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 1993 through 30 September 1994.

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, D. G. Wentzel, and A. S. Wilson; Emeritus Professors W. C. Erickson and F. J. Kerr; Adjunct Professors M. Hauser and S. Holt; Associate Professors T. A. Matthews, L. G. Mundy and S. Vogel; Visiting Associate Professors L. McFadden and S. Vrtilek; Assistant Professor J. Stone; Associate Research Scientists C. C. Goodrich, N. Gopalswamy, R. Lopez, E. Schmahl, S. Sharma and S. White; Assistant Research Scientists K. Arnaud, M. Aschwanden, A. Grossman, S. Kim, M. Schaefer and M. Tripicco; Research Associates P. Chaturverdi, D. Chornay, O. Colombo, K. Fast, E. Grayzeck, R. Kulkarni, F. Lemoine, D. Lengyel-Frey, D. McNabb, G. Milikh, J. Morgan, E. Pavlis, R. Rand, A. Raugh, J. Raulin, I. Richardson, R. Schulz, D. Smith, P. Teuben and D. Wellnitz; Hubble Fellow E. Lada; Instructors G. Deming and D. Theison; and Associate Director J. D. Trasco.

J. Wang was appointed as Assistant Professor, F. Cheng, P. Leonard, T. Livengood, D. Smith, M. Stark and T. Xie began appointments as Research Associates. J. Mattox and L. Sage (Assistant Editor of the Journal Nature) joined the department as Visiting Research Associates. R. Meier is visiting Maryland with support from a Swiss National Science Foundation Fellowship. T. Golla was promoted to Assistant Research Scientist. K. Borkowski, J. Howe, Y. Kim, J. Klavetter, A. Lipatov, R. Schultz and A. Taktakichvili completed short term appointments and left the department.

M. F. A'Hearn, L. Blitz and L. Mundy are on sabbatical. A. Wilson returned to the University after spending two years at the Space Telescope Science Institute. V. Trimble was appointed to the National Academy of Sciences National Committee on Science Education Standards and Assessment; and elected President of Commission 28 of the Internationl Astronomical Union (galaxies); and past Chair of the High Energy Astrophysics Division of the American Astronomical Society. D. Wentzel organized the IAU International Schools for Young Astronomers meetings in India (Jan. 1994) and Egypt (Sept./Oct. 1994). S. Vrtilek was selected by the Council of the AAS to act as the AAS representative to the AAAS for the term Feb. 1995 to Feb. 1998. M. A'Hearn served as Chair of the Division for Planetary Sciences of the American Astronomical Society (Nov. 1993 - Oct. 1994).

A Ph.D. degree was awarded to K. A. Weaver. M.S. degrees were awarded to S. Fantasia and S. Foster.

III. MEETINGS

The series of Washington Area Astronomers meetings initiated in September 1981 has continued. The Spring 1994 meeting was held at the Applied Physics Laboratory of Johns Hopkins University and the Fall 1994 meeting was held at the U.S. Naval Observatory. Typical attendance has been 100 persons per meeting.

The Maryland-Goddard Astrophysics series which started in Fall 1990 has continued. The most recent meeting "Dark Matter" was held at the University of Maryland in October 1994. Total attendance was approximately 250 persons.

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, six postdoctoral fellows, several graduate students and two scientific staff members. The faculty are L. Blitz (Director), W. Erickson (Professor Emeritus), M. Kundu, L. Mundy, and S. Vogel. The postdoctoral fellows are A. Grossman, J. Howe, E. Lada (Hubble Fellow), R. Rand, S. White and T. Xie. Xie joined the LMA in August, and Howe is leaving in November to take a postdoctoral position at FCRAO. The scientific staff includes J. Morgan and P. Teuben. Graduate students using the array for thesis work are T. Helfer, B. Gruendl, Y. Peng, M. Regan, M. Thornley and J. Williams. J. McMullin and M. Pound successfully defended their theses this past summer; McMullin has taken a postdoctoral position with the Submillimeter Telescope in Arizona. Pound has started a postdoc at Berkeley.

The scientific work done with the BIMA array is outlined in the relevant sections of this report in the section on Research Activities. The LMA is currently working with the Laboratory for Astronomical Imaging at the University of Illinois on the MIRIAD software package for the reduction and analysis of radio interferometric data. This package allows calibration and data reduction to be done simply and easily with a transparent user interface, and also allows mosaicking, maximum entropy and CLEANing to be done with a minimum of effort. Morgan, Mundy, and Teuben continued the joint BIMA development of the MIRIAD data reduction package. The Maryland group focusses on antenna-based calibration routines for use with the newly expanded Hat Creek 6-element array (as well as its expansion ultimately to 11 elements); holography techniques to aid in setting panels on the new antennas; rapid time integration routines for solar flares and eclipse; a new user interface for observing; 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.

In addition, BIMA has begun the development of a local World Wide Web (WWW) server to provide world wide access to information related to the BIMA project, observing at the Hat Creek telescope, the MIRIAD software package, and the University of Maryland Department of Astronomy.

Finally, BIMA has also continued its involvement with the AIPS++ software development, for which Teuben spent a small fraction of his time at NRAO in Charlottesville.

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. Installation of the system is targeted for the winter of 1995, when we expect to install two long baseline stations which will ultimately provide an angular resolution of 0.2 arcsec at a frequency of 230 GHz. Additional funding has been secured that will make it possible to have baselines of 1 km in the east-west direction as well.

Maryland is designated as the East Coast observing site for the array. Thirty percent of the observing time on the array is available to outside users, and users who come to Maryland have full use of the observatory and data reduction and analysis facilities. Observing can be done remotely from Maryland with real time access to the calibration data and other system and ambient parameters. Data are transfered automatically to Maryland at the end of each observing day.

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

The recent development of unified theories of active galactic nuclei (AGN) has indicated that there are two physically distinct classes of these objects - radio-loud and radio-quiet. A. Wilson and E.J.M. Colbert have developed a new model for the difference between these two classes. It is assumed that galaxies (e.g. spirals) which have not suffered a recent major merger event contain non-rotating or only slowly rotating black holes. When two such galaxies merge, the two black holes are known to form a binary and Wilson and Colbert assume that they eventually coalesce. In the small fraction of mergers in which the two "parent" galaxies contain very massive holes of roughly equal mass, a rapidly spinning, very massive hole results. It is proposed that such mergers are the progenitors of powerful radio sources, in which the radio jets are owered by the spin energy of the merged hole. The authors calculate the distributions of mass and spin for the merged holes from the optical luminosity function of radio-quiet AGN adopting different activity patterns. The ratio of the number of radio-loud to radio-quiet AGN's at a given thermal (e.g. optical) luminosity is determined by the galaxy merger rate. The required fraction of galaxies which merge during the average lifetime (108 yrs) of a radio-loud AGN is found to be 10^{-1}, i.e. a merger rate of 1 in 10^9 yrs. The Blandford-Znajek formalism is then used to predict the radio luminosity and radio luminosity function of the merged population. The model accounts naturally for the following observations: (1) No spiral galaxies host radio-loud AGN, (2) Powerful radio galaxies and quasars are the products of a recent merger, (3) Only a tiny fraction of galaxy mergers produce a radio galaxy (despite the belief that SMBH's are common in galactic nuclei), and (4) Radio-loud AGN are rarer than radio-quiet AGN.

A program of imaging emission-lines and continuum in Seyfert galaxies with the Hubble Space Telescope has continued. In collaboration with J. Mulchaey, G. Bower (STScI), T. Heckman, J. Krolik (JHU) and G. Miley (Leiden), Wilson completed a study of NGC 2110. The dominant line emission is associated with a strongly curved, narrow 1 (230 pc) long feature emanating from the nucleus to the north. The morphology suggests outflowing gas, perhaps as a "jet". While this optical emission-line feature and the jet-like radio emission extend along a similar p.a., their detailed brightness distributions are loosely anticorrelated. A continuum color map derived from the HST observations shows evidence for an unresolved (23 pc) region of very strong reddening at the location of the optical and radio nucleus. The location and size of the reddened region are consistent with obscuration by a dusty torus, but the observed reddening provides only a lower limit (A 4.6 mags) on the amount of obscuration to the nucleus. Nevertheless, this obscuration is sufficient to account for the "energy deficit" previously reported in this object.

Colbert, Wilson and J. Bland-Hawthorn (AAO) have obtained new radio observations of the "prototypical" ultra-luminous far-infrared galaxy NGC 6240 with the VLA. These data, along with those from four previous VLA observations, are used to perform a comprehensive study of the radio emission from NGC 6240. Approximately 70% (3 x 10^{23} W Hz^{-1}) of the total radio power at 20 cm originates from the nuclear region (1.5 kpc), of which half is emitted by two unresolved (R 36 pc) cores and half by a diffuse component. The radio spectrum of the nuclear emission is relatively flat (0.6; S^{-}). The supernova rate required to power the diffuse component is consistent with that predicted by the stellar evolution models of Rieke et al. (1985). If the radio emission from the two compact cores is powered by supernova remnants, then either the remnants overlap and form hot bubbles in the cores, or they are very young (100 yr). Nearly all of the other 30% of the total radio power comes from an "arm-like" region extending westward from the nuclear region. The western arm emission has a steep spectrum (1.0), suggestive of aging effects from synchrotron or inverse-Compton losses, and is not correlated with starlight; we suggest that it is synchrotron emission from a shell of material driven by a galactic superwind.

A program of imaging Seyfert nuclei with the ROSAT X-ray observatory High Resolution Imager has continued. K. Weaver (Penn State), R. Mushotzky, P. J. Serlemitsos (GSFC), Wilson, M. Elvis (SAO) and U. Briel (MPI) have combined their image of NGC 2110 with an X-ray spectrum obtained with the Broad band X-ray Telescope (BBXRT). The image shows an extension some 8 (1.2 kpc) to the north of the nucleus; the extension coincides with the most highly excited optical emission-line gas in the narrow line region. The BBXRT spectrum requires three components for an acceptable fit -- (i) a power law of photon index = 1.41 ± 0.15 photoelectrically absorbed by cold gas of column density N_H (2.4 ± 0.3) x 10^{22} cm^{-2}, (ii) an Fe K emission feature at 6.32 ± 0.08 keV, and (iii) a soft component detected between 0.6 and 1.2 keV. The flux of the soft excess is in excellent agreement with that of the extended emission seen by ROSAT and it is argued that the soft excess originates from the extended gas. A model is proposed in which our line of sight to the nucleus of NGC 2110 is blocked by a geometrically thick torus, which contributes the large X-ray column. The soft excess, on the other hand, originates from the kpc scale, and suffers attenuation by only the Galactic column density. The soft excess, the high excitation optical emission lines, and the radio jets are all powered by the nuclear source, the output of which is channeled along the axis of the torus.

Extended soft X-ray emission has been mapped in NGC 4151 by J. A. Morse (STScI), Wilson, Elvis and Weaver. The X-rays may be traced as far as 1.5 kpc SW and 0.5 kpc NE of the nucleus and coincide with the emission-line "string" seen in optical observations. The extended emission accounts for at least 31% of the total 0.1 - 2 keV ROSAT HRI flux and constitutes roughly half of the total soft X-ray emission observed with other X-ray detectors. The extended X-rays probably represent thermal emission from a hot (T 10^7K) outflowing wind which is in rough pressure equilibrium with the optical narrow line-emitting clouds observed over the same spatial scale.

J. Braatz, Wilson and C. Henkel (MPIfR) have discovered H_2O megamasers with (isotropic) luminosities between 47 and 135 L (H_0 = 75 km s^{-1} Mpc^{-1}) in five Seyfert and LINER galaxies, thus doubling the number of known H_2O megamasers. The galaxies have redshifts between 1500 and 4800 km s^{-1} and are the most distant H_2O sources reported to date. NGC 1052 is also the first elliptical galaxy known to contain an H_2O maser. The lack of CO emission in NGC 1052 implies a conservative lower limit to the H_2O brightness temperature of 1000 K, thus ruling out a thermal origin for the H_2O emission. The success of this survey relative to other recent searches makes it evident that H_2O megamasers are preferentially found in active galaxies.

R. Gruendl and S. Vogel have imaged the "grand design" spiral galaxy M 51 at K -band. Current work investigates the underlying connection between spiral structure and large scale massive star formation processes. The near infrared images show the distribution of the old stellar population in the disk and hence the bulk of the mass distribution. These images also show that significant amounts of K-band emission is produced by other sources that are associated with massive star formation. There is a high degree of correlation between small scale structure in the near infrared images and the H II regions in the arms of M 51. These images have also been combined with optical B and I-band images and show that the dust lanes have a high degree of correlation with the molecular gas seen in interferometric observations of the spiral arms.

R. Rand has begun several projects with the BIMA array. He has mapped two fields in the Virgo grand-design spiral NGC 4321, in which a nuclear concentration and molecular spiral structure have been found. The goal of this project is to understand how the properties of molecular gas vary from spiral to spiral, in terms of, for example, the growth of large molecular complexes, and the triggering of star formation by density waves. BIMA studies of molecular gas in Blue Compact Dwarf galaxies and NGC 5195, the companion in the M51 system, have been started with L. Sage.

