A. Extragalactic Astronomy

G. Cecil (UNC), A. S. Wilson and C. De Pree (UNC) have used the ROSAT HRI and PSPC detectors to study the soft X-ray emission of the nearby SABbc galaxy NGC 4258 (M 106). The helically twisted, nuclear jets, previously detected in radio continuum and visual emission-line studies, are found to dominate the X-ray images. The SE jet is spatially unresolved transversely along much of its 5 kpc length. The NW jet is more diffuse, and the extensive radio ``plateaus" also emit X-rays. The energy spectrum of the jets from the PSPC exposure is best fit as a Raymond-Smith plasma with $kT$ = 0.3 keV, log $N_{\rm H}$ 20.0 cm$^{-2}$, and luminosity 1.6 x 10$^{40}$ ergs s$^{-1}$ between 0.1 and 2.4 keV. Gas at this temperature can arise from planar shocks of 500 km s$^{-1}$, and may have been entrained as the jets scrape along the molecular clouds that are known to be adjacent to the jets. The range of radial velocities from published visual emission-line spectra of the jet are consistent with such a shock speed. It is estimated that the mass of hot gas in the jets is 6 x 10$^4$ (1 cm$^{-3}$/$n_e$) M$_\odot$. The inferred pressure of hot gas in the SE jet may be similar to the radio equipartition pressure, and to the ambient pressure of the ISM. The X-ray spectral fit is poor above 0.7 keV, and requires an additional hard component that peaks near the nucleus.

C. Simpson (STScI), A. S. Wilson and M. J. Ward (U. Oxford) have obtained optical and near-infrared imaging and spectroscopy of the giant radio galaxy PKS 0634-205. The images longward of 2 μm reveal the presence of an extremely

red compact source coincident with the nucleus, which is not detected at shorter wavelengths. The observed K - L color of this source, the [OIII] flux and the soft X-ray flux are consistent with the spectral energy distribution of a typical quasar observed through a visual extinction $A_V$ 30 magnitudes. Our 2 μm spectrum shows strong narrow Pa , but has insufficient sensitivity and wavelength coverage to reveal broad Pa from the putative quasar at the predicted level.

T. Storchi-Bergmann (UFRGS), A. S. Wilson and J. A. Baldwin (CTIO) have investigated the mode of fueling the putative black hole and the question of whether the circumnuclear regions of active galaxies have experienced unusual chemical processing by studying the kinematics and chemical abundances of gas in nuclear star forming rings around active galactic nuclei. Two galaxies with LINER nuclei are found to have two Inner Lindblad Resonances, with the star-forming rings located between them. The high S/N ratio of the data has allowed detection of faint ionized gas -- a warm ionized medium -- up to several kpc from the nuclei. A correlation is found between the [NII]/H and [SII]/H ratios and the FWHM of the [NII] 6584 emission-line. This correlation is strongest for the circumnuclear gas, but is also present in the warm ionized medium, and is interpreted as a result of shock ionization. The chemical composition of the HII regions in the rings and far outside them have been determined. The highest central metallicities (O/H two times solar and N/O three times solar) were found around the LINER nuclei, confirming previous results based on spectroscopy of the narrow-line region that LINER nuclei have abundances considerably in excess of solar. Nevertheless, these abundances are similar to those of the nuclei of non-active galaxies with the same morphological type and absolute magnitude.

J. S. Mulchaey (CIW, formerly UMd), Z. I. Tsvetanov (JHU) and A. S. Wilson have completed a large imaging survey of Seyfert galaxies. Flux-calibrated images in the lines of [OIII] 5007 and H +[NII] 6548,6583 and the nearby continuum have been obtained for 57 Seyfert galaxies of early morphological type. This sample includes all known Seyferts with apparent magnitude $m_V$ 14.5 and recessional velocity cz < 7000 km $s^{-1}$ in Hubble types E, S0 and S0/a. Images are also presented for an additional 26 galaxies with $m_V > 14.5$, cz > 7000 km $s^{-1}$, and/or an uncertain classification as a Seyfert galaxy. The ratio of the [OIII] 5007 to the H +[NII] image has been obtained for each galaxy with extended emission to study the spatial variation of the gaseous excitation. Maps of the V-R color distributions over the galaxies are also presented. The implications of the survey for unified schemes are under investigation.

J. S. Mulchaey (CIW, formerly UMd) and A. S. Wilson have found a strong trend for the optical continuum to align with the [OIII] 5007-emitting gas on a scale of several arc-seconds (hundreds of parsecs) in a sample of Seyfert galaxies. This trend is observed for both Seyfert types. There is no alignment, however, between the small scale emission-line axis and the overall orientation of the host galaxy. Several explanations for the alignment are considered, including the possibility that the featureless continuum is extended in Seyfert galaxies. An extended featureless continuum component in Seyferts might solve several outstanding problems in currently popular unified models.

Wilson continued an extensive program of imaging of the gas near active galactic nuclei with the Hubble Space Telescope, with principal collaborators G. A. Bower and J. S. Mulchaey. The results show that the structures of the narrow line regions of Seyfert galaxies are dominated by two effects. The first involves collimation of the ionizing photons close to the nucleus, probably through shadowing by a dusty torus. Galaxies in which this effect dominates (e.g. NGC 5728) show spectacular bi-conical emission line regions extending to hundreds of parsecs along the axis of the putative torus. The second effect involves compression and possibly ionization of the gas by shock waves driven by radio jets and lobes. In NGC 5929, the line emission is dominated by two off-nuclear clouds of ionized gas closely associated with the radio lobes. For NGC 2110, part of the line emission is associated with jet-like features extending from the nucleus. In MKn 1066 (studied with J. A. Morse [STScI], R. Gelderman [UVa], M. Whittle (UVa]), a 200 pc long emission-line jet is found coincident with the radio jet. Z. I. Tsvetanov (JHU), J. A. Morse, (STScI), A. S. Wilson and G. Cecil (UNC) have obtained HST WFPC2 images in several emission-line and continuum bands of the Seyfert 2 galaxy NGC 5252, which is known to exhibit large scale "ionization cone". The H image reveals that the nucleus is bracketed by two bright emission-line clouds. Two major and several smaller spiral filaments, tightly wound counter-clockwise, extend 3" to the NW and almost 4.5" to the SE of the nucleus. Several of the spiral filaments appear to extend from the two clouds bracketing the nucleus, possibly indicating that the three clouds comprise a bar-like structure. A clear "D"-shaped obscuration pattern is seen on the NW side of the host galaxy major axis. Most of the morphological details in the H map can also be traced in the obscuration map. The 1--2 kpc scale spiral filaments are confined to a disk significantly inclined to both the stellar disk and the radio jets. Fabry-Perot observations of the velocity field indicate that the spiral pattern is rotating.

Wilson prepared a review on the properties of "ionization cones" -- extended regions of emission-line gas apparently photoionized by oppositely directed, bi-conical beams of radiation emitted by an active nucleus. Ionization cones have been found in about 15 Seyferts, mostly of type 2. When single (one-sided) cones are seen, they generally project against the far side of the galaxy disk, suggesting that the counter cone is present but obscured by dust in the disk. So far, clear examples of cones have not been seen in radio-loud AGN's. The emission-line cone and radio axes are very tightly aligned (to 6 ), indicating that the ionizing photons and radio-emitting plasma are collimated by the same, or coplanar, disks. However, the radio ejecta are much more tightly collimated than the ionizing photons. Various lines of evidence point to strong obscuration, probably by a dusty torus, at the apex of the cones in some Seyfert 2's. The origin of the collimation of the ionizing photons remains unclear -- both shadowing of an isotropic uv source by a dusty torus and direct radiation from an intrinsically anisotropic emitter (such as a radiation torus) remain viable models. Cones may be seen in a few Seyfert 1's; possible explanations are reviewed. The observed opening angles of the emission-line cones are, in general, expected to differ from the true opening angles of the ionizing photon cones through simple projection effects.

Veilleux, D. C. Kim, D. B. Sanders (both Univ. of

Hawaii), J. M. Mazzarella (IPAC/Caltech), and B. T. Soifer (Caltech) recently published the results of a large spectroscopic study of 200 luminous IRAS galaxies (LIGs). They confirm that the fraction of Seyferts among the LIGs increase with infrared luminosity, reaching values of 54% at the highest observed luminosities. Evidence for circumnuclear starburst activity is present in many LIGs, regardless of their nuclear spectral types. Large-scale nuclear winds appear to be common in these galaxies and may be an efficient way of getting rid of the obscuring material in the nuclear region. The spatially extended LINER emission observed in many of these objects is probably due to shock ionization resulting from the interaction of the wind-accelerated gas with the ambient material of the host galaxy. Optical/infrared imaging and spectroscopy of a large unbiased sample of ultraluminous IRAS galaxies is now underway to further clarify the nature of the exotic objects at the high-luminosity end and compare their properties with those of optically-selected quasars.

In collaboration with R. W. Goodrich (STScI) and G. J. Hill (Univ. of Texas), Veilleux carried out a search for obscured broad-line regions in Seyfert 2 galaxies. For this purpose, high-quality infrared (J, K, and L bands) spectra of more than 30 galaxies were acquired. Preliminary results on 15 of these objects indicate that a surprisingly large fraction (approx. 20%) of the objects in our sample present a hidden broad-line region. In the standard unification theory of Seyferts, this high frequency of partially obscured Seyfert 2s implies that the transition zone located between the optically-thin "throat" of the torus and the optically-thick core is rather extended. Analysis of the complete data set will allow to test the statistical significance of these results and will also provide valuable information on the origin of the emission from [Fe II] and molecular hydrogen in Seyfert galaxies.

Veilleux, J. Bland-Hawthorn (Anglo-Australian Obs.), G. Cecil (Univ. of North Carolina), and R. B. Tully (Univ. of Hawaii) continued their Fabry-Perot survey of the circumnuclear gas in active galaxies. The results of detailed studies of the Seyfert galaxies NGC 3516 and the infrared-luminous galaxy NGC 3079, host of a spectacular nuclear bubble-like outflow, have been recently published. In NGC 3079, the predicted rate of kinetic energy output from the central starburst was found to be sufficient to power most of outflow, although it is possible that a central active galactic nucleus also contributes to the outflow. The Fabry-Perot data on the galactic disk of NGC 3079 suggest that intense star formation is responsible for the vertically extended morphology of the disk.

Using the TAURUS-2 imaging Fabry-Perot interferometer on the Anglo-Australian Telescope, J. Bland-Hawthorn, K. Taylor (both AAO), Veilleux, and P. Shopbell (now at Caltech) were able to disprove the detection of diffuse H emission from the Ly absorption clouds toward 3C273. The exceptional sensitivity limit of this technique was shown to bring other important detection experiments into the realm of possibility for the first time.

T. Helfer and L. Blitz have surveyed the 3 mm HCN and CS emission from the bulges of 19 spiral galaxies (Helfer and Blitz 1993). These molecules trace gas densities of $10^5$ $cm^{-3}$. Helfer and Blitz's high detection rate (68% in HCN, 50% in CS) suggests that large quantities of dense gas are quite common in galactic bulges; such high densities may be the natural response to the high-pressure environments in the centers of galaxies. The CS to CO ratio of integrated intensities in the central 700 pc of the Milky Way agrees well with those values measured over the bulges of the external galaxies surveyed; however, the same ratio measured over individual, local GMCs in the disk of the Milky Way is at least a factor of two smaller than the ratios typical for galactic bulges. Helfer and Blitz are currently studying the large-scale HCN and CS emission from GMCs in the Milky Way as well as emission from the plane of the Milky Way in order to compare the Galaxy with their results from single-dish observations of other galaxies. They have also begun a high-resolution study of dense gas emission from the bulges of some external galaxies with the use of the BIMA interferometer.

Helfer and Blitz continued their studies of dense molecular gas in external galaxies and in the Milky Way. They published a BIMA study of the molecular environment in the inner kiloparsec of the Seyfert/starburst galaxy NGC 1068 (Helfer and Blitz 1995), and Helfer presented the results of this study at the IAU Symposium 170 (CO: Twenty-Five Years of Millimeter-Wave Spectroscopy) in Tucson, AZ. The BIMA image of CO in NGC 1068 revealed a molecular bar which had not previously been detected, and which has a similar position angle and extent as the infrared bar in this galaxy. The HCN/CO intensity ratio in NGC 1068 is 0.6 and is the highest ratio measured in the center of any galaxy; the high ratio reflects the extreme densities and temperature in the inner few hundred parsecs of this galaxy. Helfer and Blitz also used BIMA to image HCN in the centers of five nearby galaxies. Like the Milky Way, the dense gas emissivity is mostly confined to the inner 500 pc or so in these galaxies.

J. Mattox continued to work with the EGRET team in the analysis of data from phases 1-3 of the GRO mission. He also began to work as an independent EGRET guest investigator. His proposal to use the outer EGRET field of view as a monitor for flaring GeV emission of blazars lead to spectacular, multi-wavelength observation of blazar PKS 1622-297. He is also investigating the properties of unidentified EGRET sources, and has been granted EGRET exposure to continue his studies of the Geminga pulsar.

