The Johns Hopkins University
Center for Astrophysical Sciences
Department of Physics and Astronomy

Baltimore, Maryland 21218

[S0002-7537(98)07001-2]

The following report covers the period from October 1996 through September 1997.

1. INTRODUCTION

Space Science within CAS continues to be vigorous. As the Faint Object Spectrograph and Hopkins Ultraviolet Telescope programs come to an end, two other programs, the Advanced Camera for Surveys (ACS) and the Far Ultraviolet Spectroscopic Explorer (FUSE), are rapidly approaching final assembly and launch. FUSE will begin final assembly in December 1997 for a launch in October 1998. The ACS is undergoing assembly that will continue through the summer of 1998, with a launch and placement into the Hubble Space Telescope (HST) planned for December 1999. Both programs are discussed in detail below. The CAS rocket program and CAS's participation in the Midcourse Space Experiment continue to be very active. CAS has two pending SMEX proposals, one for a Hopkins Ultraviolet Background Explorer (HUBE) and the other for a Hopkins Ultraviolet Telescope Spartan (HUTSPA). CAS has built two wide field, double spectrographs for the Sloan Digital Sky Survey, and has written software for archiving and retrieving SDSS data that is being adopted by several astronomical data archives. CAS plans to build a novel spectrograph for the Apache Point Observatory (APO) 3.5-m telescope. Theoretical and observational astronomy within CAS continue to be strong. Both are supported by data obtained from the Hubble Space Telescope, the APO 3.5-m telescope, and observatories around the world.

2. PERSONNEL

CAS has made a major organizational change this year, creating a position for a Director of CAS Research Programs. This person will be responsible for helping CAS identify and pursue national and international funding opportunities in space research and ground based astronomy programs that fit within the longterm research goals of CAS and the University. The Director of Research programs will provide managerial, fiscal, and technical oversight of major CAS programs. After a search that identified several outstanding candidates, Mr. James Crocker has accepted the position.

P. Knezek and D. Stutman have joined CAS as Associate Research Scientists. New postdocs are E. Agol, R. Brunner, A. Dey, B. Jain, M. May, M. SubbaRao, and A. Thakar. CAS visitors are S. Beaulieu, L. Dressel, A. Kinney, and T. Hartquist. M. Allen has left JHU. J. Daniels has returned to England. S. Doty left CAS this Fall to become an Assistant Professor at Metropolitan College of Denver. D. Hall is now at the University of Colorado. W.G. Fastie has entered retirement. C. Mihos has left to join the faculty at Case Western Reserve University. M. Spaans has accepted a Hubble Fellowship at Harvard University. P. Rosati has taken a position at ESO. Y. Pei has joined the Office of Research Programs at STScI.

Other permanent staff are: P. J. Dagdigian, A. F. Davidsen, J. P. Doering, P. D. Feldman, (Chair, Physics and Astronomy) H. C. Ford (Director, CAS), R. Giacconi (Director, ESO), T. M. Heckman, R. C. Henry (Director, Maryland Space Grant Consortium), B. R. Judd, C. W. Kim, J. H. Krolik, H. W. Moos, C. A. Norman, D. Neufeld, D. F. Strobel, A. Szalay, and R. Wyse, Professors; S. Lubow, Assistant Research Professor; W. P. Blair, and G. A. Kriss, Associate Research Professors; M. Finkenthal, Visiting Professor; L. Taff, Principal Research Scientist; L. Bianchi, R. Burg, S. Friedman, J. Kruk, S. McCandliss, J. Murthy, W. Oegerle, Z. Tsvetanov, A. Uomoto, H. Weaver and W. Zheng, Research Scientists; A. Connolly, M. Dickinson, B. Espey, D. Golimowski, C. Holmes, E. Kaiser, G. Meurer, D. Sahnow, K. Sembach, and K. Weaver, Associate Research Scientists; C. M. Carollo, M. Dickinson, and E. Murphy, Postdoctoral Fellows; K. S. Long, Associate Astronomer (STScI)/Adjunct Research Professor (JHU/CAS); H. C. Ferguson, P. Madau, and M. A. McGrath, Assistant Astronomers (STScI); and F. Paresce, Senior Astronomer (ESA/STScI).