With W. Wall (GSFC), M. Kaufman (Ohio State) and F. Bash (Texas), an interferometric study of ^{13}CO in M51 using the Owens Valley Millimeter Interferometer has been started by Rand. 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 of the rarer species has been successfully detected in this project, and maps will soon be made.

J. Higdon, B. Smith, S. Lord and Rand are continuing their search for CO emission from ring galaxies. These are generally starbursting galaxies which result from the passage of a compact companion galaxy through the disk of a spiral galaxy along its rotation axis. We have successfully detected the ring galaxy Arp 143 at the NRAO 12-m, and have a tentative detection of Arp 10. Interferometric observations of these galaxies are planned.

Rand is continuing his studies of ionized gas in edge-on galaxies. A successful run at the Kitt Peak 2.1m resulted in sensitive images of H emission in NGC 4302 and NGC 5023. Neither shows much evidence for diffuse, extraplanar emission, supporting the trend that the level of this emission is correlated with the star formation activity in the disk below.

Rand (1994) completed his study of HI in the NGC 4631 group of galaxies. The edge-on galaxy NGC 4631 shows spectacular tidal debris due to interactions, a vertically extended HI layer, and two highly energetic supershells in its disk. Several dwarfs were also discovered in the system through their HI emission.

L. Sage has recently completed the first phase of a systematic study of star formation and the interstellar medium in nearby spiral galaxies, reporting CO 1 0 data for a distance-limited sample. Follow-up observations at 2 1 transition will commence shortly. This project is a coordinated, comprehensive investigation of the gaseous interstellar medium in galaxies. It is not biased by either optical or infrared selection effects (except, of course, near the plane of the galaxy); it examines the relationship between interstellar gas and current star formation.

N_2H^+ and SiO emission were detected by Sage and Ziurys from a sample of nearby galaxies, including the Seyfert 2 system NGC 1068. N_2H^+ is a tracer of cool, dense gas which is not currently associated with massive star formation. SiO traces the hot, dense gas. This work is the first attempt to determine the relative fractions of cool and warm dense gas near the centers of galaxies, and the relationship between star formation rates (and efficiencies) and the gas content.

Sage, G. Galletta, L. Sparke and P. Sackett 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 and Galletta have detected counter-rotating CO (wrt the stars) in NGC 4546. 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.

M. Thornley is continuing her thesis work on star formation in flocculent galaxies, under the supervision of L. Mundy and in collaboration with C. Wilson (McMaster). Near infrared broadband images have been completed of four nearby flocculent spirals. These images will be used to look for underlying spiral structure in the sample galaxies in order to place limits on the strength of spiral density waves, which are not expected to be active in these weakly structured galaxies. Single-dish and BIMA interferometer maps of molecular emission have been completed for NGC 5055, and are being combined to determine the range of molecular cloud sizes present in this galaxy. In another sample galaxy, NGC 2403, Thornley and Wilson (1994) have completed a comparison of the distribution of star formation in the inner disk with the distribution predicted by Kennicutt (1989), in his formulation of a star formation law dependent on gas surface density. Thornley and Wilson find that the fully sampled map of CO emission, which confirms the low molecular gas surface density throughout the inner disk, shows no subregions of kiloparsec size which have densities high enough for star formation to occur, despite the vigorous star formation occurring in this region.

T. Helfer and L. Blitz have continued their study of emission from molecules in external galaxies and the large scale properties of molecular clouds as a function of their location in a galaxy. They have imaged the 3 mm HCN and CO emission from the nearby Seyfert 2 galaxy NGC 1068 by combining observations made with the BIMA interferometer with data from the NRAO 12 m telescope. These are the first mm interferometric maps of NGC 1068 that do not suffer from the lack of small spatial frequency visibilities, and several features appear which have not previously been observed: (1) The CO map shows a molecular bar along roughly the same position angle as the infrared stellar bar. The molecular gas kinematics is clearly affected by the presence of this bar; also, the molecular bar shows substructure similar to the dust lanes commonly observed in barred spiral galaxies. (2) Although the bulk of the CO emission comes from the spiral arms of the galaxy, there is also fairly strong CO emission from the nucleus of this galaxy that has thus far been missed by interferometers. In contrast to the CO emission, the HCN is strongly concentrated near the nucleus of NGC 1068 rather than in the spiral arms. (3) The ratio of HCN to CO emission is higher in the nucleus of NGC 1068 than in any other galaxy; since HCN traces gas densities some 100 times higher than that required to excite CO, this may be indicative of the very high central pressure near the nucleus.

Helfer and Blitz have also surveyed the HCN emission from 7 nearby and relatively normal spiral galaxies with the BIMA interferometer; they detected unresolved emission in three of the sample galaxies (M83, NGC 3628 and NGC 4826). They plan also to image CO from these galaxies with BIMA this year. Since the HCN emission is concentrated near the centers of these galaxies, it may be that the giant molecular clouds in the bulge environments of galaxies are pressure bound rather than gravitationally bound, as is common for local GMCs.

S. Vogel, R. Weymann (Carnegie), M. Rauch (Carnegie), and T. Hamilton (Caltech) used the Maryland-Caltech Fabry-Perot on the Palomar 60 inch telescope to set tight upper limits on the local cosmic ionizing radiation density. They searched for diffuse H-alpha emission toward the Giovanelli-Haynes cloud HI 1225+01, an intergalactic cloud which is optimum for measuring the metagalactic ionizing flux since it is nearly opaque to ionizing photons, is not shielded from the cosmic flux, and limits on embedded or nearby ionizing sources are unusually low. They set a 2-sigma upper limit on the local metagalactic photoionization rate of 2×10^{-13} /sec; this is the firmest available upper limit on this rate. It is a factor of ten above lower limits inferred from observations of quasars, and consistent with the truncation of HI disks of galaxies by cosmic ionizing photons. They also observed the extended H-alpha cloud reported along the line of sight toward 3C273 by Williams and Schommer, and found the initial detection to be spurious.

M. Regan and Vogel have undertaken observations of the barred spiral galaxy NGC 1530 to investigate the gas and dust in the dust lanes and in the inner ring. These observations include CO imaged with the BIMA interferometer, near infrared J, H and K band observations and observations with the Maryland-Caltech Imaging Fabry-Perot Interferometer. The near infrared observations reveal a nuclear dust ring at the location of the inner Lindblad resonance. The dust extinction follows the CO emission to a high degree. Several other galaxies have also been observed as part of a program to investigate the dust lanes in barred spiral galaxies.

M. Regan and R. Gruendl presented a paper on a new technique to make mosaics at the ADASS IV conference in Baltimore. This technique leads to much better matching of the background level of the individual frames in a mosaic.

B. Galactic Astronomy

M. Leventhal, in collaboration with W. Chen and N. Gehrels (NASA-GSFC), has considered a variety of issues concerning the mysterious Galactic Center source 1E 1740.7-2942. They concluded that the source is at most only partially embedded in a molecular cloud, that the associated radio jets are likely to be composed largely of electron/positron pairs and that it is probably a binary black hole system with a stellar mass black hole and a low mass companion accreting mainly from the ISM.

D. Smith, Leventhal, and graduate student R. Cavallo, collaborating with Gehrels, J. Tueller (NASA-GSFC), E. Chipman (USRA), and G. Fishman (NASA-MSFC) have been developing a new technique to analyze data from the Burst and Transient Source Experiment (BATSE) on the Compton Gamma-Ray Observatory (CGRO). This technique, unlike other approaches to BATSE data, is optimzed for the detection of gamma-ray lines from sources which emit on long timescales rather than in short bursts. Using this new package, Cavallo has searched the Galactic plane for recent, hidden supernovae by searching for gamma-ray emission at 847 keV and 1238 keV from Co-56; the conclusion was that there has been no such event since CGRO was launched in 1991. Smith has been using the same package to search for transient flares of positron-annihilation radiation near 511 keV. Such flares, lasting about a day, have been reported from two Galactic black-hole candidates (1E 1740.7-2942 and the x-ray transient Nova Muscae 1991) by the SIGMA imaging gamma-ray telescope on the GRANAT spacecraft.

Smith and Leventhal, with researchers at NASA-GSFC, the Naval Research Laboratory, and Northwestern University, have also searched for a gamma-ray emission feature at 170 keV from the neighborhood of the Galactic Center using data from another CGRO instrument, the Oriented Scintillation Spectrometer Experiment (OSSE). This line has been observed twice by balloon experiments with fields of view of approximately 18 degrees, so its source is unknown; the energy is suggestive of a 511 keV positron-annihilation photon which has been Compton scattered by 180 degrees. In 186 days of observation, covering about half of the field of view of the balloon instruments, this feature never appeared in the OSSE data. It is already known that the feature appears only on occasion; the joint analysis of OSSE and balloon data placed restrictions on its position of origin and duty cycle of activity.

R. Rand and A. Lyne completed their study of the magnetic field in the Milky Way, based on new Faraday Rotation Measures of distant pulsars in the inner Galaxy. Evidence for two reversals of the magnetic field direction in the inner Galaxy are now strong, and it is also found that the strength of the uniform component of the magnetic field decreases with galactocentric radius.

M. Pound and L. Blitz (1994) report the results of a millimetric and sub-millimetric search for the progenitors of brown dwarfs, proto--brown dwarfs, in nearby star-forming molecular clouds. They find three proto--brown dwarf candidates in the Ophiuchus B region. This number is far fewer than expected from extrapolations of various low-mass stellar initial mass functions proposed in the literature. Pound and Blitz conclude that that the initial mass function (IMF) in Ophiuchus is likely to be falling below 0.1 solar masses and that the brown dwarf population in Ophiuchus is probably quite small. If the IMF in the Galactic disk is similar to that in Ophiuchus, then future searches for disk brown dwarfs will find very few.

W. Reach (NASA/Goddard), Pound, D. Wilner (CfA), and Y. Lee (Korean Astronomy Observatory) (1994) have used a multi-transition study of carbon monosulfide (CS) emission in several high-latitude molecular clouds to assess the star-forming potential in these small, nearby molecular clouds. The molecular clouds MBM 7, 12, 30, 32, 40, 41, and 55 were surveyed for tracers of dense gas, including the (1--0), (2--1), and (3--2) rotational lines of CS and the (1--0) lines of HCO+ and HCN. MBM 7 and MBM 12 contain dense cores, while the other clouds contain little or no traces of dense gas. The volume density in these small cores (0.03 pc in radius) is substantially larger than in the portions of the cloud traced by CO emission. The density increases into the cores as the inverse square of radius, suggesting dynamical collapse. The masses of the cores are close to the virial mass, suggesting they are dynamically bound. The cores in MBM 7 and MBM 12 are thus likely to form stars, and represent the nearest sites of star formation. Millimeter-wave interferometric study of these dense, self-gravitating cores is currently underway.

J. Howe continued his research on conditions in star-forming Galactic molecular clouds. With E. DeGeus (Caltech) he mapped the molecular outflow from W3 IRS5 at 2 arcsec resolution using the 6-element BIMA mm array in the J = 1-0 transition of CO, ^{13}CO, and C^{18}O. They find that the blue-lobe emission is more compact than the red-lobe emission, and that the red lobe is clumped into 2 main complexes. D. Jaffe (Texas), S. Zhou (Illinois), and Howe, with N. Geis, F. Herrmann, S. Madden, A. Poglitsch, P. van der Werf (Max-Planck, Garching), and G. Stacey (Cornell) completed an investigation of the [C II] 158 micron emission from photodissociation regions (PDRs) in the L1630 cloud, including NGC 2024 and the Horsehead Nebula. They find that the [C II] emission is consistent with the flux expected from current PDR models, but that the geometry of the region is important in determining the extent of the emission. The [C

II] and molecular line distributions are comparable in extent but show differences in detail. Howe, Jaffe, and Zhou mapped the [O I] 146 micron emission in the W3 Main and M17 SW clouds , as well as [O I] 63 micron emission in M17 SW and NGC 2024, to compare with maps of [C II] and CO emission. The [O I] emission is confined to regions with the highest molecular column density and arises only from PDRs on high-density clumps of molecular gas, but the [C II] can extend to regions almost entirely photo-dissociated. In the cores of the clouds, the distribution of [O I] 63 micron emission can be quite different than either the [O I] 146 micron or [C II] 158 micron emission, indicating possible foreground absorption of the 63 micron line. Howe, E. Lada, L. Mundy, and R. Plume (Texas) observed 492 GHz [C I] and J = 2-1 $C^{18}O$ emission from the ionization front NGC 1977 to determine the origin of the neutral carbon emission. They find that the spectral profiles of the [C I] emission are quite similar to the $C^{18}O$ profiles and that $C^{18}O$ velocity components are always associated with a corresponding [C I] component. They interpret this as evidence that the [C I] emission comes from the surfaces of clumps traced by the $C^{18}O$ emission, and not from the more tenuous interclump medium. C. Wilson (McMaster U.) and Howe recently mapped the 492 GHz [C I] line in selected regions of the M17 molecular cloud to compare the C and CO abundances throughout the cloud. They will use their previous large-scale maps of the J = 2-1 and 3-2 transitions of CO in M17 to determine the CO abundances.