R. Rand (Rand 1995) has finished a study of molecular spiral structure in the grand-design spiral M100 (NGC 4321). One of the two arms has been mapped in CO from the nuclear regions out to a radial distance of about 7 kpc. Along the first half of the arm, the centroid of the CO arm coincides well with the dust lane and is displaced upstream from the H ridge. This same geometry is found in M51 (Vogel, Kulkarni, and Scoville 1988), and indicates triggering of star formation. But further along the arm, CO coincides better with the H ridge (more reminiscent of a region in M83). Several factors may influence this change of character: the reaction of molecular gas to the density wave, dominant sources of CO heating changing along the arm, and the complicating effects of the corotation region, which is near the end of the mapped arm. Streaming motions are weaker than in M51, and the inferred arm-interarm contrast of molecular gas is 2-3, somewhat lower than in M51 (Rand 1993). Many GMAs are found along the arms, and an analysis shows that gravitational instability and collisional agglomeration are both viable ways of forming such massive gas units. With J. Knapen (Montreal) and I.

Shlosman (Kentucky), an effort is now underway to compare the CO morphology of the central bar region with hydrodynamic simulations.

R. Rand has collected deep H images of nine edge-on galaxies (Rand 1996), in an attempt to observe the morphology of extraplanar diffuse ionized gas (DIG) in a large sample of galaxies. This work extends a project that began with observations of NGC 891, NGC 4565, and NGC 4631 (Rand, Kulkarni, & Hester 1990, 1992). The goal is to understand how diffuse gas is raised from the plane of galaxies and how it is ionized. None of the nine galaxies shows a prominent widespread, diffuse halo as found in NGC 891, or the kind of bright, patchy emission above the central disk of NGC 4631. Most show only a few restricted regions of high-z emission, in the form of either patches or filaments. It is suggested that in the typical spiral, only a few regions harbor sufficient star formation activity to cause much gas to be raised above the HII region layer and ionized. Considering all the galaxies observed deeply, the prominence of the extraplanar DIG layer is clearly related to the star formation rate. NGC 891 probably has such a prominent layer because of its high level of star formation. Many galaxies may have DIG mixed in with the HII region layer, but this can only be inferred from other techniques. Three of the nine galaxies show structures (filaments or loops) above the nuclear regions, suggesting outflows from nuclear starbursts are not uncommon in normal spirals.

R. Rand and J. Stone have carried out the first 3-d MHD simulations of the collision of an infalling gas cloud on a galactic disk (Rand & Stone 1995), using the ZEUS code (Stone & Norman 1992). The motivation is the discovery of two very large HI supershells in the edge-on galaxy NGC 4631 (Rand & van der Hulst 1993). These may be too energetic to be formed by multiple stellar winds and supernovae. The simulations concentrate on the more prominent and energetic shell. They are successful in reproducing many of its basic properties (mass, size, kinetic energy), as well as many of the structural and kinematic details, and allow some constraints to be placed on the geometry of the (necessarily oblique) impact. The case for a collisional origin of such energetic shells is thus strengthened, although the supernova-driven mechanism cannot be ruled out.

W. Wall (GSFC), M. Kaufman (Ohio State), F. Bash (Texas), and R. Rand are continuing a study of $^{13}$CO in M51 using the Owens Valley Millimeter Array (OVMA). The goal of this project is to understand whether patches of high extinction which show little $^{12}$CO emission are bright in $^{13}$CO. Emission has been detected, maps have been made, and analysis is continuing.

J. Higdon, S. Lord and R. Rand are continuing their study of CO emission from ring galaxies. These are starbursting galaxies which result from the passage of a compact companion galaxy through the disk of a spiral along its rotation axis. We have successfully detected several objects at the NRAO 12-m, including Arp 143 (Higdon, Smith, Lord, & Rand 1995), which we have now detected and mapped with the OVMA.

M. Thornley is continuing her thesis work on the star formation and kinematics of flocculent galaxies, under the supervision of L. Mundy and in collaboration with C. Wilson (McMaster University). Recent VLA images of the flocculent spiral NGC 5055 show ridges of HI emission which align with a two-armed spiral structure seen in the near-infrared. This morphology, combined with the detection of non-circular motions in the velocity field, may indicate the presence of a weak density wave in NGC 5055. Continuing observations of HI will help define the presence of density waves in flocculent galaxies, which lack the large-scale, optical spiral arms usually attributed to spiral density waves. In addition, molecular structures similar to the Giant Molecular Associations seen in the grand design spiral M51 have been detected in NGC 5055, using the BIMA interferometer to map the distribution of CO emission. Continuing BIMA observations are being used to map out the molecular gas distribution in a sample of flocculent galaxies.

In previous publications W. K. Rose has discussed some physical properties of relativistic, extragalactic jets including collisionless plasma processes and plausible magnetic field configurations. Recent progress in multiwavelength observations of quasars and AGNs has been substantial. During the last year, in collaboration with S. Kainer, he has interpreted some of these new results. There is evidence that the Universe contains at least ten times more nonluminous than luminous mass. It has been suggested that much of this dark matter is in the form of nonbaryonic mass such as finite mass neutrinos or hypothetical massive neutrinos. They have also studied the possibility that the evolution of some quasars and AGN's may be affected by gravitational capture of nonbaryonic dark matter.

Vogel and Weymann (OCIW) have continued their program begun last year to measure the metagalactic ionizing flux at zero redshift. New observations obtained with the Maryland-Caltech Fabry-Perot at the duPont 2.5 m telescope at Las Campanas improve upon their Palomar limits by a factor of three. The latest measurements limit the H-alpha surface brightness of the intergalactic cloud HI 1225+01 to be less than 10 mR (3 sigma), or an emission measure of 0.03 pc cm**(-6). This indicates an incident ionizing flux comparable to that modeled for quasars; if the estimates for quasars are correct, this indicates that the metagalactic ionizing flux of other sources, such as ionizing photons leaking from starburst galaxies, are negligible compared to quasars.

Regan, Vogel and Teuben are continuing their studies of the kinematics of barred spirals. Maryland-Caltech Fabry-Perot observations have been made at the Palomar 1.5 m of the barred spiral NGC 1530. These observations reveal the velocity of the gas throughout the bar region of a galaxy for the first time allowing the study of the full two-dimensional velocity field. The observations reveal a very strong shock running along the bar with an unresolved velocity jump of 300 km/sec in the plane of the galaxy. These observations complement previous work that studied the gas and dust content of the galaxy using the BIMA interferometer to observe the molecular gas.

Regan and Vogel have completed a study which uses new BIMA and infrared observations to investigate whether the galaxy NGC 6946 is really a barred spiral as is commonly thought. The paper shows that if the galaxy is a barred spiral it has characteristics unlike any other barred spiral. It may be that the galaxy is just a spiral galaxy with high pitch angle spiral arms.

Regan is working on an infrared survey of a sample of Seyfert and control galaxies with Mulchaey (Carnegie). The goal of the survey is to determine whether the Seyfert galaxies are any more "barred" than the control galaxies. The survey had used telescopes at Kitt Peak, Las Campanas, and Palomar observatories. The data collection phase of the project is almost complete.

Vogel is searching for supernova remnants in M101 with Martin (Caltech) using Maryland-Caltech Fabry-Perot observations of [SII] and H-alpha emission; the combination of line ratios and kinematics provides an excellent tracer of SNR.

Sage has been searching for emission from two recently discovered galaxies, Dw1 and the Sagittarius Dwarf; this is a joint project with Yu Gao at Stony Brook.

Sage, Galletta and Sparke are investigating the molecular gas content of a sample of galaxies known to either have counter-rotating stars and (ionized) gas, or polar rings. Sage & Galletta have detected counter-rotating CO (wrt the stars) in NGC4546. The presence of counter-rotating components makes it unlikely that those components share the same origin, and suggests that the gas was acquired during an interaction with another galaxy.

Welch, Mitchell & Sage are studying the molecular gas content of NGC205, one of the dwarf companions of M31. The gas and dust are not uniformly distributed near the center of this galaxy, which is analogous to the situation found in NGC4546. This might occur because of a recent capture of gas by N205.

A paper on one-armed spiral galaxies was completed by Phookun and Mundy (1995). In this paper they analyze the morphology and kinematics of NGC 4654. They argue that the large asymmetric HI tail in NGC 4654 is being driven by a combination of ram-pressure interaction with the Virgo intracluster medium and galactic rotation. The origin of the asymmetric spiral structure within the galaxy is less clear; it could be driven by an off-center bar but their data do not directly confirm that possibility.

## B. Galactic Astronomy

Blitz and Spergel are continuing their long standing collaboration investigating the deviations from axisymmetry of the Milky Way's bulge and disk. They are currently involved in inverting the COBE data from the DIRBE experiment to obtain a mass model for the bulge/bar, and looking into the resolution of differences between their model and that of Kuijken and Tremaine to explain ellipticities present in the Galactic disk.

D. Smith, M. Leventhal, and graduate student R. Cavallo, collaborating with N. Gehrels, J. Tueller (both NASA-GSFC) and G. Fishman (NASA-MSFC), have continued their search for gamma-ray line emission from Galactic sources using the Burst And Transient Source Experiment (BATSE) on the Compton Gamma-Ray Observatory (CGRO). They looked (Smith et al. 1996) for two bright, transient emission features near 0.5 MeV reported from the Crab and the black hole candidate 1E 1740.7-2942 by the Sigma imager on the GRANAT spacecraft. These events were not seen in the BATSE data, even though BATSE's sensitivity was higher than the original Sigma observations. They have searched the whole sky for such transients in BATSE data from 1991-1993 without finding these events, which had been attributed to the production and immediate annihilation of large numbers of positrons near compact objects.

In addition to the search for transient positron annihilation events, Leventhal and Smith have been using BATSE and another CGRO instrument, the Oriented Scintillation Spectrometer Experiment (OSSE), in an effort to map the persistent 511 keV positron-annihilation line in the Galaxy. Although it is thought that these positrons are created in supernovae, novae, accreting black holes, and perhaps other objects, the Galactic distribution of the emission is not well known. One OSSE project (with J. Tueller and others) involves determining whether the centroid of the 511 keV distribution in Galactic longitude better fits the Galactic Center or 1E 1740.7-2942, roughly 1 degree away. Another (with W. Purcell, Northwestern University, and others) seeks to map the whole Galactic Center region out to about 15 degrees using all OSSE data from the start of the CGRO mission. Finally, the BATSE data used to search for transients are also being used in a separate attempt to map the persistent line.

J. Wang and R. Sutherland (JILA) are continuing their calculation on the emission line spectra expected from photoionized nebulae surrounding isolated old neutron stars (IONS) accreting from both the dust-free and dusty atomic interstellar media. Initial results show the mid to far infrared fine structure lines (e.g., [NeII] 12.8μ, [SiII] 34.8μ) to be most prominent ( $10^{-3}$ bolometric luminosity). Many of these lines are brighter than H , the strongest optical line. The nebular lines together with their distinctive line ratios should aid the detection and identification of nearby accreting isolated neutron stars of which, at present, there are at least two prime candidates.

In collaboration with Q. Wang (Northwestern), O. Blaes (UCSB), P. Madau (STScI), R. Nelson (CITA), M. Barsony (UCI), K. Yu (Colorado), J. Wang is involved in a ROSAT HRI observing program to secure accurate positions of 20 unidentified sources in the ROSAT WFC catalog. These sources are potential IONS candidates. Successful completion of this program will enable a multi-wavelength search for IONS to proceed. To date, the HRI has observed 7 of the 20 fields.

With M. Isenberg (Chicago) and D. Lamb (Chicago), J. Wang has begun investigating cyclotron line formation in a relativistic flow. This study is motivated by narrow cyclotron absorption-like features (E/ E 4) seen in some gamma-ray bursters and is necessitated if bursters reside in a Galactic corona with radius greater than 100 kpc. The aim of the study is to determine whether narrow features, especially the scattering-dominated cyclotron fundamental, can form in such flows.

## C. Stellar Astronomy

Blitz (1995) has published an article suggesting that Brown Dwarfs should be very rare in the Milky Way. He has argued that the pressure in molecular clouds, which is nearly constant form cloud to cloud is too low by three orders of magnitude to form brown dwarfs. The stars that are expected to form in observed clouds based on the Jeans criterion turn

out to have masses in the range of observed stars.

R. P. Butler (U. C. Berkeley and San Francisco State University), R. A. Bell and R. B. Hindsley (U.S. Naval Observatory) have analyzed high resolution radial velocity data of the Cepheid variable Aql. This data, obtained by Butler, revealed differences in the radial velocity curves from the spectral lines of elements having different ionization states and excitation energies. Velocity gradients have been introduced into hydrostatic model atmospheres and synthetic spectra have been calculated using these models. These synthetic spectra show that a significant gradient is needed near the phase of maximum infall velocity to account for the observed line profile asymmetries and velocity differences.

This velocity gradient reduces the amplitude of the pulsational velocity curve, thereby making the absolute magnitude of Aql found by the Barnes-Evans method about 0.4 mag fainter, compared to that found earlier where the possibility of a velocity gradient was not allowed for.