3. THE FAR ULTRAVIOLET SPECTROSCOPIC EXPLORER

The largest project within the Center for Astrophysical Sciences is the Far Ultraviolet Spectroscopic Explorer (FUSE), a PI-class astronomy mission within the NASA Origins program. FUSE will explore the Universe through high-resolution ($R = 24{,}000$-$30{,}000$) spectroscopy at far ultraviolet wavelengths (905-1195 Å). This spectral window will permit the study of many astrophysically important atoms, ions and molecules to investigate the nature and composition of the interstellar medium, the intergalactic medium, active galactic nuclei, quasars, massive stars, supernovae remnants, planetary nebulae, and the outer atmospheres of cool stars and planets. The highest priority goals of the FUSE science team include comprehensive studies of the abundance and distribution of deuterium in the disk and halo of the Milky Way, and the distribution and kinematics of hot gas in the disk and halo of the Milky Way and other galaxies. In addition, more than half of the available observing time will be awarded by NASA to guest investigators.

JHU is responsible for the development and operation of the FUSE satellite. The Satellite Control Center and all mission and science operations activities are located in the Bloomberg Center on the Homewood Campus. The mission is scheduled for launch in the fall of 1998 on a Delta II rocket and has a nominal lifetime of three years.

JHU/CAS scientists participating in the FUSE mission are Principal Investigator Warren Moos, L. Bianchi, W. Blair, A.

Davidsen, P. Feldman, S. Friedman, G. Kriss, J. Kruk, E. Murphy, J. Murthy, W. Oegerle, D. Sahnow, K. Sembach, and H. Weaver.

4. THE ADVANCED CAMERA FOR SURVEYS

The Advanced Camera for Surveys (ACS) will be installed in the Hubble Space Telescope during the third servicing mission, scheduled for December 1999. The ACS is being built by a collaboration between Ball Aerospace, the Johns Hopkins University, and NASA Goddard Space Flight Center. Members of the science team, led by the principal investigator Holland Ford, are at JHU, the Space Telescope Science Institute, the University of Arizona, the University of California Santa Cruz, Leiden University, and Goddard. A list of team members and information about the ACS can be found at http://jhufos.pha.jhu.edu.

Ball has begun installation of mechanisms and electronics into the ACS optical bench. All optical mirrors and windows have been coated and delivered to Ball; by the end of 1997 all filters will have been manufactured, characterized, and installed in the three filter wheels.

Three excellent 2k $\times$ 4k CCDs with SITe's standard UVIS coating have been designated as the two flight CCDs and the spare for the Wide Field Camera. These CCDs will give a peak HST$\times$ACS efficiency of $\sim$36% from 600 nm to 700 nm. Additional 2k $\times$ 4k CCDs with an aluminum coating between the device and the glass ceramic substrate and with Dr. Mike Lesser's enhanced red coating are being mounted on flight headers. The aluminum coating eliminates a halo observed at $\lambda \geqslant 800$ nm. Lesser's coating gives a peak QE $\sim$90% at 650 nm. If suitable devices are produced by mid November, they will replace the present flight candidates. A SITe 1k $\times$ 1k CCD with Lesser's UV coating has been selected for the High Resolution Camera. The CCD, which fully samples the HST PSF at 500 nm, has an average QE of $\sim$50% between 200 nm and 300 nm. Because of advances in filter technology, the ACS UV filters have 3 to 3.5 times the throughput of WFPC2 filters. The net throughput with these filters and the HRC CCD will be 20 or more times higher than WFPC2. This large increase in mid-UV sensitivity will enable a wide range of new science programs with HST.

The detector for the ACS Solar Blind Channel will be a STIS flight spare 1k $\times$ 1k Multi Anode Micro Channel Array with a cesium iodide photocathode. The detector (STF7) has a QE of $\sim$22% at 121.6 nm. The DQE at 400 nm is $\sim 10^{-9}$, and decreases to a value $\sim 10^{-14}$ at 600 nm, providing excellent rejection of visible and red light. The global dark current at 37^o C is 154 cps, corresponding to $\sim$0.5 counts per pixel per hour. The ACS sensitivity at 121.6 nm should be 1.5 times better than STIS in imaging mode, and 17 times better than the FOC.

During the coming year Ball will finish manufacturing all remaining mechanical, electrical, detector, and thermal systems. The flight software, which is on schedule, will be completed and tested. After final assembly during the first half of 1998, alignment, functional testing, and calibration will done through the summer and fall of 1998.