Y. Peng, Vogel and J. Carlstrom have detected the ^{29}SiO J = 2 1 transition and the $HC^{15}N$ J = 1 0 transition in absorption towards the middle and northern HII region complexes in Sgr B2 with the BIMA array at a resolution of 8.0 x 4.7 . The velocity and line width of the ^{29}SiO absorption line are similar to NH_3 (8,8) and (9,9) absorption lines observed with the Bonn 100 m telescope. This and the low excitation temperature of the ^{29}SiO absorption line imply that the absorption arises in the same extended hot (175 K), low density (10^4 cm^{-3}) envelope as the NH_3. The SiO to HCN abundance ratio in this low-excitation gas averages 0.07, much larger than in dark clouds and close to the ratio in the Orion-KL outflow. A conservative lower limit on the fractional SiO abundance is $[SiO]/[H_2] > 4 \times 10^{-10}$. The line width of ^{29}SiO is narrower than $HC^{15}N$ and other species, which suggests that the observed SiO enhancement is not due to the destruction of dust grains by high-velocity shocks such as produced by molecular outflows, unlike the enhancement mechanism which appears to operate in other sources. They have also observed the J = 2 1 transition of the main SiO isotope and detected emission to the north of Sgr B2(N). This emission is not associated with known heating sources.

C. Stellar Astronomy

M. J. Tripicco and R. A. Bell continue to pursue various aspects of modelling the properties of old stellar populations via calculations of theoretical evolutionary tracks and synthetic spectra. In collaboration with B. Dorman (U. Virginia) and B. Hufnagel (UCSC/NRAO), isochrones and horizontal branch sequences computed at high metallicity have been applied to published BVI photometry for stars in the rich open cluster NGC 6791. The excellent fit indicates that NGC 6791 is the oldest known open cluster in the Galaxy, with an age of 10 Gyr. The metallicity of the cluster is approximately twice solar and the foreground reddening has been determined to be E(B-V)=0.21 mag. The helium-burning clump giants are found to have masses which are indistinguishable from those in globular clusters and in the solar abundance open cluster M67, despite the tremendous variation in the metallicity and masses of the red-giant predecessors among these objects. This provides important constraints on mass-loss mechanisms and on horizontal-branch morphology.

Tripicco and Bell are also using synthetic stellar spectra to model the behavior of the so-called Lick spectral indices, which are becoming widely used in work on stellar populations in galaxies and globular clusters. These indices measure the strengths of various atomic and molecular absorption features and have been used to draw conclusions about the star-formation history and chemical evolution of elliptical galaxies. Modelling these indices using synthetic spectra allows one to achieve a far greater understanding of the observations by simulating effects arising from the presence of stars with exotic abundance ratios and/or significant amounts of internal mixing.

Bell, G. Paltoglou and M. J. Tripicco have carried out detailed comparisons of observed and calculated solar spectra, showing that the list of atomic line data by Kurucz (1991) contains many lines which are not seen in the solar spectrum. In general, these are high excitation FeI lines. They have published detailed comparisons of observed and computed high resolution solar spectra. They have also shown that the line list of Kurucz & Peytremann (1975), when supplemented with molecular lines, yields colors for stellar models which are very similar to results published earlier by Bell & Gustafsson. This result contradicts a recent paper by Buser and Kurucz. Paltoglou and Bell have also used stellar models to discuss the properties of the Washington photometric system. They have compared the synthetic colors with disc dwarfs and with disc giants and have also made comparisons with globular cluster stars. The calculations show that the colors (C-M) and (M-T1) are sensitive to variations in [N/Fe] and [C/Fe] if the latter are anticorrelated. If they are correlated, the colors are strongly affected for solar abundance stars. The model colors for the gravity indicator (M-51) match the observed sequences very well. The gravity dependence of this index arises from the presence of MgII lines in the band passes.

With M. Briley (U. Wisc. at Oshkosh), J. Hesser (DAO) and M. Bolte and G. Smith (Lick), Bell has continued working on the problem of the bimodality of CN band strength among the stars near the turnoff in 47 Tucanae. New observations of 20 stars have been obtained. The analysis of these observations, based upon the improved line lists resulting from the work of Bell, Paltoglou and Tripicco, shows that 12 stars are CN strong and 8 CN weak. This ratio is comparable to that seen in the more luminous 47 Tuc stars. A general anticorrelation between CH and CN band strength is seen in the dwarfs and is also known to occur in the giants.

Briley, Bell, Hesser and Smith have prepared a review of the general problem of C, N and O abundances in globular cluster stars. Since molecular lines play a major role in the derivation of these abundances, this review will be published in the issue of the Canadian Journal of Physics celebrating the 90th birthday of G. Herzberg.

S. Vrtilek and her collaborators observed a substantial, unexpected drop in flux at X-ray energies with no change in absorbing column density during a 5-satellite multiwavelength campaign on Her X-1/HZ Her in August 1993. The pulse period was seen to increase by 7 μs from the previous measurement, contrary to the usual spin-up. The X-ray pulse profile was normal in the high state but no pulsed emission was observed above 0.9 keV in the low state. The change in torque on the neutron star implied by the switch from spinup to spindown may act to shift the disk into the line of sight. Such a disk shift is consistent with the lack of strong Fe K edge and small EW in the anomalous low state which imply an inclination angle of 70 , or a shift of 10 from the "normal" inclination.

Vrtilek, F. Cheng, and J. Raymond (CfA) are working on a model that incorporates contributions from the X-ray heated companion star, the unheated disk, and the X-ray heated disk as a function of binary phase in an attempt to explain the Her X-1 UV lightcurve and line fluxes during X-ray normal and low periods. The 28 IUE/SWP spectra obtained during the campaign have been augmented with 60 archival IUE spectra as well as two high resolution spectra obtained with the HST. During the X-ray low state the optical and UV fluxes continued to show 1.7 day modulation attributed to X-ray heating of the companion star. However, the UV flux around eclipse was significantly reduced from the expected value implying an absence of the normally observed excess attributed to X-ray heating of the disk. The NV 1240, CIV 1549, and HeII 1640 show strong correlation with the continuum flux but NV shows a much greater variation over orbital period than either CIV or HeII.

Vrtilek with collaborators R. McCray, B. Boroson (JILA), T. Kallman (GSFC), and F. Nagase (ISAS) observed Her X-1 a year later (Aug 1994) simultaneously with HST, ASCA, and ground-based optical telescopes. The observations were successful with dramatic changes seen in the NV line profile by the GHRS on HST. By observing brightness and phase correlations among the X-ray continuum, Fe-K lines, and UV line profiles, these observations should enable the measurement the light-travel times and angles from the neutron star to the fluorescing gas.

Vrtilek and graduate student C. Xu looked at ASCA observations of the low mass X-ray binary 4U1254-69. During the 17 hour duration of the observation no evidence was seen for periodic (3.9 hr) intensity dips reported by Courvoisier (1986). The observed flux (8×10^{-10} ergs/cm^2/s) is consistent with that observed by Griffith et al. (1978) and Courvoisier (1986) suggesting a constant intensity over 16 years. Most importantly, lines at 6.3 keV (equivalent width 80 eV), 1.1 keV (equivalent width 10 eV), and 0.65 keV (equivalent width 35 eV) attributable to Fe K-shell, L-shell, and O VIIII emission have been observed. This observation is one among several of LMXBs for which Vrtilek and collaborators T. Kallman (GSFC) and J. Raymond (CfA) have received ASCA observing time. The goal is to test their models of X-ray line emission from X-ray illuminated accretion disk coronae (ADC). The unique ability of ASCA to observe Fe K-shell and L-shell features simultaneously} is particularly beneficial to this effort. Ratios of the K-shell and L-shell intensities are sensitive to the distribution of ionization states and to the optical depths in the emission lines. Observations of these and other soft X-ray lines provide the first physical tests of ADC models and set constraints distinctly different from those derived from X-ray light curves. Vrtilek with collaborators R. Kelley, C. Stahle (GSFC), G. Clark (MIT), and F. Nagase (ISAS) observed the 13.5s pulsar LMCX-4 with ASCA. The pulses were detected with a pulsed fraction of 10% in the 0.6 - 10 keV energy band. A search for pulse phase dependent Doppler shift variations of the Fe K-shell features and the inversion of the pulse profiles, so far detected only during flares, in the binary X-ray pulsar LMC X-4 is underway in the non-flare state data obtained. Such effects, seen only in LMC X-4, have important implications for the physics of accretion, since the pulse-phase dependence of the Fe emission implies that we are looking deep into the magnetosphere where the accretion energy is released.

During the last year W. K. Rose has performed ^{13}CO non-LTE line profile calculations of luminous carbon stars that are undergoing rapid mass loss and discussed why such stars have low [^{13}C/^{12}C] abundance ratios.

In previously reported research Rose has described accretion disk models associated with X-ray binaries such as Cygnus X-1 and SS 433. Super-Eddington Accretion onto a stellar mass black hole is the most plausible model for the latter object. During the last year Rose has developed a model for the radio and X-ray spectra of SS 433. This model includes a discussion of physical mechanisms for electron acceleration in the bipolar jets of SS 433 and also an explanation for the origin of magnetic fields in radio emitting regions.

V. Trimble, R. Cavallo, K. Arnaud, with Z. Musielak (Alabama) and others are continuing their search for X-rays from coronae of cool, single, magnetic white dwarfs. The last 20,000 sec of ROSAT data on GD 256 are in hand and will probably yield only upper limits.

Trimble and G. Herbig (Hawaii) are continuing their HIPPARCOS project "prototypes of astrophysically interesting classes of stars".

S. White, J. Lim and M. Kundu showed that radio emission from dMe stars can be used to pose constraints on the magnetic structure of the coronae of M dwarf flare stars when combined with optical observations of photospheric magnetic fields and with X-ray data. White and E. Franciosini discussed the circular polarization of the radio emission of RS CVn binary systems, and showed using observational data that the low-frequency polarization previously attributed to the quiescent emission of these systems is probably produced by a coherent emission mechanism such as plasma emission. This interpretation removes a major difficulty in modelling the quiescent radio emission of these systems. J. Lim, White et al. discussed models for the observed directivity of the radio emission of the nearby active K dwarf star AB Doradus, while Lim and White report the first detection of radio emission from a star in the Pleiades open cluster.

White, Duncan et al. published the first high-resolution radio map of the intriguing star Eta Carinae, believed to be one of the most massive stars in the galaxy. This initial map was used to estimate the mass-loss rate, an important parameter for understanding the properties of this system. A subsequent radio outburst of Eta Carinae is analyzed by Duncan, White et al.

D. Interstellar Medium and Star Formation

T. Xie, in collaboration with B. Langer (JPL) and M. Allen (Caltech), investigated the effects of turbulence on the chemical composition of dense molecular clouds with a time-dependent chemistry code. They found that turbulent diffusion significantly modifies the chemistry in the dense interiors, increasing the abundances for C, C^+ and most other carbon-bearing species and decreasing the abundances for some other species such as H_2O and O_2.

With P. Goldsmith (Cornell), Xie continued a project on the nearby giant molecular cloud Mon R2 with extensive high-resolution maps in CO, isotops and density tracers. They found that the large scale structure of the GMC is dominated by an expanding hemispherical shell (a wok 30 pc). They suggest that there are mainly two generations of star formation in this GMC, with the older generation being responsible for the wok and the formation of the younger generation in the compressed wok shell (yeah, triggered star formation!). With Goldsmith and N. Patel (FCRAO, now CfA), Xie discovered a well-shaped bipolar outflow shell which enabled a detailed comparison with theoretical models, the radial wind "snow-plow" model of Shu et al. (1991) in particular. They found that the simple model reproduces the shell remarkably well, indicating that the model contains some essential elements of the outflow phenomenon. The current model seems to be too simplified in interpreting the mass distribution of the shell as a function of velocity. The team has also studied the structure and kinematics of the bright-rimmed globules in the Rosette region. T. Jarrett (IPAC), G. Novak (Northwestern), Xie and Goldsmith completed an R-band CCD polarimetry study of the Mon R2 region with NRAO 36 telescope, which shows clear evidence for the modification of the ambient field being modified by the wok structure in Mon R2. In collaboration with T. Jarrett and C. Beichman (IPAC), Xie obtained near infrared images of some nebulae in Mon R2 with the Polomar 200" telescope for understanding the origin of the wok and star formation. With B. Langer (JPL) and R. Wilson (Bell Lab), Xie mapped the CS J = 1- 0 emission from Mon R2 for studying the relationship of dense clumps and triggered star formation in this region. With Langer and Goldsmith, Xie has also obtained CS data with OVRO millimeter array for the UC HII region in the Mon R2 core for understanding the bipolar outflow and the gas kinematics in this site of compact cluster of YSOs. Z. Wang (CfA) and Xie searched for shocked molecular gas in supernovae remnants Kepler, G2.4 and G355.9 with CSO 10m telescope at Hawaii. All these data are being analyzed now.