M. J. Tripicco (Hughes-STX Corporation) and Bell completed an analysis of the behavior of the so-called Lick spectral indices, which are used to work on stellar populations in galaxies and globular clusters. Model indices, derived from synthetic spectra, were calculated for $T_{eff}$, log g values lying on a 5 Gyr isochrome for the galactic cluster M67. These indices were calculated for solar abundances, for twice solar abundances and with the abundances of certain elements e.g. Mg, Na, C being altered relative to their solar values. In particular, the C depletion, N enhancement seen in Population I giant stars has been included. Tripicco and Bell point out that the Fe 4668 index, which the Lick group found to be very abundance sensitive, contains many weak $C_2$ lines in its feature band pass and is very sensitive to C abundance. They also point out that the $Mg_2$ index is particularly abundance sensitive since the feature band pass contains the strong Mg b lines and Mg H lines, both of which depend strongly on abundance. The index showing the greatest sensitivity to Fe abundance is Fe 4383, owing to the occurrence of the strong 4383 line of Fe I in the feature band pass.

Bell, G. Paltaglou and Tripicco made detailed comparisons of observed and synthetic solar line spectra. Bell and Tripicco have extended this work, making comparisons of observed and calculated solar fluxes. The different observations of solar fluxes are discordant in some wavelength regions, particularly around 4000 where the data of Labs and Neckel are as much as 10% brighter than those of Lockwood, Tüg and White. Bell and Tripicco find that their models are in better agreement with the Lockwood et al. data. These data also give a bluer solar color than do the Labs and Neckel data. Improved calculations of the Fe I bound-free absorption coefficient would be of great value in these comparisons.

H. Richer (University of British Columbia) and collaborators, including Bell, have discovered an extensive cooling sequence of white dwarfs in the globular cluster M4. The absolute magnitudes of these stars correspond to masses of 0.5 M , which is consistent with the implications of horizontal branch and asymptotic giant branch evolution in this cluster.

W. K. Rose completed work on a model of radio and X-ray emission from SS433. Supernova 1993J was a bright supernova because it exploded in M81. Hydrogen lines in its initial spectrum disappeared and the subsequent presence of helium lines made it similar to a Type Ib supernova. W. K. Rose has developed a model interpreting its early radio spectrum.

F. H. Cheng, S. D. Vrtilek and J. C. Raymond (CfA) have performed an archival study of observations of Her X-1/HZ Her obtained by HST/FOS. They have utilized the system geometry as modeled by Howarth and Wilson and have added blackbody components to their X-ray heating code to allow them to match better the observed slope of the HST/FOS spectrum and the strength of the Balmer jump. By fitting their model to the HST/FOS spectrum obtained at total eclipse (binary phase 0.0), they determined the mean temperature of the unheated star surface to be 8,100 +/- 240 K, consistent with an A7 star. From the best fit model to the HST/FOS spectrum near the binary phase 0.5 they determined a mass transfer rate (6.5 +/- 0.9) x $10^{-9}$ Mo/yr.

With E.M. Sion, M. Huang (U. of Villanova), P. Szkody (U. Washington), and I. Hubeny (GSFC/NASA) Cheng worked on far ultraviolet spectra of the dwarf nova VW Hydri obtained during quiescence with the HST/FOS and HST/GHRS, and during superoutburst with the HST/FOS. A synthetic spectral analysis with hot, high gravity LTE model atmospheres yields a best fit model to the quiescent HST/FOS spectrum with the following parameters: T = 22,000 +/- 1000 K, log g = 8.0 +/- 0.3, with chemical abundances of Oxygen = 0.3 x solar, Nitrogen = 5 x solar and all other heavy elements = 0.15 x solar. Based upon their absorption line measurements in the observations at different orbital phases, they find no conclusive evidence of equivalent width variations versus orbital phase. In the absence of any significant reduction of the white dwarf's core mass by past nova explosions, its lower limit cooling age is approximately 50 million years. Their synthetic spectral analysis, to the quiescent HST/GHRS spectrum using a model grid constructed with the code TLUSTY, resulted in a reasonable fit to a white dwarf photosphere with T = 22,000 +/- 2000 K, log g = 8.0 +/- 0.3, an approximately solar Si/H abundance, and a rotational velocity, v sin i 600 km/s. The predicted boundary layer luminosity for a 0.6 M white dwarf accreting at the rate $10^{-10}$ M /yr. and rotating at 600 km/s, corresponding to VW Hydri in quiescence, is 2 x $10^{32}$ erg/s when proper account is taken for the rotational kinetic energy going into spinning up the white dwarf. By comparing the superoutburst HST/FOS spectrum with a grid of LTE model accretion disk atmospheres constructed with TLUSTY, SYNSPEC and DISKSYN, they present a pure disk fit to the observed spectra. The observed broad wings of the disk are nicely reproduced in this model.

V. Trimble in collaboration with G. Herbig were awarded about 2/3 of their desired 40 target stars on HIPPARCOS. Data will arrive in 1996 and should shed light on the luminosities, masses, space velocities, and population types of R CrB, FK Comae, cataclysmic variable, and other types of stars in unusual evolutionary stages.

### D. Interstellar Medium and Star Formation

J. Stone's research efforts are primarily concerned with hydrodynamic and magnetohydrodynamic (MHD) studies of the ISM and star formation. In collaboration with S. Balbus and J. Hawley (U. Virginia), Stone has studied angular momentum transport in accretion disks via convection.

Through direct numerical simulation, Stone and Balbus have shown that convection transports angular momentum inwards, and therefore is not a viable candidate for the anomalous viscosity in disks. Through combined analytic and numerical studies, Balbus, Hawley, and Stone have been able to understand this result physically in terms of the role epicyclic motions play in mediating angular momentum transport in disks.

Stone and graduate student J. Xu have been studying the Kelvin-Helmholtz instability in non-adiabatic protostellar jet beams. With collaborator P. Hardee (U. Alabama), the growth rates of K-H modes in cooling jets have been calculated in the linear regime. There are significant differences between the growth rates of modes in adiabatic and cooling jets. Using two-dimensional hydrodynamical simulations, Xu and Stone have followed the growth of these modes into the nonlinear regime.

Stone, Mundy, and graduate student J. Xu have proposed a model for the formation of 'bullets' in poorly collimated outflows from young stars. The model is based on temporal variability in the wind which fragments the dense shell of cooling gas which is swept up by the outflow. The model is applied to the IR observations of the OMC-1 star forming region obtained by Allen and Burton (Nature, 363, 54-56 (1993)).

Stone, M. Norman and B.-I. Jun (Illinois) have completed a study of the Rayleigh-Taylor instability in magnetized fluids. Stone and Hester (ASU) have applied the results to explain the origin of the fingers observed in the filaments of the Crab Nebula. The morphology and spacing of the observed fingers are in close agreement with the interpretation that the filaments are undergoing a magnetic R-T instability as they accelerated by the expanding synchrotron nebula inflated by the Crab pulsar.

L. Mundy participated in several papers utilizing the new long baselines capabilities of the BIMA array to study star formation. Mundy, Looney and Lada (1995) present 3.5 mm wavelength continuum observations of the Trapezium cluster core with 1.8" x 1.0" resolution. The objective was to search for dust emission from the large number of proposed young stellar disk systems in the vicinity of $^{1}$ C Ori. Very few systems were detected and those detections were consistent with extrapolation of the free-free flux from centimeter wavelengths. Converting their flux limits to mass estimates, they restrict disk masses around individual sources to be < 0.15 M . Statistical analysis of the overall sample suggests that the average disk mass is < 0.03 M . They conclude that massive circumstellar disks are not common in this cluster but their limits are not sufficient to rule out the possibility that disks in the Trapezium Cluster have a similar mass distribution to those associated with stars forming in isolation or loose aggregates. Two other papers, Plambeck et al. (1995) and Wright et al. (1995), study the continuum and SiO emission from the Orion IRc2 region. Together, these papers show that the SiO maser central source, radio source I, is one of the main centers of luminosity and outflow in the region; IRc2 itself is no longer likely to be of major importance in the region.

Chemical studies of young stellar regions is continuing with the works by McMullin, Mundy, and Blake (1994) on IRAS 05338-0624 and by Blake et al. (1995) in NGC 1333 IRAS4. The overall theme of these studies is outlined in the conference paper by Mundy, McMullin, and Blake (1995). They argue that depletions of gas-phase molecules, grain mantle evaporation, and shock interactions actively drive the chemistry in the young stellar environment and present a rough chemical evolutionary sequence which parallels the standard dynamical evolutionary sequence. In a related work, Spaans et al (1995) present a model for CO emission from young stars based on photon heating of the envelope by the 10,000 K accretion disk. This model explains the observed bright ambient-velocity emission in high rotational lines of CO without requiring shocks.

Vogel has obtained emission line observations with the Maryland-Caltech Fabry-Perot giving the full velocity field of several possible stellar wind - ambient ISM bow shocks. Observations of the peculiar planetary nebula Abell 35 with Hollis (Goddard), Van Buren (IPAC), and Jacoby (NOAO) show that the nebula is being stripped from the progenitor by a ram pressure interaction with the ambient gas.

Peng and Vogel have used the BIMA array to study several massive star-forming cores with a goal of developing chemical markers of evolutionary state using observations of 20 molecular lines. Toward the northern hot core in Sgr B2, which contains more than 5000 solar masses of gas in a 0.25 pc diameter core, they find that deuterated ammonia emission is surprisingly weak; however, this is probably not evidence for a low deuterium abundance in the galactic center region but rather a result of the high temperatures in galactic center clouds. Similarly, the unusually strong SiO emission in the low density regions of Sgr B2 is attributed to the high frequency of cloud - cloud collisions in galactic center clouds. They find additional evidence to support an evolutionary scenario in which the northern core is extremely young, with outflow commencing in the past few thousand years, whereas the middle core is much older and has dispersed much of the material surrounding it. In W33A, which had been proposed to be in a state prior to the development of an outflow, they found compelling evidence for outflow activity, although the large column densities of gas and dust indicate that much of the star-forming material remains.

T. Xie continued his investigation of the role that turbulence plays through the accompanying diffusion processes. He is extending his study to the production of large organic molecules in collaboration with E. Herbst and H. X. Lee (Ohio State U). With P. Hofner (U of Cologne), L. Mundy and S. Vogel, Xie has mapped the CS emission from the UC HII G35.2-1.74 with BIMA array and then with FCRAO 14m telescope, and found that the dynamics of the region is dominated by a massive bipolar outflow oriented East-West with the molecular gas significantly displaced from the UC HII. With L. Blitz, P. Goldsmith (Cornell), G. Moriarty-Schieven (DRAO) and N. Patel (CfA), Xie has obtained 21 cm line and continuum data with DRAO array with 1' resolution, covering most of the cometary globules in IC1396, and they have made some very surprising findings. With P. Goldsmith (Cornell), L. Mundy and R. Snell (UMASS), Xie has carried out observations of a number of interesting outflow sources with the FCRAO 14m telescope to cover the whole extents of the outflows, including L1448, B335, L1455 etc, revealing spectacular complexities in these outflows at low velocities.

Sage, Mooney and Roger are examining the HI/$H_2$ interfaces of several molecular clouds (using the DRAO interferometer), to determine how extended that region is, and how much molecular mass is not being traced by CO emission.

## E. Solar System

A. Kundu, A. Grossman, and J. Wang have analyzed the nonthermal (polarized) emission data from the VLA at 3.6 and 6.2 cm for Jupiter before, during, and after the impact of Comet Shoemaker-Levy 9. These are the shortest wavelengths (resolution 2") at which the Jovian magnetospheric emission for this event has been mapped. The emission, peaked in the equatorial regions on both sides of the Jovian disk, increased during the week of the impact (July 16-23, 1994) and remained high well after impact week, consistent with single dish measurements. The inward migration of the emission peaks during impact week is suggestive of impact-enhanced electron radial diffusion. Subsequent outward migration to pre-impact positions may be caused by azimuthal electron diffusive redistribution. The enhanced left-right asymmetry seen during impact week followed by a return to pre-impact levels by 26 July may be caused by impact-induced local energization of electrons followed by azimuthal electron diffusive redistribution. There is also evidence for enhanced electron pitch angle scattering since the emission at high latitudes increased significantly in the post-collision maps.

## F. Space Plasma Physics

A. S. Sharma and K. Papadopoulos have continued their investigation of the magnetosphere using nonlinear dynamical technique. Some of these results were published as a part of the US National Report to International Union of Geodesy and Geophysics 1991-1994.

A. S. Sharma, J. A. Valdivia (Graduate student) and K. Papadopoulos worked on the predictions of substorms. They developed a model that substorms behave as a low dimensional system which can be described by a few variables using the techniques of phase space reconstruction. The leading variables of the low dimensional dynamics was obtained by the singular spectrum analysis of the observational data, e.g. the auroral electrojet indices. These variables are then used to construct the dynamical equations describing the magnetospheric dynamics. The predictability of substorm activity using these equations are analyzed and compared with local models.

J. A. Valdivia (Graduate student), A. S. Sharma and K. 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 as forecasting tools for space weather.

A. S. Sharma, R. R. Rosa and J. A. Valdivia (both Graduate students) studied characterization of fragmentation in spatio-temporal dynamics. They introduced a new quantitative measure of the local complexity defined in terms of the asymmetry in the gradient field of the amplitudes. This asymmetric fragmentation parameter is a measure of the degree of complexity and characterizes the localized regions of a spatially extended system. The model has relevance to high resolution spatio-temporal data from remote sensing satellites or space-based astrophysical observations such as Yohkoh satellite observing the sun, or Hubble Space Telescope observing the nearby planets to the distant galaxies.