5. RESEARCH AND ACTIVITIES

Luciana Bianchi continued to study massive star populations in the Local Group Galaxies M31, M33, and NGC 6822, using HST, CFHT and WHT data. She used WFPC2 photometry in U,B,V and UV filters to detect the hottest, most massive objects in nearby galaxies. The spatial resolution achieved with HST, and the use of UV filters, are great advantages with respect to ground-based surveys for the detection of the most massive stars, because of their high temperatures. The hottest stellar candidates in NGC 6822 and M33, selected from WFPC2 photometry, were observed with the CFHT multislit spectrograph for spectral classification in August 1997, revealing new O stars and WR stars.

HST (FOS and GHRS) UV spectroscopy of five hot massive stars in NGC 6822 was analyzed and complemented with ground-based spectroscopy at the William Herschel Telescope 4.2-m (La Palma, Spain). Comparison of wind lines of stars in M33, M31, NGC 6822, LMC and the Milky Way reveals metallicity effects. Mass loss rate and wind velocity are derived by analysis of the UV (wind) and optical (photospheric) profiles with different codes, to derive stellar parameters, for comparison among different galaxies and with stellar wind theory. This program benefits from collaboration with S. Scuderi (OACT), J. Hutchings (DAO), P. Massey (KPNO), R. Bohlin (STScI), A. Bressan (OAPD).

Over fifty new stellar clusters, mostly similar to the luminous blue clusters in the LMC, have been discovered in WFPC2 images of M33. Their U,B,V and FUV colors were compared to stellar evolutionary models to derive population ages, and follow-up spectroscopy was obtained to further investigate their physical properties (thesis project of JHU graduate student R. Chandar, with H. Ford and L. Bianchi).

L.Bianchi presented results from her HST programs on massive stars in nearby galaxies at the SEA conference in San Sebastian (October 1996), where she was also invited to give a public lecture on the most important discoveries from HST, and in an invited colloquium at the Astrophysical Institute of Canarias (July 1997). Results were also reported as contributions at the 190th AAS meeting and at the conference ''The Ultraviolet Universe at Low and High Redshift: Probing the Progress of Galaxy Evolution'' (College Park, May 1997).

A similar study of the wind properties of three hot evolved objects in the Magellanic Clouds based on *HST* FOS spectra has also been completed (in collaboration with E.Vassiliadis, IAC, and M.Dopita, MSSSO).

L. Bianchi has been appointed to serve in the IAU Organization Committee of IAU Comm. 42 for the term 1997-2000.

Luciana Bianchi also participated in the definition of the FUSE ''Hot Stars'' team project, and is the Coordinator for the Public Outreach and Education program of the FUSE project.

William P. Blair is an Associate Research Professor in the Department of Physics and Astronomy. He has completed his duties as Deputy Project Scientist for the Hopkins Ultraviolet Telescope (HUT) Project this year, and is now the Chief of Mission Planning for the Far Ultraviolet Spectroscopic Explorer (FUSE) Project at JHU. While these duties have taken the bulk of his time, Blair has participated in numerous papers on supernova remnants, cataclysmic variable stars, and other related topics using data from HUT, the Hubble Space Telescope, and ground-based optical observatories.

Blair has published (with K. S. Long, STScI) an emission-line survey of two nearby Sculptor group galaxies, NGC 300 and NGC 7793, finding 28 strong supernova remnant candidates in each galaxy, many of which were confirmed with spectroscopy. This is the first such survey to push beyond the Local Group of galaxies and has demonstrated both the positive and negative aspects of pushing such surveys to larger distances. A similar survey is in progress for the more distant face-on spiral M83.

In addition, Blair performed a detailed analysis of HST/WFPC2 imagery of the Crab Nebula supernova remnant in our Galaxy, with A. Uomoto (JHU/CAS) and collaborators from four other institutions. These data resolve essentially all of the structure in the filaments and show a huge variety of filament morphologies. Relatively little ionization structure is seen on a filament by filament basis, although large scale ionization structures are apparent in some regions. Dark shadows of many filaments are seen against the bright synchrotron nebula background, and analysis indicates densities of order ten times the typical ionized filament densities are required for these dark filament cores. Ongoing HST projects include an analysis of FOS spectra of two ''oxygen-rich'' supernova remnants in the Magellanic Clouds and planning for Cycle 7 STIS observations of a position in the Cygnus Loop.