J. Stone's research efforts are primarily concerned with hydrodynamic and magnetohydrodynamic (MHD) studies of the ISM and star formation. In collaboration with J. Hawley (U. Virginia), Stone has been studying the nonlinear stage of a powerful local shear instability in weakly magnetized accretion disks. The study is focusing on three dimensional, local studies of isothermal, stratified disks. In the nonlinear stage, the instability results in MHD turbulence with a power spectrum similar to Kolmogorov. Interestingly, simulations have demonstrated that on long timescales, the amplitude of the magentic energy density in the saturated state is independent of the initial field strength or topology, suggestive of dynamo action in the disk.

In collaboration with M. Edelman (Courant Institute), Stone has studied the nonlinear evolution of the corrugation instability in slow MHD shocks. Perturbations in the shape or velocity of planar slow shocks results in large amplitude "fingers" if the magnetic field is parallel to the shock normal, and large amplitude propagating waves if the magnetic field is oblique. This instability may play a role in the variability in accreting white dwarfs, where the accretion shock is expected to be a slow MHD shock.

Stone and graduate student J. Xu have begun a study of the Kelvin-Helmholtz instability in non-adiabatic protostellar jet beams. The goal is to investigate the effect of cooling on the nonlinear stage of the instability, and to study the rate of entrainment of ambient gas and decollimation of the jet beam.

Stone and graduate student G. Piner have completed an investigation of the gas dynamics in barred galaxies. Nonaxisymmetric bars drive accretion into the center of the galaxy. If the potential of the bar becomes axisymmetric at small radii, gas collects into a dense circumstellar ring. Highly nonaxisymmetric bars can drive high accretion rates into the central regions of the galaxy, which may serve as one mechanism for fueling AGN.

M. Hollis (GSFC), D. Van Buren (IPAC), and Vogel have used the Maryland-Caltech Fabry-Perot to observe [NII] and [OIII] emission from the unique planetary nebula, Abell 35. The observations show that the bow shock seen in [OIII] is only slightly greater than Mach 1. The bow shock is apparently produced as the planetary nebula moves through the ambient medium at a speed of 100 km/sec; some of the gas stripped from the clumps in the nebula interacts with a stellar wind from the central object, producing the bow shock.

E. de Geus (Caltech) and Vogel are using the Maryland-Caltech Fabry-Perot in a search for HII regions associated with HI and CO clouds in the outer Galaxy.

Peng and Vogel have observed HCO^+ (1-0), (2_2 - 1_1), $H^{13}CN$ (1-0), $H^{13}CO^+$ (1-0), SiO (2-1), ^{13}CO (1-0) and $C^{18}O$ (1-0) with the BIMA arrays toward W33A. They have reduced part of the data and obtained the following results: (1) Continuum emission has been detected. Remarkably, it is relatively extended. Comparison with the stringent centimeter wave limits, which show only a very weak unresolved HII region, shows that the mm emission must be due to dust which is extended over 0.4 pc; (2) SO emission is not detected at a 3 limit of 0.5 K; the SO/$H^{13}CN$ ratio is significantly smaller than that in outflow sources, such as Orion-KL and Sgr B2. This seems to agree with previous observations which suggest that no compact outflow exists in W33A; (3) Broad SiO, normally considered the premier outflow tracer, is not at all consistent with it being a young outflow such as Orion IRc2. Unlike $H^{13}CN$ emission which show a compact molecular core, the SiO emission is extended. The spectra at several posions may suggest that the collision between two clouds at 32 km/s and 42 km/s has caused the star-formation at 37 km/s.

E. Solar System

M. Schaefer developed a time-dependent geochemical cycle model of the early Martian hydrosphere. It assumed a very simple system, consisting of an unweathered starting material (Ca- and Mg-bearing silicates), a carbon dioxide atmosphere, an ocean of water in contact with both the atmosphere and the unweathering starting material, and both calcite and dolomite precipitates. Several interesting points arose from this model. If other factors do not act to change the system too drastically, a 1-bar carbon dioxide atmosphere can be removed by carbonate precipitation alone in about half a billion years. This is roughly fifty times longer than earlier estimates, which were not based on time-varying models. This longer atmospheric lifetime may be enough to explain the large number of channels seen on older Martian terrain. In the past year work has begun on modifying and extending this model to represent more realistically an early Martian ocean. Several additional reservoirs are being added, including iron oxides and sulfides; iron carbonate; and calcium, magnesium, and iron sulfates. Iron- and sulfur-bearing species in solution are also included.

G. Milikh and S. Sharma have proposed a thermal instability as the mechanism for the ion pileup observed at a distance of about 10^4 km from the nucleus of P/Halley. They show that the cooling of the electrons has a strong peak at a temperature of about 4000 K due to collisional excitation of transitions in water molecules. This leads to an instability for temperatures greater than 4000 K and the rapid cooling in turn leads to a decrease in the abundance of electrons and ions by recombination at distances between 5,000 and 10,000 km, where this temperature occurs. S. J. Kim, M. A'Hearn, and C. Arpigny (U. de Liege) completed calculations of the fluorescence of CH showing that the observed structure of emission bands requires that the CH be formed in excited rotational states which do not have time to relax to equilibrium before the CH itself is destroyed. This constrains the formation mechanism and may help identify the parent molecule for CH. They also showed that the g-factor or fluorescence efficiency is relatively insensitive to the heliocentirc velocity, in strong contrast to other simple diatoms such as OH and CN, despite the fact that the sun exhibits absorption lines of CH.

P. Esterle and M. A'Hearn completed an analysis of stereoscopic imaging of comet P/Halley from Giotto and Earth and determined instantaneous projected angular speeds of the widely observed jets. They showed that, although the projected angular speeds are reasonably high, the data are still best fit by the slowly rotating Long Axis Mode (LAM) models favored by Belton, et al., and by Samarasinha and A'Hearn. Their numerical simulations showed that the projected angular speeds from both fast and slow models cover the same range, even though the true rotational velocities of the nucleus are quite dissimilar in the two models.

After check-out observations at the Goddard Optical Research Facility 36-inch (91-cm) Telescope in January 1994, D. Wellnitz took the University of Maryland CCD Imaging and Spectroscopic System for Comets (CISCo) to Perth, Western Australia, to continue the program of regularly observing Comet Encke. Unfortunately, Encke's show this year was not very spectacular: Encke faded very quickly after perihelion, and only a few nights of good images were obtained. Luckily, there were a great variety of other comets which could be observed to good advantage from the southern hemisphere, and continuing good observing weather permitted useful observations of comets McNaught-Russell (1993v), Kushida (1994a), Mueller (1993p), Shoemaker-Levy 9 (1993e), and Takamizawa (1994i). The participants included Wellnitz, R. Schulz and U. Keller (Max Planck Institute for Aeronomie), D. Schleicher (Lowell Observatory), and staff members of the Perth Observatory: P. Birch, R. Martin, C. Bowers, A. Verveer, T. Smith and A. Williams (UWA).

R. Meier has focussed on a detailed analysis of sulfur in UV spectra of comets. Measured column densities and line ratios of the sulfur $^3S^0$ ^3P transitions indicate that even in a moderately dense cometary coma the SI triplet at 1814 is impaired by opacity effects. A Monte Carlo model has been developed that determines line intensities of these sulfur transitions in an optical deep coma. Unlike the well-established radiation transfer models of cometary H our Monte Carlo model has to account for the non-negligible radial outflow velocity of sulfur. We assume locally thermalized sulfur, i.e. we consider the random velocity component to be isotropic, 3-dimensional and Maxwellian-distributed. This is an appropriate approximation of the inner coma where both attenuation of solar or scattered photons and multiple scattering become important. A real 3-dimensional frequency redistribution function is used to describe the details of the scattering process. Collisional excitation (neutrals and/or electrons) and excitation by trapped photons have been studied. Recent Hubble Space Telescope measurements recorded by the Faint Object Spectrograph as well as the extended UV-database on comets of the International Ultraviolet Explorer are currently investigated and compared with model results.

Comet Shoemaker-Levy 9

The discovery of Comet Shoemaker-Levy 9 (1993e) in March of 1993, followed soon by the prediction that it would impact Jupiter in July 1994, offered a unique opportunity to observe the first predicted impact of one solar system body into another. L. McFadden and M. A'Hearn organized a two-day meeting in January 1994, attended by more than 250 people interested in participating in the observing campaign, who learned more about the extremely broad theoretical range of possibly observable phenomena, and pursued opportunities to optimize and coordinate observing programs.

M. A'Hearn, L. McFadden, P. Esterle, L. Woodney and C. Lisse (Hughes STX/GSFC) carried out an extensive program of ground-based imaging of comet SL9 in both the optical and the infrared during the first half of 1994. The optical observations were made with 1.2-meter Burrell Schmidt telescopes at Cerro Tololo and Kitt Peak in UBVRI colors, while the infrared observations were made with NSFCam at the NASA InfraRed Telescope Facility in J and K. There are suggestions of color differences among the nuclei and with distance from the nucleus (on a scale of 5 arcseconds) but the data do not show any evidence for temporal variability. The data are being fit with dynamical models including solar and Jovian radiation pressure and gravity forces, and with scattering models for various materials in order to constrain the size distribution, composition and evolutionary history of the grains in the comet. Additional observations of SL9 fragments were made with the IRTF during impact week, but these have not yet been reduced.

In continuing collaborative work with the Space Telescope Science Institute, the Hubble Space Telescope was used to monitor the near-nuclear regions of comet SL9 prior to the impacts and to observe one fragment as it transited the

Jovian magnetosphere. The monitoring observations, from July 1993 to June 1994, show relatively little change in the comet, other than the stretching due to Keplerian lag, over the entire period. The data are all consistent with the larger fragments containing solid bodies with diameters of 2 to 4 km, but the evidence for such solid bodies is not obvious in these data. When fragment G was near 50 Jovian radii, a position near the boundary of the magnetosphere and somewhat more than three days before impact, it exhibited a transient strong emission line due to Mg+ and, 20 minutes later, exhibited a large increase in the brightness and reddening of the continuum which lasted no more than 20 minutes. These effects may be due to charging and explosive destruction of cometary grains.

The University of Maryland CCD Imaging and Spectroscopic System for Comets (CISCo) was used on the Lowell 24-inch (91-cm) Telescope at the Perth Observatory in Western Australia, as part of the Comet Imaging Network Experiment (CINE), for observations of the interactions of SL9 and Jupiter. The most successful of the planned observations were images of Jupiter in a variety of filters, the high-image-rate observations of the satellites and limb of Jupiter and the plumes rising from the impact sites, and the low-resolving-power spectrographic observations of Jupiter's clouds and new spots. The participants included D. Wellnitz, M. A'Hearn, L. Woodney and R. Meier as well as extensive local help from Perth: R. Martin, A. Verveer, T. Smith and J. Biggs of the Perth Observatory, A. Williams of UWA, and local students: M. Bullo, S. Gibbon and K. Minko. Early results from this work will be presented at the Division of Planetary Sciences (DPS) meeting in October 1994.

Due to the low probability of clear skies at Perth Observatory during impact week, a three-person expedition was sent to Mount Singleton, in outback Western Australia, where the probability of clear skies was much higher. L. Woodney, R. Meier and T. Smith (of Perth Observatory) used a high-speed photometer on a portable 14-inch Celestron telescope to look for flashes reflected from Io or Europa during the expected impact times of five fragments of comet SL9, including that of fragment K, which occurred while Europa was in eclipse, offering the best chance of detecting a flash. The observations yielded possible detections of the bolide flash from the impacts of fragments D and E; additional data analysis will be required to interpret the observations of the other impacts. Support in planning and technical assistance for this project were provided by D. Wellnitz, M. A'Hearn and A. Verveer (of Perth Observatory). Early results of this work will also be presented at the DPS meeting in October.

From images taken at Perth, M. A'Hearn and R. Knacke (Penn State-Erie) estimated the mass of the clouds produced on Jupiter by the impacts of SL9, using observed estimates of the optical depth and various constraints on the size of the cloud particles. They estimate 10^{14} grams in the cloud produced by fragment G. Most of the assumptions make this a lower limit,
so uncertainties in the assumptions would move the mass of condensed material upwards.

A. Grossman, A. Kundu and S. M. White participated in the radio observations of the impact of SL9 into Jupiter using a wide variety of telescopes around the world. They found that Jupiter showed no measurable effects at centimeter wavelengths, which sample Jupiter's atmosphere at a pressure of a few bars. They found significant effects in the long-wave radiation from the magnetosphere, including an increase in the flux and a change in the positions of peak emission.