SPP continued their activity in the Active Aurora Research Program (HAARP). Recently released report which describes the scientific uses and the wide range of applications created by the HAARP, was based on the deliberation of a scientific committee convened by the University of Maryland and Naval Research Laboratory. Papadopoulos is the committee chairman, and Milikh is the committee executive secretary.

Regarding the HAARP activity, G. M. Milikh, M. J. Freeman and L. M. Duncan (Clemson University) presented a one-dimensional, self-consistent model to predict electron temperature and density changes in the lower ionosphere caused by high power, high frequency (HF) radio wave heating. The model was used to obtain first estimates of ionospheric perturbations due to the proposed HF HAARP heating instrument.

K. Papadopoulos, G. M. Milikh and C. L. Chang (Science Application International Corp.) presented the first physical model of a high altitude lightning. This new phenomenon is manifested as high altitude optical flashes appear at altitudes in excess of 30 km, which correlated with the presence of giant thunderstorms in the atmosphere below. The model is based on low frequency RF breakdown of the upper atmosphere, ignited by the upward propagating electromagnetic pulses caused by conventional low altitude lightning.

A. S. Sharma and G. M. Milikh have continued their studies of the structure and dynamics of inner cometary plasmas. A model of the cometary plasma consisting of water group ions, bulk electrons and energetic electrons produced mainly by photoionization has been presented. The dominant losses in the inner coma are the radiation from the excitation of vibrational levels of water molecules. The electron energy losses due to these processes peak near 4000 K, and at temperatures higher than this value a localized cooling leads to a thermal instability. The resulting increase in recombination leads to an ion density depletion, and the estimates for this depletion at comet Halley agree with the observations. The effects caused by diffusion and thermal conductivity have been studied.

A. S. Lipatov (IKI, Russia) and A. S. Sharma worked on simulations of comet Shoemaker-Levy 9 interaction with Jovian magnetosphere. Using a one dimensional hybrid code they show that the mass loading of the solar wind by the cometary ions leads to the formation of a bow shock behind which the plasma density is 2-3 $cm^{-3}$ and the electron temperature is 4 eV. The interaction of this system with the Jovian bow shock yields local enhancements of the magnetic field and the plasma density by factors of 4-5 and the electron temperature by 2-3.

A. S. Sharma and K. Papadopoulos worked over the

solar wind -- comet interaction. They studied the alpha particle heating by the Landau damping of kinetic Alfven waves. The Alfven wave heating was shown to be the dominant mechanism for the observed proton heating, but it is found to be insufficient to account for the observed alpha particle heating. The transit time damping due to the interaction of the ions with the electric fields associated with the magnetic field compressions of magnetohydrodynamic waves is found to heat the alpha particles preferentially over the protons. Comparison of the calculated heating times for the transit time damping with the observations from comet Halley shows good agreement. These processes contribute to the thermalization of the solar wind by the conversion of its directed energy into the thermal energy in the transition region at comet-solar wind interaction.

A. Taktakishvili (IKI, Russia), R. E. Lopez and C. C. Goodrich studied energization of ions in near-Earth current sheet disruptions based on the in situ satellite observations of energetic ion bursts during seven substorm periods. The observations were compared to analytic calculations of particle acceleration. It was found that the acceleration region size, which was assumed to be essentially the current disruption region, to be on the order of 1 $R_E$. These results add additional support for the view that the particle bursts observed during turbulent current sheet disruptions are due to inductive acceleration of ions.

R. E. Lopez, C. C. Goodrich, G. D. Reeves, R. D. Belian (both Los Alamos) and A. Taktakishvili studied midtail plasma flows and the relationship to near-Earth substorm activity. In this study they examine observations made by satellites as well as by ground based stations during 04/08/95. This event is unique because one of the satellites was located near the neutral sheet during ongoing activity. It was obtained that processes at the inner edge of the cross-tail current, that cause a disruption of the current, and a consequent dipolarization and current wedge may be unrelated to the formation of a macroscale reconnection region.

D. L. Book studied high-frequency electrostatic models in non-neutral plasmas. He employed a fluid description to derive the dispersion relation for cyclotron models in a cylindrical non-neutral plasma confined by a uniform magnetic field inside a chamber with conducting walls. The eigenvalues are found, as well as the eigenfrequencies for high-frequency electrostatic models.

D. L. Book investigated instability of an expanding charged-particle beam. It is shown that a uniform collisionless charged-particle beam expanding under the influence of electrostatic and internal pressure forces is linearly unstable. The instability, which tends to cause spreading and change the radial profile of the beam, implies a limit on the achievable focusing even when the lens system corrects for expansion.

D. L. Book studied the Sedov self-similar points blast solutions in the nonuniform media. He found that the character of a spherical blast wave changes dramatically as and the adiabatic index vary. Plots of the Sedov formulas for the density, velocity, and pressure profiles behind the shock front for a selection of different parameters illustrate this and suggest that some of the solutions satisfy the conditions for the Rayleigh-Taylor or convective instability.

D. L. Book and D. G. Sibek (APL, Johns Hopkins University) studied plasma transport through the magnetopause by turbulent interchange processes, which can cause magnetospheric field lines at the magnetopause to develop localized regions of negative curvature. These regions are unstable with respect to interchange, which can lead to significant transport of mass and energy across the magnetopause. The rate at which magnetosheath plasma crosses the magnetopause is estimated to be of order $10^{26}$ $s^{-1}$, which is consistent with estimates based on observations.

K. Papadopoulos, P. K. Chaturvedi, P. N. Guzdar (Physics Department, UMD) in cooperation with M. J. Keskinen and S. L. Ossakow (both from NRL) developed a model of the self-focusing instability of high power radio waves in the ionosphere in the presence of density irregularities. This study addresses the role of preexisting density irregularities which are always presented in the instability region. The presence of ambient irregularities results in the excitation of wave-numbers which, base on homogeneous theory of the self-focusing instability, should be stable. This effect can explain the puzzling observations that indicate growth of the medium scale (<100's meters) irregularities during atmospheric heating.

C. C. Goodrich, K. Papadopoulos, M. Wiltberger (Graduate student) and J. G. Lyon (Dartmouth College) studied energy and momentum transport from the solar wind into the magnetosphere during a substorm. They found that the propagation of the Poynting flux is determined by the dynamic state of the magnetosphere. During the substorm growth phase of this flux penetrates the magnetopause and is focused toward the central plasma sheet in a region about 6--10 RE. The Poynting flux focusing provides a natural interpretation of the observations showing the strongest substorm growth phase effects occur near 8--15 RE location. They further confirm the suggestion earlier made by Papadopoulos that the magnetosphere acts as an equivalent lens that, during a substorm growth phase, focuses the solar wind field momentum in the vicinity of 6--10 RE.

K. Papadopoulos and D. Book in cooperation with the experimentalists from the Hebrew University (Israel) headed by A. Zigler, studied the current response of an electrically biased magnetoplasma to a short photoionizing laser pulse. It is found that the behavior in the approach to the asymptotic state varies from monotonic to oscillatory, depending on the ratios of the collision frequency to the cyclotron frequency for the carriers. Of particular interest is the case equivalent to a critically damped oscillator, which allows the photonic pulse to be mapped to a short electric pulse, independently of the carrier lifetime. This corresponds to transient breakdown of the magnetic insulation during the photoionization time.

The in situ observations of wave data (0 -1 MHz) obtained by the Unified Radio and Plasma Wave Experiment (URAP) on the Ulysses spacecraft have been extensively used in the studies of solar type III radio bursts as well as collisionless shock waves by T. Golla, D. Lengyel-Frey and D. G. Wentzel in collaboration with scientists from Goddard Space Flight Center. In Thejappa, Wentzel and Stone (1995), several bursts of Langmuir waves in association with electro-magnetic low frequency waves have been identified in type III burst source regions. The Langmuir waves are observed to occur as intense broad and narrow spikes, which are identified as envelope and collapsing solitons, respectively. The low-frequency waves are identified as

electro-magnetic lower hybrid waves. The energy densities of these waves are also observed to exceed the strong turbulence thresholds. In this study the strong turbulence processes, such as Langmuir soliton formation and Langmuir collapse are shown to dominate over the weak turbulence processes, such as parametric decay instabilities involving Langmuir and low-frequency waves. The electromagnetic lower hybrid waves are proposed to arise from currents associated with gradients in the electron beams originating at sites where Langmuir waves scatter the beam electrons.

### G. Solar Radio Physics

Kundu, and White along with Nitta (Lockheed), Enome and Shibasaka (Nobeyama) investigated radio and X-ray imaging data for two solar flares in order to test the idea that asymmetric precipitation of nonthermal electrons at the two ends of a magnetic loop is consistent with the magnetic mirroring explanation. The events were observed in May 1993 by HXT and SXT X-ray telescopes on the Yohkoh spacecraft, and by the Nobeyama 17 GHz radioheliograph. The hard X-ray images in one case show two well-separated sources; the radio images indicate circularly-polarized nonthermal radio emission with opposite polarities from these two sources, indicating oppositely directed fields and consistent with a single-loop model. In the second event there are several sources in the HXT images which appear to be connected by soft X-ray loops. The strongest hard X-ray source has unpolarized radio emission, whereas the strongest radio emission lies over strong magnetic fields and is polarized. In both events the strongest radio emission is highly polarized and not coincident with the strongest hard X-ray emission. This is consistent with asymmetric loops in which the bulk of the precipitation (and hence the X-ray emission) occurs at the weaker-field footpoint.

White, Kundu, Enome and Shibasaki (Nobeyama) and Shimuju (NAOJ) searched for radio emission from active-region soft X-ray transient brightenings identified in Yohkoh Soft X-ray Telescope observations of active region AR 7260. They presented detailed observations of four events in which 17 GHz radio emission is clearly detected in observations by the Nobeyama Radioheliograph. The time profiles of the 17 GHz data are very similar to those of the soft X-ray fluxes, and the 17 GHz flux is very close to that expected from plasma with the temperature and emission measure derived for the soft X-ray-emitting material from filter ratios. No impulsive nonthermal radio emission was detected from any of the 4 events, although each was at least GOES class B1 in soft X-ray size. Weak hard X-rays may have been detected by GRO/BATSE from the strongest of the events, but not from two others. These negative results leave open the possibility that there is a difference between active region transient brightenings and solar flares, in that the former do not convert a significant amount of the released energy into accelerated electrons. However, confirmation of this hypothesis will require a larger sample of events.

Gopalswamy and Kundu, in collaboration with scientists at Nobeyama Radio Observatory and Lockheed, studied a very slowly moving prominence observed by the Nobeyama radioheliograph. The prominence moved in a nonradial (probably helical) path. The event was also fully observed by Yohkoh/SXT. A peculiar loop-shaped eruption was seen by the SXT from the same region. Temperature and emission measure analysis showed that a coronal volume much larger than the prominence was affected by the eruption. Several hours after the eruption, a new prominence formed just to the south of the original position. The event resembles a coronal mass ejection (CME) but the X-ray loop decelerates unlike regular CMEs.

Gopalswamy, Kundu, Hanaoka, Enome (Nobeyama) and Lemen (Lockheed) have detected nonthermal radio emission from a bright point flare observed by the Nobeyama radioheliograph and the Yohkoh's Soft X-ray Telescope. The bright point flare had completely different manifestations in X-rays and microwaves. The radio structure was much larger than the X-ray structure and the emission peaks did not coincide with each other. The radio source also showed fast time variability which suggests nonthermal mechanism for the microwave emission. Since the bright point flare was observed using two filters, the temperature and emission measure of the flare plasma were determined which also seem to support nonthermal process for the radio emission. Preliminary calculations show that gyrosynchrotron emission at a harmonic number > 50 from nonthermal electrons with a power-law distribution can explain the observed radio emission. The extended structure seems to be the radio counterpart of large scale magnetic structure sometimes seen in association with X-ray bright point flares.

Gopalswamy, Raulin, Kundu, Kruger and Hildebrandt (Germany), and Nitta (Lockheed) have reported ring structure in sunspot-associated radio emission at 3.6 cm. Previously, ring structure was observed at 6 cm by the Maryland group. Active region 7542 was observed for three days (July 8, 11 and 13, 1993) when the sunspot was at E41, W02 and W40 longitudes so the effect of aspect angle could be studied. The viewing angle seems to play a major role in deciding the overall appearance of the sunspot at radio wavelengths. The ring structure was also seen at 6 cm and 2 cm during this observation which shows the vertical structure of the ring structure. The ring becomes incomplete at shorter wavelengths due to the distribution of aspect angles and magnetic field strengths.

Gopalswamy, Lara and Kundu have completed the analysis of Nobeyama, VLA, and Yohkoh soft X-ray data for AR 7477 in order to study the evolution of the region over several days during April 19-27, 1993. The images correspond to different heights in the corona and hence it was possible to compare thermal emission structure as a function of height. Similarities as well as striking differences were found in the morphology of the active region sources observed in different wavelength regimes.

Aschwanden, Schwartz (GSFC), and Alt (CWU) discovered a systematic time delay of order 20 ms between the 25 keV and 50 keV hard X-ray emission, using high-time resolution (64 ms) data from the COMPTON Gamma Ray Observatory (CGRO) during 640 solar flares. This small time delay is interpreted as time-of-flight difference of electrons between the coronal acceleration site in typical heights of 10,000 km and the chromosphere, where the electrons lose their energy by bremsstrahlung detectable in hard X-rays.