Blair has contributed to a number of papers using HUT data or expanding on previously published HUT results. With graduate student B. Greeley (JHU/CAS), Long, and C. Knigge (STScI), an analysis of the HUT spectrum and far-ultraviolet time variability of the magnetic cataclysmic variable system EX Hya has been published. Much larger variations are seen in the continuum level than in the lines, arguing for physically distinct sites for these emissions. With Knigge, Long, and R. Wade (Penn State), a detailed model of the line profiles from the wind in the cataclysmic variable Z Cam in outburst has been published. With J. C. Raymond (SAO) and others, detailed analyses of HUT data for a Vela supernova remnant filament and the Herbig-Haro object HH2 have been completed. With J. M. Laming (NRL), Raymond, and B. M. McLaughlin (SAO), a detailed model of electron-ion equilibration in fast shock waves has been calculated and compared with HUT data from SN 1006. Many additional HUT-related papers are still in progress. Blair, Greeley and Long also observed magnetic cataclysmic variable stars as part of the ORFEUS/SPAS II Guest Investigator program in November 1996.

C. Marcella Carollo joined CAS in October 1996, as a Hubble Fellow. Using HST/WFPC2 multicolor data, in collaboration with I.J. Danziger (Trieste, Italy) and M. Rich (Columbia University), she has investigated several open questions related to the nuclear properties of elliptical galaxies with kinematically-distinct cores, and found that: (i) If there is a direct effect of environment on the nuclear properties of such systems, this is similar to that acting on kinematically-normal galaxies. Dynamically hot systems preferentially have low nuclear densities and shallow cusps when in clusters, and high nuclear densities and steep cusps when in the field. The highest nuclear densities are reached in the field. (ii) Within the limits imposed by the angular resolution of WFPC2 data and by the presence of nuclear dust, these systems have symmetric nuclei. This result is independent of environment, form of the nuclear light profiles, nuclear morphology, and presence of an unresolved, likely non-thermal, central source. (iii) The known Mg_2 index-enhanced kinematically-distinct cores are not all nuclear disks embedded in anisotropic stellar bodies, as previously thought. Three galaxies, namely NGC 2434, NGC 7192 and NGC 7626, do not show any photometric signature for a nuclear disk associated with their Mg_2-rich distinct cores. (iv) There is a residual dependence of the nuclear cusp slope γ on the Mg_2 line-strength: the higher the Mg-enrichment, the shallower the nuclear cusp slope. (v) The Mg_2-enhanced distinct cores do not occupy any special location in the correlation between γ and Mg_2 (correlation which worsens significantly if for the distinct cores one considers the Mg_2 value extrapolated from the outer galactic regions). Therefore, the nuclei of galaxies with kinematically-distinct cores are not the relic nuclei of the underlying galactic bodies, unperturbed by the formation of the cores. By contrast, these new results suggest that the nuclei of these galaxies were formed together with, and by the same processes which formed, the distinct cores.

In collaboration with M. Stiavelli (STScI) and P.T. de Zeeuw (Leiden), Carollo has analysed HST WFPC2 F606W images of a sample of 75 early-type spiral galaxies. The results of this analysis are quite surprising: (i) Several galaxies, despite their classification as relatively early spirals, do not show morphological evidence for any significant spheroidal component, i.e., a bulge. Even in the few almost featureless bulges, dust lanes are detected down to the nuclei, similar to what is observed in early-type galaxies. (ii) In several galaxies spiral structure, as detected by spiral-like dust lanes or star forming knots, reaches down to the innermost accessible scales, i.e., less than about 100 parsec at the average distance of our sample. The presence of regular spiral structure in the innermost regions suggests, even if this is detected only as dust absorption, that the outer stellar disks often extend down to the galactic center. (iii) In several galaxies, a central component possibly distinct from the outer disk is identified, but does not have the spheroidal morphology typical of a ''classical bulge.'' This inner component often has a highly irregular morphology, similar to that of a dwarf irregular galaxy, or is very flattened, i.e. reminiscent of a bar-like structure. (iv) Very compact but resolved, central ''star clusters'' are found in most of the galaxies. (v) Star forming regions are often present within the inner 100 parsecs of the galaxies. In several cases this occurs on the nuclear spiral arms, in others it is spread over the entire nuclear region. In some cases it is likely that star formation occurs in the central structure identified either as a possible bulge or as an irregular or bar-like bulge. In six galaxies, the star formation has the typical morphology of the star forming rings of nuclear starbursts. These results are relevant for understanding secular evolution processes, since e.g., dynamical arguments have been put forward suggesting that bulges might form from the thickening of the inner disk after the formation of a bar.