F. Space Plasma Physics

The Space Plasma Physics (SPP) group emphasizes interdisciplinary research and transition to technology in areas involving important collective phenomena. Such areas involve modeling of magnetosphere and the ionospheres of the Earth and other planets, comets, lightning, solar radio bursts and space weather prediction. On the other extreme research interests involve interactions of femtosecond lasers with semiconductor plasmas with emphasis on femtosecond technology. SPP is currently developing the research initiatives of the HF Active Aurora Research Program (HAARP), the $100M new HF facility under construction in Alaska. D. Papadopoulos is the faculty member directing the SPP group. Others of the group are D. Book, P. Chaturvedi, C. Goodrich, R. Lopez, G. Milikh, A. Sharma and P. Sprangle. C. Chang (SAIC) and J. Lyons (Dartmouth) are under contract to the SPP group. Graduate students involved in the SPP research are J. Valdivia, H.B. Zhou and M. Wiltberger.

G. Solar Radio Physics

N. Gopalswamy, T. Payne, E. Schmahl, M. Kundu, J. Lemen (LPARL), K. Strong (LPARL), R. Canfield (U. Huwaii) and J. de La Beaujardiere (U. Huwaii) have discovered weak transient microwave brightenings in solar active regions in association with soft X-ray brightenings observed by the Soft X-Ray Telescope aboard the Yohkoh satellite. These brightenings correspond to an energy release smaller than in subflares. Analysis of the energy release mechanisms shows that the brightenings seem to be due to nonthermal gyrosybchrotron emission from 100 keV electrons, spiralling in a magnetic field of about 1200 G. Assuming that all the energy released in the transient goes into nonthermal particles, we estimate about 10^{25} ergs released in each transient. Thus, these transients seem to qualify for Parker's nanoflares and hence may be a potential candidate for coronal heating. Preliminary estimates show that the occurrence rate of the transients is large enough to compensate for the losses in the coronal loop

Gopalswamy, Kundu and J. P. Raulin have completed the analysis of the M1.5 flare of 1993 April 22 from AR 7477. There was an intense noise storm located above the flaring active region at 90 cm with no relation to the flare that occurred underneath. The flare was also fully observed by all the instruments on board the Yohkoh satellite. The Soft X-ray Telescope (SXT) and Hard X-ray Telescope (HXT) observed the flare in its entirety and hence enhances the scientific output from this flare. Both SXT and HXT data show two footpoints and they are coincident. There are some sublte differences in one of the footpoints and we shall investigate their implications to flare energy release. The initial soft X-ray emission comes from the footpoints of a loop which spreads and finally confines to the loop-top. The 20 cm radio emission also starts near a footpoint and moves towards the loop top, although not cospatial with the soft X-ray emission. The difference could be attributed to the fact that the X-ray and radio instruments are sensitive to plasmas of different temperatures. We shall investigate the 20 cm source motion which may be related to chromospheric evaporation. The availability of data at multiple wavelengths enables us to develop a consistent picture of the flare and derive the physical quantities of the hot plasma.

Gopalswamy, S. White, Kundu, Schmahl, Lemen, Strong (LPARL), and J. Schmelz (Rhodes College) have undertaken a study of the solar active regions using simultaneous VLA and Yohkoh Soft X-ray Imaging. Images of solar active regions were obtained by the Very Large Array and the Yohkoh satellite during the Coronal Structure Observing Campaign (CoMStOC '92) in 1992. The VLA was pointed at AR 7128 on April 11, 1992 and the observations were made at 20, 6, 3.6 and 2 cm wavelengths. The Soft X-ray Telescope (SXT) aboard Yohkoh satellite obtained full frame images of the Sun and partial frame images of the target active region. Since the VLA field of view covers the whole solar disk at 20 cm, they were able to compare the full frame SXT images with the radio image to understand the morphology of all the active regions visible on the disk at the two wavelengths. For the target active region, they used the partial frame SXT images and the 6, 3.6 and 2 cm VLA images. They determined the physical parameters of the active regions using the combined data set.

Gopalswamy and colleagues observed very slowly moving prominence using the Nobeyama radioheliograph. The snap shot images taken every one hour showed that the source detached itself and the separation between the lower edge of the prominence source and the limb increased with time at a rate of about 3.8 km/s. The centroid also showed a similar speed (3.2 km/s). The source area started declining along with the brightness temperature right from the beginning. In the last image, the source appears to split into two pieces. The event was also fully observed by the Yohkoh's soft X-rays. A peculiar loop-shaped eruption was seen by the SXT from the same region. Initially the two transients coincided in position and subsequently, the X-ray feature moved to larger heights. The event occurred at the boundary of the north-polar coronal hole. It is possible that a polar crown filament had erupted. The SXT will give the temperature and emission measure of the X-ray transient and allow them to determine the expected thermal bremsstrahlung to compare with the observed radio emission.

Gopalswamy and Kundu reviewed the current status of coronal shocks, interplanetary shocks and coronal mass ejections. They found that mere temporal association between radio bursts and CMEs does not reveal the physics of these transient phenomena and that only imaging observations can clarify the physical connection between CMEs, flares and shock waves. From exisiting observations, they argued that the CME-driven shocks originate at large heights in the solar corona which are inaccessible to the existing radio instruments; absence of type II bursts during many fast CMEs may be due to this reason.

Gopalswamy and Kundu have obtained Nobyama radioheliograms for AR 7477 for several days during April 19-27, 1993. These maps will be used to investigate the change in the SVC as the region rotates from the east limb to the west. We would like to study the evolution of intensity, polarization and two dimensional structure of the active region over this period which corresponds to nearly half a rotation. Since we have observed the same region for several days using the Very Large Array at 20 and 90 cm wavelengths, we can also study the higer layers of the active region in relation to the changes at lower levels as observed with the Nobeyama Radioheliograph. We have two or three emission mechanisms at work to produce the observed emission so that we can obtain the physical parameters of the region for a better understanding of the nonthermal phenomena. Using full and partial frame images obtained by the Yohkoh SXT, we have considerable information on the X-ray emitting material contained in the active region.

Gopalswamy, Schmahl and Kundu detected sunspot associated variability over a time scale of minutes. To our knowledge, this is the first time such rapid variability has been observed in microwave radiation from a sunspot. These observations were obtained by the Very Large Array (VLA) on April 24, 1992 at 2 cm. The time evolution of the peak flux of these sources showed significant time variations which were sometimes periodic. The period of these oscillations was approximately 3 min, similar to that of intensity and Doppler shift oscillations observed in optically thin, transition region lines such as C IV (1548.19 angstroms) in sunspot umbrae. The most striking feature of the oscillations is the lower polarization (50%) compared to the other umbral sources. This could be explained by a combination of gyroresonance and free-free emission from the upper transition region in the sunspot atmosphere.

M. Aschwanden (1994c) reviewed simultaneous imaging observations of the (quiet) solar corona in soft X-rays (or EUV) and radio, and outlined recent developments that involve three-dimensional (3D) reconstruction techniques, such as stereoscopy and tomography. The 3D reconstruction of coronal structures involves not only accurate measurements of geometric parameters (position, altitude, rotation rate), but also the deconvolution of physical parameters (density, temperature, magnetic field) along the line-of-sight, which is most feasible with simultaneous observations in complementary wavelengths, e.g. in soft X-rays, EUV, and radio.

Aschwanden and A. Benz (ETHZ) discovered the process of chromospheric evaporation and decimetric radio emission during solar flares. Evidence for the radio detection of chromospheric evaporation is based on the radio-inferred values of (1) the electron density, (2) the propagation speed, and (3) the timing, which are found to be in good agreement with statistical values inferred from the blueshifted CaXIX soft X-ray line. The physical basis of the proposed model is that free-free absorption of plasma emission is strongly modified by the steep density gradient and the large temperature increase in the upflowing flare plasma. The step-like density increase at the chromospheric evaporation front causes a local discontinuity in the plasma frequency and produces a slowly drifting high-frequency cutoff. The physical parameters have been studied in 21 flare episodes observed with radio data from Phoenix, hard X-ray data from the Compton Gamma Ray Observatory (BATSE), and soft X-ray data from GOES. Aschwanden, M. Montello (CUA), B. Dennis (GSFC), and A. Benz (ETHZ) studied correlated sequences of hard X-ray and type III bursts during solar flares, analyzing radio data from Ikarus and the Hard X-Ray Burst Spectrometer (HXRBS) on SMM. Correlated burst groups were found with an epoch-folding technique in virtually all strong flares. The correlated HXR and radio pulses, with durations of 0.2-2.0 s were found to have the same duration in both wavelengths, and are believed to reflect the intrinsic duration of elementary electron acceleration processes in solar flares.

Raulin, Gopalswamy, Kundu and N. Nitta (Lockheed) presented VLA observations of a coronal flare which occurred on 1993 April 22, above a weak photospheric magnetic field region. The event begins with the apparition of a new 20 cm radio emission (T_B - 5 10^6K), followed an hour later by a bright (T_B up to 1.9 10^{10}K) 90 cm radio emission. Full disk Yohkoh images shows that there is no major modification of the active region's structure associated with the apparition of these radio emissions. Second harmonic plasma emission due to nonthermal distribution of electrons, has been invoked to explain both radio emissions. Nevertheless it has been shown that the electrons responsible for the centimetric emission, can not supply the higher coronal regions where the metric emission occurs. Consequently, the energetic electrons which produce the 90 cm emission, are accelerated at high coronal altitudes in agreement with what is deduced from observations of energetic electrons in the interplanetary medium.

Kundu, White, M. Pick (Meudon) and colleagues from Yohkoh/SXT team provided the first evidence for nonthermal processes in flaring x-ray bright points (XBP's). X-ray bright points are known to show variability on a number of timescales, including impulsive X-ray brightenings. The relationship between these XBP "flares" and normal solar falres is poorly known. A fundamental question is whether nonthermal acceleration of particles takes place in XBP flares. This issue was addressed by searching for nonthermal radio emssion at metric wavelengths from flaring XBPS identified in Yohkoh/SXT data. Unequivocal evidence for type III-like radio bursts, usually attributed to beams of nonthermal electrons on open field lines was found. This suggests that XBP flares are similar to normal flares and can indeed accelerate nonthermal populations of energetic particles.

Kundu, Nitta (Lockheed), K. Shibasaki and S. Enome (NRO) used observations made with the Nobeyama radio heliograph (NRH) at 17 GHz and the Yohkoh Soft X-ray Telescope (SXT) experiment and reported the first detection of 17 GHz signatures of coronal X-ray bright points (XBP's). This was also the first reported detection of flaring bright points in microwaves. They detected four BP's at 17 GHz out of eight identified in SXT data on July 31, 1992, for which they looked for 17 GHz emission. For one XBP located in a quiet mixed-polarity region, the peak times at 17 GHZ and X-rays were very similar, and both were long lasting -- about 2 hours in duration. There was a second BP (located near an active region) which was mostly likely flaring also, but the time profiles in the two spectral domains were not similar. The other two 17 GHz BPs were quiescent with fluctuations superposed upon them. For the quiet region XBP, the gradual, long-lasting and unpolarized emission suggests that the 17 GHz emission is thermal.

Kundu, White, Gopalswamy and Lim made a number of important observations regarding the properties of MeV-energy electrons, using the BIMA telescope they demonstrated that millimeter interferometers are sensitive enough to detect such electrons even in small flares, and that they are commonly produced in flares of all sizes. The properties of electrons at these energies can most easily be studied with millimeter observations. They cannot be deduced from a study of the electrons which produce hard X-rays; they often seem to be different populations, which is an important result. Most of the properties can be seen by comparing multi-wavelength data for a number of solar flares they observed with BIMA during the major campaign of 1991 June. The wavelengths are diagnostics of energetic electrons in different energy ranges. The flares in the June 1991 active period were remarkable in two ways: all have very high turnover frequencies in the microwave spectra, and very soft hard-X-ray spectra. The sensitivity of the microwave and millimeter data permitted them to study the more energetic (> 0.3 MeV) electrons even in small flares, where their high-energy bremsstrahlung is too weak to present detectors. The millimeter data show delays in the onset of emission with respect to the emissions of lower-frequency electrons and differences in time profiles, energy spectral indices incompatible with those implied by the hard X-ray data, and a range of variability of the peak flux in the impulsive phase when compared with the peak hard X-ray flux which is two orders of magnitude larger than the corresponding variability in the peak microwave flux. All these results suggest that the hard X-ray-emitting electrons and those at higher energies which produce millimeter emission must be regarded as separate populations.

Kundu, Raulin, Pick (Meudon) and Strong (Lockheed) combined imaging observations in soft X-rays and at metric radio wavelengths to study the association between flaring X-ray bright points and radio type III bursts. It has been shown that in addition to heating coronal material up to 5 10^6 K, X-ray bright point flares produced electron beams which propagate along magnetic field lines. The simple nature of these X-ray features may give new insights to the more general problem of acceleration of electrons during solar flares

Raulin, Kundu, Nitta (Lockheed), Hudson (Hawaii) and Raoult (Meudon), presented simultaneous observations of soft X-ray jets and metric radio type III bursts. For the first time it was possible to produce simultaneous images of electron beams and hot coronal structures in which the beams propagate. It was shown that electron acceleration is compatible with a shock acceleration scenario, and that the density of the ambient medium allows a plasma emission process to develop.

Working closely with B. Dennis (GSFC), E. Schmahl provided inputs to the definition phase of the High Energy Solar Physics mission, a satellite which will image solar hard X-rays and Gamma rays with 2 arc second resolution. With simulations of the imaging process using 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 image intervals on short time scales.