Aschwanden and Schwartz (GSFC) analyzed time delays in solar hard X-rays in detail and quantified the

accuracy and uncertainties of delay measurements at the Poisson limit. From a survey of 622 flares they found different regimes of time delays that could be attributed to 4 different physical processes: (1) time-of-flight differences, (2) energy loss time differences, (3) trapping time differences, and (4) convolution effects with thermal processes.

Aschwanden, Lim (CALTECH), Gary (CALTECH), and Klimchuk (NRL) performed the first stereoscopic experiments at microwave frequencies of 10-14 GHz and could map the dependence of the solar magnetic field strength and temperature as a function of altitude (between 2,500 and 11,000 km) for a gyroresonance source above a sunspot in an active region.

Aschwanden, Benz (ETHZ), Dennis (GSFC), and Schwartz (GSFC) completed a statistical survey of electron beam signatures simultaneously detected in hard X-rays and at radio wavelengths during some 500 flares observed with SMM and CGRO between 1980-1993. The analysis of these events provides information on the relative timing of upward and downward accelerated electron beams, yields evidence for bi-directional electron acceleration, and provides information on acceleration times, electron velocities, and saturation levels of (beam-driven) coherent radio emission.

Kundu and Raulin along with Hudson (Hawaii), Nitta (Lockheed) and Raoult (Meudon) completed the study of type III radio bursts associated with soft X-ray coronal jets. They have used high temporal resolution imaging observations in both wavelength regimes (soft X-rays and radio), to show for the first time an excellent temporal as well as spatial association between accelerated electron beams propagating in the corona, and dense coronal structures observed on the solar disk known as jets. This association shows that the electron beams propagate along the relatively dense paths formed by the jets. Furthermore it was possible to estimate the density observed at the location of the radio emission, which turns out to be close to the critical plasma density.

Raulin and Kundu along with Nitta (Lockheed) and Raoult (Meudon) have used simultaneous imaging observations in soft X-rays and radio wavelengths provided by Yohkoh/SXT and the Nancay Radioheliograph and found a new elongated and dense coronal structure which appeared after the impulsive phase of a small flare in AR 7773. Electron beams accelerated during the impulsive phase have used the new soft X-ray structure as a guide to propagate through the corona. As they propagate, they pass through progressively higher levels in the corona and generate type III radiation at lower and lower frequencies. At the place where the high frequency radio bursts are observed, the ambient electron density is close to the critical plasma density, that is compatible with a fundamental plasma emission mechanism.

For many years it has been known that the activity of the Sun appears in the time series of the solar flux in microwaves, and various frequencies have been used as proxies for solar activity in the visible range. Schmahl and Kundu have shown that the flux from sunspots dominates that from plage in the rotationally modulated flux, and therefore, the flux can be used to estimate the areas of sunspot and the extent of irradiance blocking by spots. They have extended the proxy relationship between irradiance and microwaves by using the daily solar fluxes from Toyokawa and Ottawa Observatories at five frequencies for the years 1980-1989. The five-frequency spectral measurements of microwave flux allow one to separate the sunspot and coronal features, providing an improved proxy of solar variability.

Working with B. Dennis (GSFC), Schmahl provided inputs to the definition phase of the High Energy Solar Imager, a satellite proposed to image solar hard X-rays and Gamma rays with 2 arc second resolution. Using simulations of the imaging process with soft X-ray images and synthetic hard X-ray/gamma ray images of solar flares, he has defined the parameter space within which it is possible to make reliable images on short time scales or in the presence of poor photon statistics.

Schmahl and S. F. Nerney and S. T. Suess (NASA/MSFC) modelled the magnetic field of the heliopause beyond the solar wind termination shock. They showed that the Archimedean spiral inside the terminal shock is rotated back in the heliosheath into nested spirals that are advected in the direction of the interstellar wind. The twenty-two year solar magnetic cycle is imprinted onto these field lines in the form of unipolar magnetic envelopes surrounded by volumes of strongly mixed polarity. Magnetic reconnection is likely to occur in these regions of opposing magnetic field, and the resulting large cross-field diffusion coefficients are likely to enhance the heliospheric access and propagation of galactic cosmic rays.

In collaboration with C. Crannell, C. J. Gaither, and the HEIDI team Schmahl made a final analysis of the laser calibration of the HEIDI telescope. Their analysis showed that an expanded laser beam, with careful attention to the effects of diffraction, can be used to make an end-to-end test of a hard X-ray imaging telescope. Methods using X-rays are expected to be much more costly in hardware and manpower. They believe that their technique can be applied to future imaging hard X-ray telescopes, such as the High Energy Solar Spectrographic Imager.

Skylab EUV observations in 1975 and 1974 showed that there were ubiquitous coronal structures absorbing in the Lyman continuum (912-400 Angstroms). Recent examination by Schmahl with D. Batchelor (NASA/GSFC) of the Yohkoh soft X-ray images of the Sun reveal a number of features which appear to be caused by absorption in the 1-40 Angstrom range. It is possible that this absorption is by singly ionized helium. Narrow band observations in this spectral range will be required to confirm this.

## H. Other

V. Trimble has completed an investigation of the productivity of large, American optical telescopes, as determined by published papers based on data collected with them and citations to those papers. The publicly owned four-meters (KPNO and CTIO) are somewhat more productive than the privately owned Lick three meter and Palomar five meter (though Lick comes top if normalized by area of glass). CFHT is a relative newcomer to the arena and remarkably productive, as is the 2.1 meter KPNO telescope.

An investigation of the original Curtis-Shapley debate, undertaken as part of the 75th anniversary restaging called "The Distance Scale of Gamma Ray Bursters" shows that each protagonist got the right answer when he relied on data collected by others or, especially, on theoretical

considerations. This is slightly ominous in the gamma ray context.

P. E. Seiden and D. G. Wentzel modeled the emergence of the magnetic fields of solar active regions in terms of percolation in the solar interior. The observed active-region size distribution, power-law at small sizes and exponential at larger sizes, is characteristic of percolation. All theoretical parameters are constrained by the size and age distributions and the magnetic complexity of active regions.

## J. Publications


Acosta-Pulido, J. A., B. Vila-Vilaró, I. Pérez-Fournon, A. S. Wilson, and Z. Tsvetanov, 1994, "Evidence and Implications of Anisotropy in Seyfert Galaxies", In "The Nature of Compact Objects in Active Galactic Nuclei", Eds. A. Robinson and R. J. Terlevich, p. 44, Cambridge University Press.

Acosta-Pulido, J. A., B. Vila-Vilaró, I. Pérez-Fournon, A. S. Wilson, and Z. Tsvetanov, 1995, "Towards an Understanding of the Seyfert 2 Galaxy NGC 5252: A Spectroscopic Study", *Astrophys. J.*, in press.

Anantharamaiah, K. R., W. C. Erickson, H. E. Payne, and N. G. Kantharia, 1994, "High Rydberg State Carbon Recombination Lines Towards Cas A: 332 MHz VLA Observations and Comparison with HI and Molecular Lines", *Astrophys. J.*, **430**, 682.

Aschwanden, M. J. and A. O. Benz, 1995, "Chromospheric Evaporation and Decimetric Radio Emission in Solar Flares", *Astrophys. J.*, **438**, 997-1012.

Aschwanden, M. J., A. O. Benz, B. R. Dennis, and R. A. Schwartz, 1995, "Solar Electron Beams Detected in Hard X-Rays and Radiowaves", *Astrophys. J.*, **455**, 347-365.

Aschwanden, M. J. and R. A. Schwartz, 1995, "Accuracy, Uncertainties, and Delay Distribution of Electron Time-of-Flight Measurements in Solar Flares", *Astrophys. J.*, **455**, 512-521.

Aschwanden, M. J., J. Lim, D. E. Gary, and J. A. Klimchuk, 1995, "Solar Rotation Stereoscopy in Microwaves", *Astrophys. J.*, **453**, in press.

Aschwanden, M. J., M. L. Montello, B. R. Dennis, and A. O. Benz, 1995, "Sequences of Correlated Hard X-Ray and Type III Bursts During Solar Flares", *Astrophys. J.*, **440**, 394-406.

Aschwanden, M. J. 1995, "Imaging, Stereoscopy, and Tomography of the Solar Corona in Soft X-Rays and Radio", (Invited Review), in "Coronal Magnetic Energy Releases", (A. O. Benz and A. Kruger, eds.), *Lecture Notes in Physics*, **444**, 13-34.

Aschwanden, M. J., R. A. Schwartz, and D. M. Alt, 1995, "Electron Time-of-Flight Differences in Solar Flares", *Astrophys. J.*, **447**, 923-935.

Aschwanden, M. J. 1995, "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 eds.), Springer-Verlag, p. 261-291, in press.

Batchelor, D.A. and E. J. Schmahl, 1994, "X-ray Absorbing Structures in the Yohkoh Images of the Corona", Proc. of the third SOHO Workshop--Solar Dynamic Phenomena and Solar Wind Observations, Estes Park, Colorado, 26-29 September 1994 (ESA SP-373 December 1994).

Blake, G. A., G. Sandell, E. F. van Dishoeck, T. D. Groesbeck, L. G. Mundy, and C. Aspin, 1995, "A Molecular Line Study of NGC 1333 IRAS4", *Ap. J.*, in press.

Bland-Hawthorn, J., K. Taylor, S. Veilleux, and P. L. Shopbell, 1994, "A Search for Diffuse H Emission from Ly Absorption Clouds Towards 3C273", *Ap. J.*, **437**, L95.

Book, D. L. 1994, "Instability of An Expanding Charged-Particle Beam", *J. Appl. Phys.*, **76**, 7682-7689.

Book, D. L. 1994, "The Sedov Self-Similar Point Blast Solutions in Nonuniform Media", *Shock Waves*, **4**, 1-10.

Book, D. L. 1995, "High-Frequency Electrostatic Modes in Non-Neutral Plasmas", *Phys. Plasmas*, **2**, 1293-1403.

Book, D. L. and D. G. Sibeck, 1995, "Plasma Transport Through the Magnetopause by Turbulent Interchange Processes", *J. Geoph. Res.*, **100**, 9567-9573.

Bower, G. A., A. S. Wilson, J. S. Mulchaey, G. K. Miley, T. M. Heckman and J. H. Krolik, 1994, "HST Images of the Seyfert Galaxies NGC 5929 and MCG8-11-11", *Astron. J.*, **107**, 1686.

Bower, G. A., A. S. Wilson, J. S. Mulchaey, G. K. Miley, T. M. Heckman and J. H. Krolik, 1994, "HST Images of the Seyfert Galaxy NGC 5929 and its Companion NGC 5930", In "Multi-Wavelength Continuum Emission of AGN", IAU Symposium Nr. 159, p. 440, Eds. T. J.-L. Courvoisier and A. Blecha (Kluwer Academic Publishers).

Bower, G. A. and A. S. Wilson, 1995, "HST Images of the Nuclear Star Forming Region in NGC 5930", *Astrophys. J. Suppl. Ser.*, **99**, 543.

Bower, G. A., A. S. Wilson, J. A. Morse, R. Gelderman, M. Whittle and J. S. Mulchaey, 1995, "Radio and Emission-Line Jets in the Type 2 Seyfert Galaxy Mkn 1066 (UGC 2456)", *Astrophys. J.*, **454**, 106.

Braatz, J. A., A. S. Wilson and C. Henkel, 1994, "The Discovery of Five New $H_2O$ Megamasers in Active Galaxies", *Astrophys. J. Letters*, **437**, L99.

Braatz, J. A., A. S. Wilson and C. Henkel, 1995, "$H_2O$ Megamasers in Active Galaxies", In "Proceedings of the Oxford Torus Workshop", Ed. M. J. Ward, p. 77.

Briley, M. M., R. A. Bell, J. E. Hesser, and G. H. Smith, 1994, "Light Element Abundance Anomalies in Globular Clusters: Probing Star Formation and Evolution in the Early Milky Way", *Can. J. Phys.*, **72**, 772.

Briley, M. M., J. E. Hesser, R. A. Bell, M. Bolte, G. H. Smith, 1994, "Anticorrelated CN and CH Variations on the 47 Tucanae Main Sequence Turnoff", *A.J.*, **108**, 2183.

Butler, R. P., R. A. Bell, and R. B. Hindsley, 1995, "The Effect of Velocity Gradients on Cepheid Spectra : Models", *Ap. J.*, in press.

Cabrera-Guerra, F., I. Pérez-Fournon, J. A. Acosta-Pulido, A. S. Wilson and Z. Tsvetanov, 1995, "Long-Slit Spectroscopy of Cygnus A at High Spatial Resolution", in Proceedings of the Greenbank Cygnus A Workshop, Eds. D. Harris and C. Carilli, (in press).

Cecil, G., C. De Pree and A. S. Wilson, 1994, "Hot Shocked Gas in the Jet of NGC 4258 (M 106)", In "The Soft X-ray Cosmos", AIP Conference Proceedings 313, p. 358, Eds. Eric M. Schlegel and R. Petre (American Institute of Physics).

Cecil, G., A. S. Wilson and C. De Pree, 1995, "Hot Shocked Gas along the Jets of NGC 4258 (M106)", *Astrophys. J.*, **440**, 181.