It is well known that the activity of the Sun appears in the time series of the solar flux at 2800 MHz, and this frequency is commonly used as a proxy for activity. Schmahl and Kundu have extended the proxy relationship between irradiance and microwaves by using the daily solar fluxes from Toyokawa Observatory at 1000, 2000, 3750 and 9400 MHz in addition to the Ottawa 2800 MHz flux for the years

1980 - 1989. They have found that the flux at 1000 MHz is better correlated with irradiance than the flux at higher frequencies--a result that was not predicted, but in retrospect, is consistent with the current understanding of the radiation mechanisms. The five-frequency spectral measurements of microwave flux allow one to separate the sunspot and coronal features, providing an improved proxy of solar variability.

H. Instrumentation

Early in the fall of 1993, the Photometrics CCD camera system used at the University of Maryland Observatory for teaching observational astronomy was found to be inoperable, apparently due to a power surge which destroyed various components of the computer system and camera electronics. D. Wellnitz undertook diagnosing and repairing the problems with the system, which required replacement of the computer system, repair of the Photometrics camera system electronics and cooling system, integration of new hardware and software compatible with the new computer system, and backup and documentation of the re-worked system. This emergency repair work was accomplished quickly, resulting in minimal delay of the observational astronomy course.

I. Other

V. Trimble has completed a study of the early history of gamma ray astronomy, attempting to understand its very different progress from the beginnings of radio and X-ray astronomy. Strong radio and X-ray sources were uniformly serendipitous discoveries, requiring new physics for their interpretation, and were found by pure instrumentalists defying theoretically-based expectations of null results. In contrast, no gamma ray sources were anything like as bright as the early predictions for supernovae and active galaxies. Curiously, many of these were closely connected with the steady state cosmological model.

Trimble has begun a study of numbers and citation rates of papers making primary use of data from the main US-operated large optical telescopes (including KPNO and CTIO 4-m's, Palomar, and Lick) designed to determine whether the Lick 120" is still a competitive instrument. The answer will probably be a marginal "yes", but less so than it was a decade ago.

J. Publications

Acosta-Pulido, J. A., B. Vila-Vilaro, I. Perez-Fournon, A. S. Wilson and Z. Tsvetanov, 1993, "Evidence and Implications of Anisotropy in Seyfert Galaxies", in Cambridge AGN Conference.

Allissandrakis, C. E., A. Nindos and M. R. Kundu, 1993, "Evidence for Ordinary Mode Emission from Microwave Bursts", Solar Physics, 147, 343-358.

Aschwanden, M. J. 1994a, "Irradiance Observations of the 1-8 A Solar Soft X-Ray Flux from GOES", Solar Phys., 152, 53-59.

Aschwanden, M. J. 1994b, "Tracing Electron Beams in Solar Flares", in Proc. Conf. on Research Trends in Physics, LaJolla, CA, 1993 Novemer 8-10, Institute of Advanced Physics Studies and American Institute of Physics, (ed. V.Stephan), in press.

Aschwanden, M. J. 1994c, "Imaging, Stereoscopy, and Tomography of the Solar Corona in Soft X-Rays and Radio", (Invited Review), A. O. Benz & A. Krüger (eds.), Lecture Notes in Physics, Berlin:Springer, in press.

Aschwanden, M. J. and T. S. Bastian, 1994a, "VLA Stereoscopy of Solar Active Regions: I. Method and Tests", Astrophys. J., 426, 425-433.

Aschwanden, M. J. and T. S. Bastian, 1994b, "VLA Stereoscopy of Solar Active Regions: II. Altitudes, Relative Motion, and Center-to-Limb Darkening of 20 cm Emission", Astrophys. J., 426, 434-448.

Aschwanden, M. J. and A. O. Benz, 1994, "Periodic or Random Acceleration in Solar Flares?", Space Sci. Rev., 68, 193-198.

Aschwanden, M. J. and A. O. Benz, 1994, "Chromospheric Evaporation and Decimetric Radio Emission in Solar Flares", Astrophys. J., 438, in press.

Aschwanden, M. J., A. O. Benz, B. R. Dennis and M. R. Kundu, 1994, "Pulsed Acceleration in Solar Flares", Astrophys. J. Suppl. Ser., 90, 631-638.

Aschwanden, M. J., A. O. Benz and M. Montello, 1994, "Coherent-Phase or Random-Phase Acceleration of Electron Beams in Solar Flares", Astrophys. J., 431, 432-449.

Aschwanden, M. J., M. Montello, B. R. Dennis and A. O. Benz, 1994, "Correlated Sequences of Hard X-Ray and Type III Bursts During Solar Flares", Astrophys. J., 440, 1995 Feb. 10 issue, in press.

Bartlett, L. M., S. D. Barthelmy, N. Gehrels, M. Leventhal, B. J. Teegarden, J. Tueller and C. J. MacCallum, 1994, "High Resolution Phase Resolved Spectroscopy of the Crab", in The Second Compton Symposium, edited by C. Fichtel, N. Gehrels and J. P. Norris, AIP Conf. Proc. No. 304, p. 67-71.

Bell, R. A., G. Paltoglou and M. J. Tripicco, 1994, "The Calibration of Synthetic Colours", MNRAS, 268, 771.

Benz, A. O., T. Kosugi, M. J. Aschwanden, S. G. Benka, E. L. Chupp, S. Enome, H. Garcia, G. D. Holman, V. Kurt, T. Sakao, A. V. Stepanov and M. Volwerk, 1994, "Particle Acceleration in Flares", Solar Phys., 153, 33-53.

Bettoni, D., G. Galletta, L. J. Sage, 1993, "Detection of a Bar-Driven Gas Infall in the SBO Galaxy NGC 4684", A. & A., 278.

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

Borkowski, K. J., J. P. Harrington, W. P. Blair and J. Bregman, 1994, "Dust in the Hydrogen-Poor Ejecta of A30", Astrophys. J., 435, in press.

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.

Braatz, J. A., A. S. Wilson, D. Y. Gezari, F. Varosi and C. A. Beichman, 1993, "High Resolution Mid-Infrared Imaging and Astrometry of the Nucleus of the Seyfert Galaxy NGC 1068", Astrophys. J. Lett., 409, L5.

Braatz, J. A., A. S. Wilson and C. Henkel, 1994, "The Discovery of Five New H_2O Megamasers in Active Galaxies", Astrophys. J. Lett., submitted.

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

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

Bryan, G. L., M. L. Norman, J. M. Stone, R. Cen and J. P. Ostriker, 1994, "A Piecewise Parabolic Method for Cosmological Hydrodynamics", Computer Physics Communications, in press.

Burkhart, G. R., P. B. Dusenbery, T. W. Speiser and R. E. Lopez, 1993, "One-D Simulation Studies of Current Sheet Catastrophe; 1. Comparison to Observations", J. Geophys. Res., 21373-21390.

Cattell, C., C. Roller and R. E. Lopez, 1994, "Multi-Spacecraft Observations of Substorm Onsets and Precursor Events", Proc. International Conference on Substorms-2, in press.

Cavallo, R., K. A. Arnaud and V. Trimble, 1993, "An Upper Limit to Coronal X-rays from Single, Magnetic White Dwarfs", J. Astrophys. Astron., 14, 141-143.

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. E. M. Schlegel and R. Petre (American Institute of Physics).

Cecil, G., A. S. Wilson and C. De Pree, 1994, "Hot Shocked Gas along the Jets of NGC 4258 (M106)", Astrophys. J., in press.

Chang, C. L., A. S. Lipatov, A. T. Drobot, K. Papadopoulos and P. Satya-Narayana, 1994, "Hybrid Simulations of Whistler Waves Generation and Current Closure by a Pulsed Tether in the Ionosphere", Geoph. Res. Lett., 21, 11, 1015-1018.

Chen, W., N. Gehrels and M. Leventhal, 1994, "On the Optical Counterparts, Long-Term Variabilities, Radio Jets and Accretion Sources in 1E 1740.7-2942 and GRS 1758-258", Astrophys. J., 426, 586-598.

Cheng, F. H., T. R. Marsh, K. Horne and I. Hubeny, 1994, "The Cooling of the White Dwarf in OY Car After the 1992 Superoutburst", in "The Evolution of X-ray Binaries", AIP Conference Proceedings 306, AIP Press: New York, 197.

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., in press.

Consolmagno, S. J. and M. W. Schaefer, 1994, Worlds Apart, A Textbook in Planetary Sciences, Prentice-Hall, Englewood Cliffs, NJ, p. 323.

Davis, D. R., M. A'Hearn, E. Grayzeck, M. V. Sykes, E. M. Alvarez del Castillo, D. Tholen and K. Garlow, 1993, "An Overview of Datasets on Small Bodies Available Through the Planetary Data System and Soard", Asteroids, Comets, Meteors, 483-488.

Davis, D. S., C. M. Bird, R. F. Mushotzky and S. C. Odewahn, 1994, "Abell 548: An X-ray and Optical Analysis of Substructure", Ap. J., in press.

Davis, D. S., R. F. Mushotzky, J. S. Mulchaey, D. M. Worral, M. Birkinshaw and D. Burstein, 1994, "Hot Diffuse Gas in the NGC 4261 Group of Galaxies", Ap. J., submitted.

Dopita, M. A., E. Vassiliadis, S. J. Meatheringham, H. C. Ford, R. Bohlin, P. R. Wood, T. P. Stecher, S. P. Maran and J. P. Harrington, 1994, "Hubble Space Telescope Observations of Planetary Nebulae in the Magellanic Clouds. II. SMP 85, a Young Planetary", Astrophys. J., 426, 150.

Duncan, R. A., S. M. White, J. Lim, G. J. Nelson, S. A. Drake and M. R. Kundu, 1994, "Giant Radio Outburst from the Super–Massive Star Eta Carinae", Ap. J. Lett., submitted.

Gopalswamy, N. 1994, "A study of Active Region Magnetic Field Structure using Radio, X-ray and Optical Observations", Proc. of the National Solar Observatory Summer Workshop, Sacramento Peak, CA, in press.

Gopalswamy, N. and M. R. Kundu, 1994, "Surprises in the Radio Signatures of CMEs", (ed) A. O. Benz and A. Kruger, Springer Veralg, in press.

Gopalswamy, N., M. R. Kundu, A. Raoult and M. Pick, 1994, "Non-radial Magnetic Field Structures in the Solar Corona", Solar Phys., 150, 317.

Gopalswamy, N., M. R. Kundu and O. C. St. Cyr, 1994, "Nonthermal Radio Emission Associated With a Coronal Disconnection Event", Astrophys. J. Lett., 424, L135.

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., in press.

Gopalswamy, N., E. J. Schmahl, M. R. Kundu, J. R. Lemen, K. T. Strong, R. C. Canfield and J. de La Beaujardiere, 1993, "A Study of Active Region Magnetic Field Structure Using VLA-Radio, YOHKOH- X-ray and Mees-Optical Observations", Proc. 6th IAU Asia-Pacific regional Meeting, Pune, India, in press.

Gopalswamy, N., E. J. Schmahl, M. R. Kundu, J. R. Lemen, K. T. Strong, R. C. Canfield and J. de La Beaujardiere, 1994, "Study of Active Region Magnetic Field Structure Using VLA-Radio, YOHKOH- X-ray and Mees-Optical Observations", Proc. of the Kofu Symposium, (eds.) S. Enome and T. Hirayama, p. 347.

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., in press.

Gurevich, A. V., G. M. Milikh and R. Roussel-Dupre, 1994, "Nonuniform Runaway Air-Breakdown", Phys. Lett. A, 187, 197.

Harrington, J. P., K. J. Borkowski and Z. Tsvetanov, 1995, "GHRS Observations of Mass-Loaded Flows in Abell 78", Astrophys. J., in press.

Hashimshony, D., C. Cohen, A. Zigler and K. Papadpoulos, 1994, "Dark Current Reduction in High Power Photoconducting Semiconductor Switches", Applied Phys. Lett., in press.

Hawley, J. F. and J. M. Stone, 1994, "MOCCT: A Numerical Technique for Astrophysical MHD", Computer Physics Communications, in press.

Higdon, J. L., B. J. Smith, S. L. Lord and R. J. Rand, 1994, "The Detection of Molecular Gas from the Ring of Arp 143", Ap. J. Lett., in press.

Howe, J. E., D. T. Jaffe and S. Zhou, 1994, "Far-IR Line Mapping of L1630, M17, and W3: Comparison of [O I] and [C II] Distributions", in Proc. of the Airborne Astronomy Symp. on the Galactic Ecosystem: From Gas to Stars to Dust, ed. M. R. Haas, J. A. Davidson and E. F. Erickson, (San Francisco: ASP), in press.

Howe, J. E., E. A. Lada, L. G. Mundy and R. Plume, 1994, "Neutral and Ionized Carbon in the NGC 1977 Photodissociation Region: Clump or Interclump Emission?", in Proc. of the 2nd Cologne-Zermatt Symp. on The Physics and Chemistry of Interstellar Molecular Clouds, ed. G. Winnewisser and J. Stutzki, (Berlin: Springer-Verlag), in press.

Jaffe, D. T., S. Zhou, J. E. Howe, F. Herrmann, S. C. Madden, A. Poglitsch, P. P. van der Werf and G. J. Stacey, 1994, "Ultraviolet Illuminated Molecular Cloud Boundaries: Extended [C II] 158 Micron Emission Toward L1630", Ap. J., 435, in press.

Jarrett, T. H., G. Novak, T. Xie and P. F. Goldsmith, 1994, "Magnetic Field Structure in Monoceros R2", Ap. J., 430, 743.

Kallman, T. R., D. Liedahl, A. Osterheld, W. Goldstein, S. Kahn and S. Vrtilek, 1994, "Photoionization Equilibrium Modelling of Iron L Line Emission", Ap. J., submitted.

Klavetter, J. J. and M. F. A'Hearn, 1994, "An Extended Source for CN Jets in Comet Halley", Icarus, 107, 322-334.

Kramer, S. B., C.-C. Wu, D. M. Crenshaw and J. P. Harrington, 1994, "IUE Spectra and Photoionization Models of the Seyfert 2 Galaxies NGC 7674 and I Zw 92", Astrophys. J., 434, 171.

Kundu, M. R., K. T. Strong, M. Pick, K. T. Harvey, S. R. Kane, S. M. White and H. S. Hudson, 1994, "Metric Type III Bursts from Flaring X-ray Bright Points", A New Look at the Sun, Proc. of the Kofu Symposium, S. Enome and T. Hirayama (eds.), p. 343.

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

Kundu, M. R., K. Shibasaki, S. Enome and N. Nitta, 1994, "Detection of 17 GHz Radio Emission from X-ray Bright Points", Ap. J., 431, L155.

Kundu, M. R., K. Shibasaki, S. Enome and N. Nitta, 1994, "Observation of 17 GHz Radio Emission from X-ray Bright Points", A New Look at the Sun, Proc. of the Kofu Symposium, S. Enome and T. Hirayama (eds.), p. 79.

Kundu, M. R., K. Shibasaki, S. Enome, N. Nitta, M. Bruner, T. Sakao and T. Kosugi, 1994, "Evolution of an Active Region and Flare Productivity", A New Look at the Sun, Proc. of the Kofu Symposium, S. Enome and T. Hirayama (eds.), p. 353.

Kundu, M. R., S. M. White, N. Gopalswamy and J. Lim, 1994, "Millimeter, Microwave, Hard X-ray and Soft X-ray Observations of Energetic Electron Populations in Solar Flares", Astrophys. J. Supp., 90, 599.

Kundu, M. R., S. M. White, N. Gopalswamy and J. Lim, 1994, "Interferometry of Solar Flares at 3 mm Wavelength", in IAU Symposium 154: Infared Solar Physics, D. H. Rabin (ed.), p. 131.

Leonard, P. J. T., 1994, "How to Observe Comet Impact", Nature, 369, 613.

Li, G., E. R. Seaquist, J. M. Wrobel, Z. Wang, L. J. Sage, 1993, "The Molecular Gas and Star Formation in IRAS Luminous SO Galaxies: I. NGC 7625", Ap. J., 413, 150.

Li, J. G., E. R. Seaquist, Z. Wang, L. J. Sage, 1994, "Interferometric Observations of HI and CO in NGC 3928", A. J., 107, 90.

Liberman, M. A., V. V. Bychkov, S. M. Golberg and D. L. Book, 1994, "Stability of a Planar Flame Front in the Slow-Combustion Regime", Phys. Rev., E 49, 455.

Lim, J. and S. M. White, 1994, "First Radio Detection of a (G Dwarf) Star in the Pleiades Cluster", Astrophys. J. Lett., in press.

Lim, J., S. M. White, G. J. Nelson and A. O. Benz, 1994, "Directivity of the Radio Emission from the K1-dwarf Star AB Doradus", Astrophys. J., 430, 332.

Lopez, R. E., 1993, "On the Location of the Substorm Initiation Region", Adv. Space Res., 13, 4, 189-198.

Lopez, R. E., 1994, "On the Role of Reconnection During Substorms", Proc. International Conference on Substorms-2, in press.

Lopez, R. E., 1994, "An Interdisciplinary Undergraduate Space Physics Course", J. of College Science Teaching, in press.

Lopez, R. E. and D. N. Baker, 1994, "Evidence for Particle Acceleration During Magnetopsheric Substorms", Ap. J. S., 90, No. 2, 531-539.

Lopez, R. E., C. C. Goodrich, G. D. Reeves, R. D. Belian and A. Taktakishvili, 1994, "Mid-tail Plasma Flows and the Relationship to Near-Earth Substorm Activity: A Case Study", J. Geophys. Res., in press.

Lopez, R. E. and J. Tuomi, 1994, "Elementary Science Education Reform: A Brief Note on the Essentials", Educational Leadership, in press.

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., in press.

MacLow, M.-M., M. Elitzur, J. M. Stone and A. Konigl, 1994, "A Protostellar Jet Model for the Water Masers in W49N", Astrophys. J. Letts., in press.

MacLow, M.-M., C. F. McKee, R. I. Klein, J. M. Stone and M. L. Norman, 1994, "Shock Interactions with Magnetized Interstellar Clouds", Astrophys. J., in press.

Maran, S. P., R. D. Robinson, S. N. Shore, J. W. Brosius, K. G. Carpenter, B. E. Woodgate, J. L. Linsky, A. Brown, P. B. Byrne, M. R. Kundu, S. M. White, J. C. Brandt, R. A. Shine and F. M. Walter, 1994, "Observing Stellar Coronae with the Goddard High Resolution Spectrograph. I. The dMe Star AU Microscopii", Astrophys. J., 421, 800.

McFadden, L.A., 1994, "Remote Sensing of Comets and Asteroids," U.S. National Report to the IUGG, American Geophysical Union, in press.

Milikh, G. M., 1994, "First Estimates of HF-Induced Modifications of the D Region by the HF Active Auroral Research Program Facility", Radio Science, 29, 5, 1355-1362.

Milikh, G. M., J. M. Hinds and L. M. Ducan, 1993, "A Computer Simulation of the Production of Artifically Ionized Layer Using the Arecibo Facility", Radio Science, 28, 6, 1029-1038.

Milikh, G. M., K. Papadopoulos and C. L. Chang, 1994, "On the Physics of High Altitude Lightning", Geophys. Res. Letts., in press.

Milikh, G. M. and A. S. Sharma, 1994, "Thermal Instability in the Inner Coma of a Comet", Geophys. Res. Letts., in press.

Morse, J. A., A. S. Wilson, M. Elvis and K. A. Weaver 1994, "Extended Soft X-ray Emission in Seyfert Galaxies: ROSAT HRI Observations of NGC 3516, NGC 4151 and Markarian 3", Astrophys. J., in press.

Mulchaey, J. S., E. Colbert, A. S. Wilson, R. F. Mushotzky and K. A. Weaver, 1993, "Soft X-ray Spectra of Seyfert 2 Galaxies", Astrophys. J., 414, 144.

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., in press.

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., in press.

Nerney, S. F., S. T. Suess and E. J. Schmahl, 1993, "Flow Downstream of the Heliospheric Termination Shock: The Magnetic Field on the Heliopause", J. Geophys. Res., Vol. 98, 15, 169-215, 176.

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.

Ohtani, S., B. J. Anderson, D. G. Sibeck, P. T. Newell, K. Takahashi, L. J. Zanetti, T. A. Potemra, R. E. Lopez, V. Angelopoulos, R. Nakamura, D. M. Klumpar and C. T. Russell, 1993, "A Multisatellite Study of a Pseudosubstorm Onset in the Near-Earth Magnetotail", J. Geophys. Res., 19355-19367.

Paltoglou, G. and R. A. Bell, 1994, "Properties of the Washington System Derived from Synthetic Spectra", MNRAS, 268, 793.

Papadopoulos, K., C. L. Chang and H. B. Zhou, 1993, "Cerenkov Excitation of Helicon Waves by Ionospheric HF Heating", J. Geophys. Res., in press.

Papadopoulos, K., G. M. Milikh, A. V. Gurevich, A. Drobot and R. Shanny, 1993, "Ionization Rates for Atmospheric and Ionospheric Breakdown", J. Geophy. Res., 98, A10, 17593-17596.

Papadopoulos, K., G. M. Milikh and P. Sprangle, 1993, "Triggering the HF Breakdown of the Atmopshere by Barium Release", Geophys. Res. Letts., 20, 6, 471-474.

Papadopoulos, K. and A. S. Sharma, 1993, "Is the Magnetosphere a Lens for MHD Waves?", Geoph. Res. Lett., 20, 24, 2809-2812.

Papadopoulos, K., G. M. Milikh, A. W. Ali and R. Shanny, 1994, "Remote Photometry of the Atmosphere Using Microwave Breakdown", J. Geoph. Res., 99, D5, 10387-10394.

Papadopoulos, K., H. B. Zhou and A. S. Sharma, 1994, "The Role of Helicons in Magnetospheric and Ionospheric Physics", Comm. in Plasma Physics, in press.

Papadopoulos, K., A. Z. Zigler, D. L. Book, C. Cohen and D. Hasimshony, 1994, "Response to a Magnetized Semiconductor Plasma to a Laser Pulse", Phys. Rev. Lett., in press.

Papadopoulos, K., A. Zigler, D. Book and R. Shanny, 1994, "Magnetically Insulated Photoconducting Semiconductor Switches", Comments on Plasma Phys., in press.

Patel, N., T. Xie and P. F. Goldsmith, 1994, "Cometary Globules in the South-East Quadrant of the Rosette Nebula", Ap. J., 413, 593.

Peng, Y., S. N. Vogel and J. Carlstrom, 1993, "Deuterated Ammonia in Sagittarius B2", Astrophys. J., 418, 113.

Peng, Y., S. N. Vogel and J. Carlstrom, 1994, "Silicon Chemistry in Sagittarius B2", Ap. J., submitted.

Perez-Fournon, I., B. Vila-Vilaro, J. A. Acosta-Pulido, J. I. Gonzalez-Serrano, M. Barcells, A. S. Wilson and Z. Tsvetanov, 1993, "Spectroscopy of the Extended Emission Line Regions in NGC 4388", Cambridge AGN Conference.

Phookun, B., S. N. Vogel, L. G. Mundy and S. N. Vogel, 1993, "NGC 4254: A Spiral Galaxy with an M=1 Mode and Infalling Gas", Astrophys. J., 418, 113.

Pieters, C. M. and L. A. McFadden, 1994, "Meteorite and Asteroid Reflectance Spectroscopy: Clues to Early Solar System Processes", Annu. Rev. Earth Planet. Sci., 22, 457-497.

Pound, M. W. and L. Blitz, 1994, "Proto--Brown Dwarfs II. Results in the Ophiuchus and Taurus Molecular Clouds", Ap. J., in press.

Rand, R. J., 1994, "Atomic Hydrogen in the NGC 4631 Group of Galaxies", A. & A., 285, 833.

Rand, R. J. and A. G. Lyne, 1994, "New Rotation Measures of Distant Pulsars in the Inner Galaxy and Magnetic Field Reversals", MNRAS, 268, 497.

Reach, W. T., M. W. Pound, D. J. Wilner and Y. Lee, 1994, "Dense Gas in High-Latitude Clouds", Ap. J., in press.

Regan, M. and S. N. Vogel, 1994, "The Infrared Structure of M33", Astrophys. J., in press.

Rose, W. K. 1994, "X-Ray Pulsar Hydrodynamics: Collisionless Shock Waves and Steady State Infall Hydrodynamics", In <u>The Evolution of X-Ray Binaries</u>, S. S. Holt and C. S. Day (eds.), AIP Conf. Series 308, 499-501.

Rose, W. K. 1994, "Millimeter Wavelength CO Emission Lines from Carbon Stars", to appear in "The Analysis of Emission Lines".

Roussel-Dupre, R. A., A. V. Gurevich, T. Tunnell and G. M. Milikh, 1994, "Kinetic Theory of Runaway Air Breakdown", Phys. Rev., 49, 3.

Rucinski, S. M., J. S. Kaastra, R. Mewe, O. Vilhu and S. M. White, 1994, "Spectroscopic EUVE Observations of the Active Star AB Doradus", Astrophys. J., submitted.

Sage, L. J., 1993, "Molecular Gas in Nearby Spiral Galaxies: II. The Data", A. & A.S., 100, 537.

Sage, L. J., G. Galletta, 1993, "Evolution in Dust-Lane Elliptical Galaxies: Detection of Accreted Molecular Gas", Ap. J., 419, 544.

Sage, L. J., G. Galletta, 1994, "Counter-Rotating Molecular Gas in NGC 4546", A. J., in press.

Sawant, H. S., R. R. Rose, J. R. Cecatto and N. Gopalswamy, 1994, "Solar Simple Bursts Observed with High Spectral Resolution in the range of 18--23 GHz", Astrophys. J. Suppl. Series, 90, 693.