Cheng, F. H, S. D. Vrtilek and J. C. Ramond, 1995, "An Archival Study of the HST Observations of Her X-1/HZ HER", *Ap. J.*, in press.

Clemens, D. P., M. Berkovitch, J. L. Yun, N. A. Patel, and T. Xie, 1995, "The Dense Core, Outflow, and Jet in L810", *Ap. J.*, in press.

Colbert, E. J. M., A. S. Wilson and J. Bland-Hawthorn, 1994, "The Radio Emission from the Ultra-Luminous Far-Infrared Galaxy NGC 6240", *Astrophys. J.*, **436**, 89.

Di Francesco, J., N. J. Evans, P. M. Harvey, L. G. Mundy, and H. M. Butner, 1994, "Constraining Circumstellar Environments - Far-Infrared Observations of Herbig Ae/Be Stars", *Ap. J.*, **432**, 710.

Erickson, W. C., D. McConnell, and K. R. Anatharamaiah, 1995, "Low Frequency Carbon Recombination Lines in the Central Regions of the Galaxy", *Astrophys. J.*, in press.

Evans, I. N., A. P. Koratkar, T. Storchi-Bergmann, H. Kirkpatrick, T. M. Heckman and A. S. Wilson, 1995, "An Atlas of HII Regions in Nearby Seyfert Galaxies", *Astrophys. J. Suppl.*, in press.

Fierro, J. M., Z. Arzoumanian, M. Bailes, J. F. Bell, D. L. Bertsch, K. T. S. Brazier, J. Chiang, N. D'Amico, B. L. Dingus, J. A. Esposito, C. E. Fichtel, R. C. Hartman, S. D. Hunter, S. Johnston, G. Kanbach, V. M. Kaspi, D. A. Kniffen, Y. C. Lin, A. G. Lyne, R. N. Manchester, J. R. Mattox, H. A. Mayer-Hasselwander, P. F. Michelson, C. von Montigny, H. I. Nel, D. Nice, P. L. Nolan, E. J. Schneid, S. K. Shriver, P. Sreekumar, J. H. Taylor, D. J. Thompson, and T. D. Willis, 1995, "EGRET High-Energy Gamma-ray Pulsar Studies. II. Individual Millisecond Pulsars", *Ap. J.*, **447**, 807-812.

Goodrich, R. W., S. Veilleux, and G. J. Hill, 1994, "Infrared Spectroscopy of Seyfert 2s: A Look through the Obscuring Torus?", *Ap. J.*, **422**, 521.

Goodrich, C. C., K. Papadopoulos, M. Wiltenberger and J. G. Lyon, 1995, "The Flow of Electromagnetic Energy and Momentum During the Growth Phase of a Magnetosphere Substorm", *Geoph. Res. Letts.*, in press.

Gopalswamy, N., 1994, "A Study of Active Region Magnetic Field Structure Using Radio, X-ray and Optical Observations", in Solar Active Region Evolution: Comparing Models with Observations, (ed) K. S. Balasubramaniam and G. W. Simon, Astronomical Society of the Pacific Conference series, Vol. 68, p. 394.

Gopalswamy, N., T. E. W. Payne, E. J. Schmahl, M. R. Kundu, J. R. Lemen, K. T. Strong, R. C. Canfield and J. de La Beaujardiere, 1994, "Transient Microwave Brightenings in Solar Active Regions: Comparison Between VLA and Yohkoh Observations", *Astrophys. J.*, **437**, 552.

Gopalswamy, N., V. V. Zheleznyakov, S. M. White and M. R. Kundu, 1994, "Polarization Features of Solar Radio Emission and Possible Existence of Current Sheets in Active Regions", *Solar Phys.*, **155**, 339.

Gopalswamy, N. and M. R. Kundu, 1995, "Surprises in the Radio Signatures of CMEs", (ed) A. O. Benz and A. Kruger, Lecture Notes in Physics, Springer, Berlin, p. 223.

Gopalswamy, N. and M. R. Kundu, 1995, "Coronal Shocks, Interplanetary Shocks and Coronal Mass Ejections", in the Proc. SOLTIP Symposium, in press.

Gopalswamy, N., J.-P. Raulin, M. R. Kundu, N. Nitta, J. R. Lemen, D. Zarro, and T. Kosugi, 1995, "VLA and Yohkoh Observations of an M1.5 Flare", *Astrophys. J.*, (in press).

Gopalswamy, N., M. R. Kundu, Y. Hanaoka, S. Enome, and J. R. Lemen, 1995, "Detection of Large-Scale Structure and Plasma Flow During a Solar Bright Point Flare", *Astrophys. J. (Lett.)*, in press.

Guzdar, P. N., P. K. Chaturvedi, K. Papadopoulos, M. J. Keskinen and S. L. Ossakow, 1995, "The Self-Focusing Instability in the Presence of Density Irregularities in the Ionosphere", *J. Geophys. Res.*, in press.

Heckman, T. M., J. Krolik, G. Meurer, D. Calzetti, A. Kinney, A. Koratkar, C. Leitherer, C. Robert, and A. S. Wilson, 1995, "The Nature of the Ultraviolet Continuum in Type 2 Seyfert Nuclei", *Astrophys. J.*, **452**, 549.

Helfer, T. T. and L. Blitz, 1995, "High Resolution BIMA Observations of CO, HCN, and 13CO in NGC 1068", *Ap. J.*, **450**, 90.

Hester, J. J., J. M. Stone, et al., 1995, "WFPC-2 Studies of the Crab Nebula: III. Magnetic Rayleigh-Taylor Instabilities and the Origin of the Filaments", *Ap. J.*, in press.

Higdon, J. L., B. J. Smith, S. L. Lord, and R. J. Rand, 1995, "The Detection of Molecular Gas in the Ring Galaxy Arp 143", *Ap. J.*, **438**, L79.

Hildebrandt, J., A. Kruger, N. Gopalswamy, J.-P. Raulin, and M. R. Kundu, 1995, "VLA Observations of a Solar Active Region at 6.2 and 3.5 cm Wavelength Compared with Model Calculations", University of Barcelona Conference on "Radio Emission From the Stars and the Sun", Barcelona, Spain, 3-7 July 1995.

Hills, J. G. and P. J. T. Leonard, 1995, "Near-Earth Asteroids: The Last Days Before Earth Impact", *A. J.*, **109**, 401-417.

Hollis, J. M., D. Van Buren, S. N. Vogel, W. A. Feibelman, G. H. Jacoby, and J. A. Pedelty, 1995, "The Abell 35 Nebula Inside Out", *Ap. J.*, in press.

Huang, M., E. M. Sion, I. Hubeny, F. H. Cheng, and P. Szkody, 1995, "HST FOS Spectroscopy of VW Hyi in Superoutburst", *Ap. J.*, in press.

Hurley, K., B. L. Dingus, R. Mukherjee, P. Sreekumar, C. Kouveliotou, C. Meegan, G. J. Fishman, D. Band, L. Ford, D. Bertsch, T. Cline, C. Fichtel, R. Hartman, S. Hunter, D. J. Thompson, G. Kanbach, H. Mayer-Hasselwander, C. von Montigny, M. Sommer, Y. Lin, P. Nolan, P. Michelson, D. Kniffen, J. Mattox, E. Schneid, M. Boer, and M. Niel, 1994, "Detection of a Gamma-Ray Burst of Very Long Duration and Very High Energy", *Nature*, **372**, 652.

Huchtmeier, W. K., L. J. Sage, and C. Henkel, 1995, "Neutral Hydrogen Observations of Elliptical Galaxies II: the IRAS Sample", *A & A*, in press.

Jun, B.-I., M. L. Norman, and J. M. Stone, 1995, "A Numerical Study of Rayleigh-Taylor Instability in Magnetic Fluids", *Ap. J.*, in press.

Kassim, N. E., R. A. Perley, W. C. Erickson, and K. S. Dwarakanath, 1993, "Sub-Arcminute Resolution Imaging of Radio Sources at 74 MHz with the VLA", *Astron. J.*, **106**, 2218.

Kim, D.-C., D. B. Sanders, S. Veilleux, J. M. Mazzarella, and T. M. Soifer, 1995, "Optical Spectroscopy of Luminous Infrared Galaxies. I. Nuclear Data", *Ap. J.*, **98**, 129.

Korista, K. T., et al. 1995, "Steps Toward Determination of the Size and Structure of the Broad-Line Region in Active Galactic Nuclei. VII. An Intensive HST, IUE, and Ground-Based Study of NGC 5548", *Ap. J.*, **97**, 285.

Krucker, S., A. O. Benz, M. J. Aschwanden, and T. S. Bastian, 1995, "Location of a Type I Radio Continuum and Bursts on Yohkoh Soft X-ray Maps", *Solar Phys.*, **160**, 151-169.

Krucker, S., M. J. Aschwanden, T. S. Bastian, and A. O. Benz, 1995, "First VLA Observation of a Solar Narrowband, Millisecond Spike Event", *Astron. Astrophys.*, **302**, 551-563.

Kundu, M. R. 1995, "Radio Emission from X-ray Bright Point Flares and Jets", Proc. "Second China-Japan Workshop on Solar Physics", September 2-5, 1994, Dunhuang, China.

Kundu, M. R., N. Nitta, S. M. White, K. Shibasaki, S. Enome, T. Sakao, T. Kosugi and T. Sakurai, 1995, "Microwave and Hard X-ray Observations of Footpoint Emission from Solar Flares", *Ap. J.*, in press.

Kundu, M. R., J.-P. Raulin, M. Pick, and K. T. Strong, 1995a, "Metric Type III Bursts Associated with a Flaring X-ray Bright Point Near an Active Region", *Ap. J.*, **444**, 922.

Kundu, M. R., J.-P. Raulin, N. Nitta, H. S. Hudson, M. Shimojo, K. Shibata, A. Raoult, 1995b, "Detection of Nonthermal Radio Emission from Coronal X-ray Jets", *Ap. J. Lett.*, **447**, L135.

Kundu, M. R., J.-P. Raulin, N. Nitta, H. S. Hudson, A. Raoult, K. Shibata, and M. Shimojo, 1995, "Detection of Nonthermal Radio Emission from Coronal X-ray Jets", IAU Colloq. No. 153 on "Magnetodynamic Phenomena in the Solar Atmosphere -Prototypes of Stellar Activity", Makuhari, Japan, 22-26 May 1995.

Kundu, M. R., J.-P. Raulin, N. Nitta, H. S. Hudson, and A. Raoult, 1995, "Nonthermal Radio Emission from Coronal X-ray Jets", University of Barcelona Workshop on "Radio Emission From the Stars and the Sun", Barcelona, Spain, 3-7 July 1995.

Kundu, M. R., K. T. Strong, M. Pick, K. Harvey, S. R. Kane, S. M. White and H. S. Hudson, 1994, "Nonthermal Processes in Flaring X-ray Bright Points", *Ap. J. Lett.*, **427**, L59.

Kundu, M. R., S. M. White, N. Nitta, K. Shibasaki, S. Enome, 1995, "Characteristics of Two Simple Microwave Bursts", (ed.) A. O. Benz and A. Kruger, Lecture Notes in Physics, Springer, Berlin, p. 75.

Leonard, P.J.T. 1994, "February's Bizarre Event", *Nature*, **372**, 616-617.

Leonard, P.J.T. 1995, "Blue Stragglers in Star Clusters", in The Origins, Evolution and Destinies of Binary Stars in Clusters, edited by E. Milone and J.-C. Mermilliod, ASP Conference Proceedings, in press.

Leonard, P.J.T. 1995, "Impact Consensus Emerges", *Nature*, **375**, 358.

Leonard, P.J.T. 1995, "Merged Dynamically-Ejected Runaway Stars", *MNRAS*, in press.

Leonard, P.J.T. 1995, "Three Decades of N-Body Simulations: A Meeting in Honor of Sverre Aarseth", *Comments on Astrophysics*, **17**, 361-382.

Leonard, P.J.T. and M. Livio, 1995, "The Rotational Rates of Blue Stragglers Produced by Physical Stellar Collisions", *A. J.*, **447**, L121-L123.

Li, J. G., J.-H. Zhao, P. T. P. Ho, and L. J. Sage, 1995, "Detection of CO Emission from Dwingeloo 1", *A & A*, in press.

Lipatov, A. S. and A. S. Sharma, 1994, "Hybrid Simulation of Comet Shoemaker-Levy 9 Interaction with Jovian Bow Shock", *Geoph. Res. Letts.*, **21**, 1059-1062.

Lopez, R. E., C. C. Goodrich, G. D. Reeves, R. D. Belian and A. Taktakishvili, 1994, "Midtail Plasma Flows and the Relationship to Near-Earth Substorm Activity: A Case Study", *J. Geoph. Res.*, **99**, 23561-23569.

MacKenty, J. W., S. M. Simkin, R. E. Griffiths, J. S. Ulvestad and A. S. Wilson, 1994, "Markarian 315: A Test-Bed for the AGN-Merger Hypothesis?", *Astrophys. J.*, **435**, 71.

MacKenty, J. W., S. M. Simkin, R. E. Griffiths and A. S. Wilson, 1994, "Evidence for a Tidal Interaction in the Seyfert Galaxy Markarian 315", In "Mass-Transfer Induced Activity in Galaxies", p. 353, Ed. Isaac Shlosman (Cambridge University Press).