Schaefer, M. W. 1993, "Aqueous Geochemistry on Early Mars", Geochimica et Cosmochimica Acta, 57, 4619-4625.

Schaefer, M. W. 1993, "Volcanic Recycling of Carbonates on Mars", Geophysical Review Letters, 20, 827-830.

Schmahl, E. J. and M. R. Kundu, 1994, "Solar Cycle Variation of the Microwave Spectrum", Solar Phys., 152, 167.

Schmitt, H. R., T. Storchi-Bergmann, A. S. Wilson and J. A. Baldwin, 1993, "Star Formation in Active Galactic Nuclei: the Cases of NGC 5135, NGC 6221 and NGC 7130", In "Active Galactic Nuclei Across the Electromagnetic Spectrum", IAU Symposium No. 159, Eds. A. Blecha and T. Courvoisier (Kluwer), in press.

Schulz, R., M. F. A'Hearn, P. V. Birch, C. Bowers, M. Kempin and R. Martin, 1993, "CCD Imaging of Comet Wilson (1987 VII): A Quantitative Coma Analysis", Icarus 104, 206-225.

Schulz, R., M. F. A'Hearn and N. H. Samarasinha, 1993, "On the Formation and Evolution of Gaseous Structures in Comet P/Halley", Icarus 103, 319-328.

Schulz, R., L. A. McFadden, A. B. Chamberlin, M. F. A'Hearn and D. G. Schleicher, 1994, "Variability in Comet P/Swift-Tuttle", Icarus 109, 145-155.

Shapiro, V. D., V. I. Shevchenko, A. S. Sharma and K. Papadopoulos, 1993, "Lower Hybrid Turbulence at Cometary Bow Wave and Acceleration of Cometary Protons," J. Geophys. Res., 98, A2, 1325-1331.

Shapiro, V. D., V. I. Shevchenko, P. J. Cargill and K. Papadopoulos, 1994, "The Modulational Instability of Lower Hybrid Waves at the Magnetopause", J. Geophys. Res., in press.

Sharma, A. S, D. Vassiliadis and K. Papadopoulos, 1993, "Resconstruction of Low Dimensional Magnetospheric Dynamics by Singular Spectrum Analysis", Geophys. Res. Lett., 20, 5, 335-338.

Sharma, A. S., D. A. Roberts, D. Vassiliadis, A. J. Klimas, D. N. Baker and K. Papadopoulos, 1994, "Low Dimensional Attractor in Magnetospheric Dynamics", Phys. Rev. Lett., communicated.

Sharma, A. S. and K. Papadopoulos, 1994, "Alpha Particle Heating at Comet-Solar Wind Interactions Regions", J. Geophys. Res., in press.

Silber, A., S. D. Vrtilek and J. C. Raymond, 1993, "Concurrent X-ray and Optical Observations of Two Dwarf Novae in Outburst, Ap. J., 425, 829.

Simpson, C., D. L. Clements, M. J. Ward, S. Rawlings and A. S. Wilson, 1993, "Buried Quasars in RadioGalaxies", In "Active Galactic Nuclei Across the Electromagnetic Spectrum", IAU Symposium No. 159, Eds. A. Blecha and T. Courvoisier (Kluwer), in press.

Sion, E. M., F. H. Cheng, K. S. Long, P. Szkody, R. Gilliland, M. Huang and I. Hubeny, 1994, "HST FOS Spectroscopy of the Ultra-Short Period Dwarf Nova WZ Sagittae", Ap. J., in press.

Smith, D. M., M. Leventhal, N. Gehrels, J. Tueller, W. N. Johnson, R. L. Kinzer, J. D. Kurfess, M. S. Strickman, D. A. Grabelsky, W. R. Purcell and M. P. Ulmer, 1994, "Search for Compton-Backscattered Annihilation Radiation from the Galactic Center with OSSE", Astrophys. J., in press.

Spencer, J. R., B. E. Clark, L. M. Woodney, W. M. Sinton and D. Toomey, 1994, "Io Hot Spots in 1991: Results from Europa Occultation Photometry and Infrared Imaging", Icarus 107, 195-208.

Stone, J. M. and M. L. Norman, 1994, "Numerical Simulations of Magnetic Accretion Disks", Astrophys. J., in press.

Storchi-Bergmann, T., J. A. Baldwin and A. S. Wilson, 1993, "Discovery of Double-Peaked Broad Line Emission from the LINER Nucleus of NGC 1097", Astrophys. J. Lett., 410, L11.

Storchi-Bergmann, T., M. Eracleous, M. Livio, A. S. Wilson, A. V. Filippenko and J. P. Halpern, 1994, "The Variability of the Double-Peaked Balmer Lines of NGC 1097", Astrophys. J., in press.

Taktakishvili, A., R. E. Lopez and C. C. Goodrich, 1994, "Energization of Ions in Near-Earth Current Sheet Disruption", Geophys. Res. Lett., in press.

Thejappa, G. and M. R. Kundu, 1994, "Effects of Large and Small Scale Density Structures on the Radio Emission from Coronal Streamers", Solar Phys., 149, 31.

Thornley, M. D. and C. D. Wilson, 1994, "Constraining the Influence of Star Formation on the Lowest ^{12}CO Line Ratios in M33", Ap. J., 421, 458.

Trimble, V. 1993, "Globular Clusters from Space" in The Globular Cluster - Galaxy Connection, J. Brodie and G. Smith (eds.), ASP Conf. Series 51, 633-643.

Trimble, V. 1993, "Blue Stragglers: Concluding Remarks" in Blue Stragglers, R. Saffer (ed.), ASP Conf. Series 53, 155-162.

Trimble, V. 1993, "Patterns in Citations to Papers by British Astronomers", QJRAS, 32, 301-314.

Trimble, V. 1993, "Evolutionary Links in the Zoo of Interacting Binaries", Comm. on Astrophys., 17, 159-173.

Trimble, V. 1993, "Some Faint, Particular Stars, Part II", SLAC BeamLine 23, No. 3, 45-52.

Trimble, V. 1994, "An Overview of Wide Field Imaging" in Astronomy from Wide Field Imaging, H. T. MacGillivray (ed.), IAU Symp. 161 (Dordrecht: Kluwer), 745-752.

Trimble, V. 1994, "The Solar Neutrino Problem and How We Know the Stars Run on Nuclear Energy", SLAC BeamLine 24, No. 1, 35-44.

Trimble, V. 1994, "Report of Commission 28 (Galaxies)" in J. Bergeron, IAU Transactions XXIIA (Commission Reports) 277-303.

Trimble, V. 1994, "Creators' Records: The Pre-History of Single and Binary Neutron Stars" in Evolution of X-ray Binaries, S. S. Holt and C. S. Day (eds.), AIP Conf. Series 308, 665-672.

Trimble, V. 1994, "Bursters and the Quest for Cosmological Effects" in Gamma Ray Bursts, Second Workshop, G. Fishman et al. (eds.), AIP Conf. Series 307, 171-221.

Trimble, V. 1994, "Fossil Radioactivities and How We Know the Solar System Formed in a Hurry", SLAC BeamLine 24, No. 2, 28-37.

Trimble, V. 1994, "The Students' Observatory 1935-42: When Aller Measured Radial Velocities and Popper Interpreted Spectra, with Updates on the Significance of DQ Her, SN 1937C, Alpha Cygni, RY Scuti, and the Rotation of M33", Comm. on Astrophys. 17, No. 5, 273-284.

Trimble, V. and P. J. T. Leonard 1994, "Astrophysics in 1993", PASP, 106, 1-24.

Vassiliadis, D., A. S. Sharma and K. Papadopoulos, 1993, "An Empirical Model Relating the Auroral Geomagnetic Activity to the Interplanetary Magnetic Field", Geophys. Res. Lett., 20, 16, 1731-1734.

Vogel, S. N. 1994, "Massive Star Formation: IAU Colloquim 140, Astronomy with Millimeter and Submillimeter Interferometry", ed. M. Ishiguro, (San Francisco: ASP).

Vogel, S. N., R. Weymann, M. Rauch and T. Hamilton, 1994, "New Upper Limits on the Local Metagalactic Ionizing Radiation Density", Astrophys. J., in press.

Vrtilek, S. D., A. Silber, J. C. Raymond and J. Patterson, 1993, "ROSAT Observations of Cataclysmic Variables: A Search for the Boundary Layer Emission", Ap. J., 425, 787.

Vrtilek, S. D., A. Silber, F. A. Primini and J. C. Raymond, 1994, "ROSAT Observations of TV Col", Ap. J., submitted.

Vrtilek, S. D. et al. 1994, "Multiwavelength Observations of Hercules X-1/HZ Herculis", Ap. J. Lett., in press.

Weaver, H. A., P. D. Feldman, M. F. A'Hearn, C. Arpigny, R. A. Brown, E. F. Helin, D. H. Levy, B. G. Marsden, K. J. Meece, S. M. Larson, K. S. Noll, J. V. Scotti, Z. Sekanina, C. S. Shoemaker, E. M. Shoemaker, T. E. Smith, A. D. Storrs, D. K. Yeomans and B. Zellner, 1994, "Hubble Space Telescope Observations of Comet P/Shoemaker-Levy 9 (1993e)", Science, 263, 787-791.

Weaver, H. A., P. D. Feldman, J. B. McPhate, M. F. A'Hearn, C. Arpigny and T. E. Smith, 1994, "Detection of CO Cameron Band Emission in Comet P/Hartley 2 (1991 XV) with the Hubble Space Telescope", Ap. J., 422, 374-380.

Weaver, K. A., R. F. Mushotzky, P. J. Serlemitsos, A. S. Wilson, M. Elvis and U. Briel, 1994, "The Origin of the Soft X-ray Excess in the Seyfert 2 Galaxy NGC 2110", Astrophys. J., in press.

White, S. M., 1994, "Energetic Electron Populations in Solar Flares", in High Energy Solar Phenomena - A New Era of Spacecraft Measurements, J. Ryan and W. T. Vestrand (ed.), AIP (Conf. Proc. 294), New York, p. 199.

White, S. M., R. A. Duncan, J. Lim, G. J. Nelson, S. A. Drake and M. R. Kundu, 1994, "The radio source around Eta Carinae", Astrophys. J., 429, 380.

White, S. M. and E. Franciosini, 1994, "Circular Polarization in the Radio Emission of RS CVn Binaries", Astrophys. J., in press.

White, S. M. and M. R. Kundu, 1994, "Observations of the 1991 Eclipse at 3.5 mm Wavelength", in IAU Symposium 154: Infrared Solar Physics, D. M. Rabin (ed.), p. 167.

White, S. M., J. Lim and M. R. Kundu, 1994, "Radio Constraints on Coronal Models for dMe Stars", Ap. J., 422, 293.

White, S. M., A. S. Silva, I. de Pater, R. P. Lin, D. E. Gary, H. S. Hudson, J. G. Doyle, M. J. Hagyard and M. R. Kundu, 1994, "Multiwavelength Observations of a Solar Flare", Proc. of the Kofu Symposium, S. Enome and T. Hirayama (eds.), p. 203.

Wilson, A. S. 1993, "Emission-Line Diagnostics of Extragalactic Jets", in "Astrophysical Jets", Vol. 6 STScI Symposium Series, Eds. D. Burgarella, M. Livio and C. P. O'Dea, p. 121.

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

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, & P. J. Quinn, p. 275, Astronomical Society of the Pacific Conference Series Vol. 54.

Wilson, A. S., J. A. Braatz, T. M. Heckman, J. H. Krolik and G. K. Miley, 1993, "The Ionization Cones in the Seyfert Galaxy NGC 5728", Astrophys. J. Lett., 419, L61.

Wilson, A. S. and E. J. M. Colbert, 1994, "The Difference between Radio-Loud and Radio-Quiet Active Galaxies", Astrophys. J., in press.

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

Xie, T., M. Allen and W. D. Langer, 1995, "Turbulent Diffusion and Its Effects on the Chemistry of Molecular Clouds", Ap. J., Feb 20 issue.

Xie, T. and P. F. Goldsmith, 1994, "The Giant Molecular Cloud Monoceros R2. I. Shell Structure", Ap. J., 430, 252.

Xie, T., P. F. Goldsmith and N. Patel, 1993, "A Well-Shaped Bipolar Outflow Shell in Monoceros R2", Ap. J., 419, L33.

Xie, T., P. F. Goldsmith, R. L. Snell and W. Zhou, 1993, "Dust Temperature Distributions in Star-Forming Condensations", Ap. J., 402, 216.

Zhou, S., D. T. Jaffe, J. E. Howe, N. Geis, F. Herrmann, S. C. Madden, A. Poglitsch and G. J. Stacey, 1993, "The [C II] 158 Micron Emission from the Horsehead Nebula", Ap. J., 419, 190.

Zucker, D., J. C. Raymond, A. Silber, P. Mason, S. Curiel, S. D. Vrtilek and E. Schlegel, 1994, "Phase-Resolved IUE and Optical Observations of the Polar BY Cam", Ap. J., submitted.