McMullin, J. P., L. G. Mundy, and G. A. Blake, 1994, "The Circumstellar Environment of IRAS 05338-0624", *Ap. J.*, **437**, 305.

Milikh, G. M., M. J. Freeman and L. M. Ducan, 1994, "First Estimates of HF-induced Modifications of the D Region by the HF Active Auroral Research Program Facility, *Radio Science*, **29**, 1355-1362.

Milikh, G. M., K. Papadopoulos and C. L. Chang, 1995, "On the Physics of High Altitude Lightning", *Geoph. Res. Lett.*, **22**, 85-89.

Milikh, G. M. and A. S. Sharma, 1995, "Thermal Instability in the Inner Coma of a Comet", *Geoph. Res. Lett.*, **22**, 639-642.

Morgan, J. A. 1995, "WIP - An Interactive Graphics Software Package", in: "Astronomical Data Analysis Software and Systems IV", (R. A. Shaw, H. E. Payne, and J. J. E. Hayes, eds.), PASP Conf Series 77, 129-132.

Morse, J. A., A. S. Wilson, M. Elvis and K. A. Weaver, 1995, "Extended Soft X-ray Emission in Seyfert Galaxies: ROSAT HRI Observations of NGC 3516, NGC 4151 and Markarian 3", *Astrophys. J.*, **439**, 121.

Mukherjee, R., H. D. Aller, M. F. Aller, D. L. Bertsch, W. Collmar, S. W. Digel, B. L. Dingus, J. A. Esposito, C. E. Fichtel, R. C. Hartman, S. D. Hunter, W. N. Johnson, G. Kanbach, D. A. Kniffen, Y. C. Lin, J. R. Mattox, H. A. Mayer-Hasselwander, P. F. Michelson, C. von Montigny, P. L. Nolan, P. V. Ramanamurthy, E. Schneid, P. Sreekumar, H. Terasranta, D. J. Thompson, and S. J. Wagner, 1995, "EGRET Gamma-ray Sources: GRO J0744+54 and GRO J0957+65 (= BL Lacertae Object 0954+658)", *Ap. J.*, **445**, 189-195.

Mulchaey, J. S., A. S. Wilson, G. A. Bower, T. M. Heckman, J. H. Krolik and G. K. Miley, 1994, "Hubble Space Telescope Imaging of the Seyfert 2 Galaxy NGC 2110", *Astrophys. J.*, **433**, 625.

Mulchaey, J. S., A. Koratkar, M. J. Ward, A. S. Wilson, M. Whittle, R. R. J. Antonucci, A. L. Kinney and T. Hurt, 1994, "Multiwavelength Tests of the Dusty Torus Model for Seyfert Galaxies", *Astrophys. J.*, **436**, 586.

Mulchaey, J. S. and A. S. Wilson, 1995, "An Alignment Between Optical Continuum and Emission Line Structures in the Circumnuclear Regions of Seyfert Galaxies", *Astrophys. J. Letts.*, (in press).

Mulchaey, J. S., A. S. Wilson and Z. Tsvetanov, 1995, "An Emission-Line Imaging Survey of Early-Type Seyfert Galaxies -- I. The Observations", *Astrophys. J. Supplements*, (in press).

Mundy, L. G. and J. P. McMullin, 1995, "Observations of Chemical Processing in the Circumstellar Environment", *Astro. Sp. Sci.*, **224**, 81.

Mundy, L. G., L. W. Looney, and E. A. Lada, 1995, "Constraints on Circumstellar Disk Masses in the Trapezium Cluster", *Ap. J. Letts.*, in press.

Nelson, R. W., J. C. L. Wang, E. E. Salpeter, I. Wasserman, 1994, "A Potential Cyclotron Line Signature in Low Luminosity X-Ray Pulsars", in The Evolution of X-Ray Binaries, S. S. Holt and C. S. Day (ed.), AIP (Conf. Proc. 308), New York, 592-596.

Nelson, R. W., J. C. L. Wang, E. E. Salpeter, and I. Wasserman, 1995, "A Potential Cyclotron Line Signature in Low Luminosity X-Ray Sources", *Ap. J.*, **438**, L99-L102.

Nerney, S. F., E. J. Schmahl, and S. Suess, S., 1995, "Flow Downstream of the Heliospheric Terminal Shock: Magnetic Field Line Topology and Solar Cycle Imprint", *J.G.R.*, **100**, A3, 3463.

Nerney, S. F., E. J. Schmahl, and Z. E. Musielak, 1995, "Analytical Solutions of the Vector Burgers Equation", *Quarterly J. of Appl. Math.*, in press.

Papadopoulos, K., D. Book and A. Zigler, 1995, "Collisionless Breakdown of Magnetic Insulation in Plasma", *Physical Review Letters*, in press.

Papadopoulos, K., J. G. Lyon, C. C. Goodrich, P. J. Cargill, A. S. Sharma, R. Kulkarni, C. L. Chang and A. Mankofsky, 1995, "Global and Local Geospace Modeling in ISTP", *Space Science Reviews*, **71**, 671-690.

Papadopoulos, K., A. Zigler, D. L. Book, and R. Shanny, 1995, "Magnetically Insulated Photoconducting Semiconductor Switches", *Comments Plasma Phys. Controlled Fusion*, **16**, 221--230.

Papadopoulos, K., D. L. Book, and A. Zigler, 1995, "Collisionless Breakdown of Magnetic Insulation in Plasmas", *Phys. Rev. Lett.*, in press.

Papadopoulos, K., A. Zigler, D. L. Book, C. Cohen and D. Hashimshony, 1995, "Breakdown of Magnetic Insulation in Semiconductor Plasmas", *IEEE Transactions Plasma Sci.*, in press.

Patel, N. A., P. F. Goldsmith, R. L. Snell, T. Hezel, T. Xie, 1995, "The Large Scale Structure, Kinematics and Evolution of IC 1396", *Ap. J.*, in press.

Payne, H. E., K. R. Anatharamaiah, and W. C. Erickson, 1994, "High Rydberg State Carbon Recombination Lines Towards Cas A: Physical Conditions and a New Class of Models", *Astrophys. J.*, **430**, 690.

Pécontal, E., P. Ferruit and A. S. Wilson, 1995, "Impact of Nuclear Activity on Extended Emission Line Regions of Nearby Galaxies", In "Tridimensional Optical Spectroscopic Methods in Astrophysics", IAU Colloquium Nr. 149, (in press).

Peng, Y. and S. N. Vogel, 1995, "SiO Chemistry in Sagittarius B2", *Ap. J.*, in press.

Pérez-Fournon, I., B. Vila-Vilaró, J. A. Acosta-Pulido, J. I. González-Serrano, M. Barcells, A. S. Wilson, and Z. Tsvetanov, 1994, "Spectroscopy of the Extended Emission Line Regions in NGC 4388", In "The Nature of Compact Objects in Active Galactic Nuclei", Eds. A. Robinson and R. J. Terlevich, p. 40, Cambridge University Press.

Pérez-Fournon, I., F. Cabrera-Guerra, J. Burgos-Martín, J. A. Acosta-Pulido, A. S. Wilson and Z. Tsvetanov, 1995, "Circumnuclear Emission Line Regions in Cygnus A", In Oxford Astrophysics Workshop "Evidence for the Torus", Ed. M. J. Ward, p. 47.

Phookun, B. and L. G. Mundy, 1995, "NGC 4654: A Virgo-Cluster Spiral Interacting with the Intergalactic Medium", *Ap. J.*, in press.

Plambeck, R. L., M. C. H. Wright, L. G. Mundy, and L. W. Looney, 1995, "Subarcsecond Resolution 86 GHz Continuum Maps of Orion-KL", *Ap. J. Letts.*, in press.

Ramanamurthy, P.V., D. L. Bertsch, B. L. Dingus, J. A. Esposito, J. M. Fierro, C. E. Fichtel, S. D. Hunter, G. Kanbach, D. A. Kniffen, Y. C. Lin, A. J. Lyne, J. R. Mattox, H. A. Mayer-Hasselwander, M. Merck, P. F. Michelson, C. von Montigny, R. Mukherjee, P. L. Nolan, and D. J. Thompson, 1995, "EGRET Detection of Pulsed Gamma Radiation From PSR B1951-32", *Ap. J.*, **447**, L109-112.

Rand, R. J., S. R. Kulkarni, and J. J. Hester, 1990, "The Distribution of Warm Ionized Gas in NGC 891", *Ap. J.*, **352**, L1

Rand, R. J., S. R. Kulkarni, and J. J. Hester, 1992, "Warm Ionized Gas in the Edge-on Galaxies NGC 4565 and NGC 4631", *Ap. J.*, **396**, 97.

Rand, R. J. 1995, "BIMA Observations of Molecular Spiral Structure in M100", *A.J.*, **109**, 2444.

Rand, R. J. 1996, "Diffuse Ionized Gas in Nine Edge-on Spiral Galaxies", *Ap. J.*, in press.

Raulin, J.-P., M. R. Kundu, N. Nitta, H. S. Hudson, and A. Raoult, 1995, "Metric Type III Bursts Associated with Soft X-ray Coronal Jets", *A & A*, in press.

Regan, M. W. and S. N. Vogel, 1994, "The Infrared Structure of M33", *Ap. J.*, **434**, 536.

Regan, M. W. and S. N. Vogel, 1995, "NGC6946: Molecular Spiral Arms Masquerading as a Bar?", *Ap. J.*, in press.

Regan, M. W., S. N. Vogel, and P. J. Teuben, 1995, "Dust and Molecular Gas in the Barred Spiral Galaxy NGC 1530", *Ap. J.*, **449**, 576.

Richer, H. B., G. C. Fahlman, R. A. Ibata, P. B. Stetson, R. A. Bell, M. Bolte, H. E. Bond, W. E. Harris, J. E. Hesser, G. Mandushev, C. P. Pryor, and D. A. VandenBerg, 1995, "Hubble Space Telescope Observations of White Dwarfs in the Globular Cluster M4", *Ap. J. Letts.*, **451**, L17.

Rosa, R. R., J. A. Valdivia and A. S. Sharma, 1995, "Characterization of Fragmentation in Spatio-Temporal Dynamics", *Physica D.*, in press.

Rose, W. K. 1994, "X-ray Pulsar Hydrodynamics: Collsionless Shock Waves and Steady State Infall Hydrodynamics", in "The Evolution of X-ray Binaries", eds., S. S. Holt and C. S. Day (AIP:NY).

Rose, W. K. 1995, "A Model for Radio and X-ray Emission from SS433", *MNRAS*, in press.

Rose, W. K. 1995, "Millimeter Wavelength CO Emission Lines from Carbon Stars", to appear in "The Analysis of Emission Lines".

Sage, L. J. and G. Galletta, 1994, "Counter-rotating Molecular Gas in NGC 4546", *A. J.*, **108**, 1633.

Sage, L. J. and L. M. Ziurys, 1995, "Towards Extragalactic Chemistry: $N_2H^+$ and SiO Emission from Nearby Galaxies", *Ap. J.*, **447**, 625.

Sault, R. J., P. J. Teuben, and M. C. H. Wright, 1995, "A Retrospective View of Miriad", in: "Astronomical Data Analysis Software and Systems IV", (R. A. Shaw, H. E. Payne, and J. J. E. Hayes, eds.), PASP Conf Series 77, 433-436.

Schlegel, E. M., P. E. Barrett, O. C. De Jager, G. Chanmugam, S. Hunter, and J. R. Mattox, 1995, "Gamma-Ray Emission from Cataclysmic Variables. I. The COMPTON EGRET Survey", *Ap. J.*, **439**, 322.

Schmahl, E. J. and M. R. Kundu, 1995, "Microwave Proxies For Sunspot Blocking and Total Irradiance", *J. Geophys. Res.*, in press.

Seiden, P. E. and D. G. Wentzel, 1995, "Solar Active Regions as a Percolation Phenomenon", *Astrophys. J.*, **460**, 1996.

Sharma, A. S., 1995, "Nonlinear Dynamical Studies of Global Magnetospheric Dynamics", In Nonlinear Waves and Chaos in Space Plasmas", edited by T. Hada, H. Matsumoto and B. Tsurutani.

Sharma, A. S., 1995, "Nonlinear Dynamics of the Magnetosphere", in Physics of Space Plasmas, edited by T. Chang.

Sharma, A. S., 1995, "Assessing the Magnetosphere's Nonlinear Behavior: Its Dimension is Low, Its Predictability, High", *Rev. Geoph. Suppl.*, 645-650.

Sharma, A. S. and G. M. Milikh, 1995, "Structure and Dynamics of Innter Cometary Plasmas", *JGR*, in press.

Sharma, A. S. and G. M. Milikh, 1995, "Thermal Instability and Transport Effects in Comets", *JGR*, in press.
Sharma, A. S. and K. Papadopoulos, 1995, "Alpha Particle Heating in Comet-Solar Wind Interaction Regions", *J. Geoph. Res.*, **100**, 7891-7897.

Sharma, A. S., J. A. Valdivia and K. Papadopoulos, 1995, "Low Dimensional Dynamics and Prediction of Substorms", Proceedings of the Second International Conference on Substorms, Fairbanks, Alaska.

Simpson, C. J., M. J. Ward, D. L. Clements, S. Rawlings and A. S. Wilson, 1994, "Buried Quasars in Radio Galaxies?", In "Multi-Wavelength Continuum Emission of AGN", IAU Symposium Nr. 159, p. 522, Eds. T. J.-L. Courvoisier and A. Blecha (Kluwer Academic Publishers).

Simpson, C., M. J. Ward and A. S. Wilson, 1995, "Evidence for an Obscured Quasar in the Giant Radio Galaxy PKS 0634--205", *Astrophys. J.*, **454**, 683.

Simpson, C., J. S. Mulchaey, A. S. Wilson, M. J. Ward and A. Alonso-Herrero, 1995, "An Ionization Cone and Dusty Disk in Mkn 348: The Obscuring Torus Revealed?", *Astrophys. J. Letts.*, in press.

Sion, E. M., F. H. Cheng, K. S. Long, P. Szkody, R. Gilliland, M. Huang, and I. Hubeny, 1995, "HST/FOS Spectroscopy of the Ultra-Short Period Dwarf Nova WZ Sagittae: The Underlying Degenerate", *Ap. J.*, **439**, 957-962.

Sion, E. M., M. Huang, P. Szkody, and F. H. Cheng, 1995, "HST High Resolution Spectroscopy of the Exposed White Dwarf in the Dwarf Nova VW Hyi in Quiescence: A Rapidly Rotating White Dwarf", *Ap. J.*, **445**, L31-L34.

Sion, E. M., P. Szkody, F. H. Cheng, and M. Huang, 1995, "A HST Study of the Underline White Dwarf in the Dwarf Nova VW Hyi Dring Quiescence", *Ap. J.*, **444**, L97-L100.

Smith, D. M., M. Leventhal, R. Cavallo, N. Gehrels, J. Tueller, and G. Fishman, 1996, "Limits on Reported Transient Emission Events Near 0.5 MeV from the Crab and 1E 1740.7-2942", *Ap. J.*, in press.

Spaans, M., M. R. Hogerheijde, L. G. Mundy, and E. F. van Dishoeck, 1995, "Photon Heating of Envelopes around Young Stellar Objects: An Explanation for CO J=6-5 Emission", *Ap. J. Letts.*, in press.

Stone, J. M., J. Xu, and L. G. Mundy, 1995, "The Formation of Bullets in Stellar Mass Outflows via Hydrodynamical Processes", *Nature*, in press.

Stone, J. M., 1995, "The formation of Bullets in Stellar Mass Outflows", *Nature*, in press.

Stone, J. M. and R. J. Rand, 1996, "Modeling the HI Supershell in the Edge-on Galaxy NGC 4631 as an Impact of a HVC", *A.J.*, in press.

Stone, R. G., R. J. MacDowall, J. Fainberg, S. Hoang, M. L. Kaiser, P. J. Kellog, N. Lin, V. A. Osherovich, J. L. Bougeret, P. Canu, N. Cornilleau-Wehrlin, M. D. Desch, K. Goertz, M. L. Goldstein, C. C. Harvey, D. Lengyel-Frey, R. Manning, M. J. Reiner, J. L. Steinberg, G. Thejappa, 1995, "Ulysses Radio and Plasma wave Observations at High Southern Heliographic Latitudes", *Science*, **268**, 1026.

Storchi-Bergmann, T., A. S. Wilson and J. A. Baldwin, 1994, "Star Formation and Nuclear Activity in Three Galaxies with Nuclear Rings", In "Multi-Wavelength Continuum Emission of AGN", IAU Symposium Nr. 159, p. 460, Eds. T. J.-L. Courvoisier and A. Blecha (Kluwer Academic Publishers).

Storchi-Bergmann, T., J. S. Mulchaey, and A. S. Wilson, 1994, "Are there Dusty Tori in Seyfert 2 Galaxies?", In "The Nature of Compact Objects in Active Galactic Nuclei", Eds. A. Robinson and R. J. Terlevich, p. 31, Cambridge University Press.

Storchi-Bergmann, T., M. Eracleous, M. Livio, A. S. Wilson, A. V. Filippenko and J. P. Halpern, 1995, "The Variability of the Double-Peaked Balmer Lines in the Active Nucleus of NGC 1097", *Astrophys. J.*, **443**, 617.

Storchi-Bergmann, T., A. S. Wilson and J. A. Baldwin, 1995, "Nuclear Rings in Active Galaxies", *Astrophys. J.*, (in press).

Taktakishvilli, A., R. E. Lopez and C. C. Goodrich, 1995, "Energization of Ions in Near-Earth Current Sheet Disruptions", *Geoph. Res. Letts.*, **22**, 627-630.

Teuben, P. J. 1995, "The Stellar Dynamics Toolbox NEMO", in: "Astronomical Data Analysis Software and Systems IV", (R. A. Shaw, H. E. Payne, and J. J. E. Hayes, eds.), PASP Conf Series 77, 398-401.

Thejappa, G., D. G. Wentzel, and R. G. Stone, 1995, "Low-frequency Waves Associated with Langmuir Waves in Solar Wind", *J. Geophys. Res.*, **100**, 3417-3426.

Thejappa, G., D. Lengyel-Frey, R. G. Stone and M. L. Goldstein, 1995, "Evaluation of Solar Type III Burst Theories Using Ulysses URAP Observations", in Theoretical Geoplasma Physics, edited by T. Chang, MIT Press (in press).

Thornley, M. D. and C. D. Wilson, 1995, "Molecular Gas in the Inner 3.2 Kiloparsecs of NGC 2403: Star Formation at Subcritical Gas Surface Densities", *Ap. J.*, **447**, 616.

Trimble, V. 1994, "Conference Summary: Interacting Binaries, Past, Present, and Future", in F. D'Antona & V. Caloi eds. Mem. Soc. Astron. Ital., **65**, 393-402.

Trimble, V. 1995, "The World Line of Dark Matter: Its Existence and Nature Through Time", in D. B. Cline Ed. Critique of the Sources of Dark Matter in the Universe, Singapore: World Scientific, 9-19.

Trimble, V. 1995, "Conference Summary: Looking Inward", in G. W. Henry & J. A. Eaton eds. Robotic Telescopes, ASO Conf. Series No. 79, 1-7.

Trimble, V. and S. Parker, 1995, "Meet the Milky Way", *Sky and Telescope*, **89**. No. 1, 26-33.

Trimble, V. 1995, "Summary Remarks: Hitting Bottom", in C. Tinney Ed. The Bottom of the Main Sequence and Beyond, Springer-Verlag, ESO Astrophysics Symposium, 297-308.

Trimble, V. and P. J. T. Leonard, 1995, "Astrophysics in 1994", Publications of the Astronomical Society of the Pacific, **107**, 1-21.

Trimble, V. 1995, "Looking Backward, Darkly", in S. S. Holt et al. eds., Dark Matter, AIP Conf. Series No. 336, 57-68.

Trimble, V. 1995, "Papers and Citations Resulting from Data Collected at Large, American Optical Telescopes", *Pub. Astron. Soc. Pac.*, 107, in press.

Trimble, V. 1995, "Astrophysics in 1994", *BeamLine 24*, No. 3, 40-46.

Trimble, V. 1995, "JD5: Activity in the Central Parts of Galaxies", Comments on Astrophysics, **18**, 1-10.

Trimble, V. 1995, "COBE and How We Know the Universe Went Through a Hot, Dense Phase", *BeamLine 25*, No. 2, 25-33.

Tripicco, M. J. and R. A. Bell, 1995, "Modelling the Lick/IDS Spectral Feature Indices Using Synthetic Spectra", *A.J.*, in press.

Tripicco, M. J., R. A. Bell, B. Dorman, B. Hufnagel, 1995, "Derived Parameters for NGC 6791 from High-Metallicity Isochrones", *A.J.*, **109**, 1697.

Tsvetanov, Z. I., J. A. Morse, A. S. Wilson and G. Cecil, 1996, "Complex Gaseous Structure in the Nucleus of NGC 5252", *Astrophys. J.*, (in press).

Valdivia, J. A., A. S. Sharma and K. Papadopoulos, 1995, "Prediction of Magnetic Storms by Nonlinear Dynamical Models", *Geoph. Res. Letts.*, in press.

Veilleux, S., G. Cecil, J. Bland-Hawthorn, R. B. Tully, A. V. Filippenko, and W. L. W. Sargent, 1994, "The Nuclear Superbubble of NGC 3079", *Ap. J.*, **433**, 48.

Veilleux, S., G. Cecil, and J. Bland-Hawthorn, 1995, "The Interstellar Disk-Halo Connection in the Spiral Galaxy NGC~3079", *Ap. J.*, **445**, 152.

Veilleux, S., D.-C. Kim, D. B. Sanders, J. M. Mazzarella, and B. T. Soifer, 1995, "Optical Spectroscopy of Luminous Infrared Galaxies. II. Analysis of the Nuclear and Long-Slit Data", *Ap. J.*, **98**, 171.

Vogel, S. N., R. Weymann, M. Rauch, and T. Hamilton, 1995, "New Upper Limits on the Local Metagalactic Ionizing Radiation Density", *Ap. J.*, **441**, 162.

von Montigny, C., D. L. Bertsch, J. Chiang, B. L. Dingus, J. A. Esposito, C. E. Fichtel, J. M. Fierro, R. C. Hartman, S. D. Hunter, G. Kanbach, G., D. A. Kniffen, Y. C. Lin, J. R. Mattox, H. A. Mayer-Hasselwander, P. F. Michelson, P. L. Nolan, H.-D. Radecke, E. Schneid, P. Sreekumar, D. J. Thompson, and T. Willis, 1995, "High-Energy Gamma-Ray Emission From Active Galaxies: EGRET Observations and Their Implications", *Ap. J.*, **440**, 525-553.

Vourlidas, A., T. S. Bastian, N. Nitta, and M. J. Aschwanden, 1995, "Joint Radio and Soft X-Ray Imaging of an "Anemone" Active Region", *Solar Physics*, in press.

Wang, J. C. L., 1994, "Conference Report: Highlights of the Second Huntsville Gamma Ray Burst Workshop", *Comm. on Astrophys.*, **17**, 313-324.

Wang, J. C. L. and R. W. Nelson, 1994, "A Possible Cyclotron Line Signature from Quiescent Gamma-Ray Burst Counterparts", in Gamma-Ray Bursts: Second Workshop, G. J. Fishman, J. J. Brainerd, and K. Hurley (ed.), AIP (Conf. Proc. 307), New York, 615-619.

Weaver, K. A., R. F. Mushotzky, P. J. Serlemitsos, A. S. Wilson, M. Elvis and U. Briel, 1995, "The Origin of the Soft X-ray Excess in the Seyfert 2 Galaxy NGC 2110", *Astrophys. J.*, **442**, 597.

Welch, W. J. and 37 others, 1995, "The Berkeley-Illinois-Maryland-Association Millimeter Array", Pub. Astron. Soc. Pac., in press.

Wells, L. A., et al. 1994, "The Type Ia Supernova 1989B in NGC 3627 (M66)", *A.J.*, **108**, 2233.

White, S. M., M. R. Kundu, T. Shimizu, K. Shibasaki, and S. Enome, 1995, "The Radio Properties of Solar Active Region Soft X-ray Transient Brightenings", *Ap. J.*, **450**, 435.

Wilson, A. S., G. A. Bower, T. M. Heckman, J. S. Mulchaey, J. A. Braatz, J. H. Krolik, and G. K. Miley, 1994, "HST Observations of the Seyfert 2 Galaxy NGC 5728", In "The First Stromlo Symposium: The Physics of Active Galaxies", Eds. G. V. Bicknell, M. A. Dopita and P. J. Quinn, p. 275, Astronomical Society of the Pacific Conference Series vol. 54.

Wilson, A. S. 1994, "Extended X-ray Emission in Seyfert Galaxies", In "The Soft X-ray Cosmos", AIP Conference Proceedings 313, p. 115, Eds. Eric M. Schlegel and R. Petre (American Institute of Physics).

Wilson, A. S. and Z. I. Tsvetanov, 1994, "Ionization Cones and Radio Ejecta in Active Galaxies", *Astron. J.*, **107**, 1227.

Wilson, A. S., J. A. Braatz and C. Henkel, 1995, "The $H_2O$ Megamaser in the Galaxy NGC 2639 -- Evidence for an Accretion Disk in a LINER Nucleus", *Astrophys J. Letts.*, in press.

Wilson, A. S. and E. J. M. Colbert, 1995, "The Difference between Radio-Loud and Radio-Quiet Active Galaxies", *Astrophys. J.*, **438**, 62.

Wilson, A. S., 1995, "Ionization Cones", in Proceedings of the Oxford Torus Workshop, (ed.) M. J. Ward, p. 55.

Wright, M. C. H., R. L. Plambeck, L. G. Mundy, and L. W. Looney, 1995, "SiO Emission from a 1000 AU Disk in Orion-KL", *Ap. J. Letts.*, in press.

Xie, T., M. Allen, and W. D. Langer, 1995, "Turbulent Diffusion and Its Effects on the Chemistry of Molecular Clouds", *Ap. J.*, **440**, 674.

Xie, T. 1995, "The C/CO Ration Problem: Chemical Effects of Turbulence", IAU Proceedings, CO Symposium, in press.

Xie, T., P. F. Goldsmith, J. Bally, W. Langer, and R. W. Wilson, 1995, "The GMC Mon R2: A Large Expanding Wok Shell", in press.