In collaboration with M. Spaans (recently moved to Harvard from JHU), she has constructed models of the cosmological star formation and metal production history of protogalaxies with varying axis ratios. This study shows that more massive and/or roughly spherical systems reach the threshold-metallicity for a transition to a multi-phase (cold, warm and hot) interstellar medium earlier than less massive, more flattened systems. Therefore, more flattened, lower-mass systems start to form stars actively at smaller redshifts. This effect is due to the overall robustness of the interstellar medium against complete expulsion (blow-away) at high total masses, and in the prevention of metal enrichment in the outer regions due to axial outflow along the symmetry axis of a non-spherical proto-galaxy (blow-out).

Carollo and Spaans have also suggested that the observed predominance of spheroidal systems observed at high redshift, e.g. in the Hubble Deep Field, is due to this effect: At $z \approx 3-5$, roundish proto-galaxies with total (dark+baryonic) masses of about 10^{11} $M_{\odot}$ and/or the inner spheroidal cores of similarly massive flattened systems sustain a multi-phase interstellar medium, and therefore a high star-formation rate, whose magnitude depends on the fraction of baryonic matter in the systems. Conversely, the peak at $z \approx 1-2$ in the observed cosmological metal production rate coincides with the epochs of star formation of lower mass spheroidals, as well as of massive proto-galactic disks.

Arthur F. Davidsen served as Interim Dean of the Faculty of Arts and Sciences at JHU and also continued work on the intergalactic medium.

Mark Dickinson has continued research on high redshift galaxies and galaxy clusters using ground– and space–based observations. Using very deep infrared observations of the Hubble Deep Field obtained in 1996, he has analyzed the properties of galaxies at $z > 2$ and examined the evolutionary history of elliptical galaxies at high redshift. With C. Steidel (Caltech) and collaborators, he has continued working on an extensive survey of galaxies at $z \approx 3$ which has identified $\sim$1300 candidates and spectroscopically confirmed $\sim$350. He is presently analyzing the ultraviolet luminosity function of these objects and interpreting it in terms of the distribution of star formation rates in the early universe. He has continued HST and ground–based infrared observations of galaxy clusters at $z > 1$, and has used the Rosat X–ray satellite to demonstrate the presence of extended X–ray emission around several radio galaxies at $1 < z < 2$. These are therefore the most distant X–ray clusters known, with luminosities similar to those of rich clusters in the local universe.

Brian R. Espey continued his work analyzing symbiotic and active galactic nuclei (AGN) spectra from the HUT Astro-2 mission. He continued his collaboration with the atomic physics group at the Queen's University of Belfast and visited Belfast in July 1997 sponsored by a NATO grant and a visiting fellowship from QUB. The aim of this collaboration is to develop improved diagnostics for nebular material using the most up-to-date atomic data, and this has led to the submission of two papers this year, with a third in preparation.

Espey continued his research with co-I R. Schulte-Ladbeck, and graduate student J. Birriel at the University of Pittsburgh on the analysis of Astro-2 and ground-based data of symbiotic star systems. Espey continues to supervise Birriel's study of the spectrum of the symbiotic binary Z And using data obtained during the Astro-2 mission and a paper is due shortly. Further thesis work will study how the presence or absence of Raman scattered OVI emission is influenced by the symbiotic star environment.

Work with D. Turnshek of the University of Pittsburgh has resulted in a paper on the 'Cloverleaf' gravitational lens. Espey's contribution was the analysis of the photometry and spectroscopy of the different sightlines to show that there is evidence for sightline-dependent dust extinction. The preferred explanation is that this dust resides in the host galaxy of the QSO as emission from molecular gas is also seen in this object. Using dust extinction models, Espey attempted to derive the relative brightness of each component, corrected for extinction.

A paper summarizing the results of a survey of eighteen low redshift broad absorption line QSOs was published in conjunction with Turnshek. Surprising findings of this work are that the covering factor of the absorbing gas may be larger by up to a factor of three than the canonical value of $\approx$0.1. There is also some support for broad absorption systems being more common in the most luminous sample objects.

Work with A. Cooke (ROE) and R. Carswell (IoA) resulted in an esimate of the strength and evolution of the intergalactic ionizing radiation field over the range $2.0 < z < 4.5$. Using a maximum likelihood technique it was found that the ionizing background is relatively constant in intensity, with no sign of the fall-off expected due to the decreasing space density of QSOs at high redshift. Possible explanations for this effect are discussed in a MNRAS paper.

During the summer, Espey worked with undergraduate S. Andreadis of Yale University on the analysis of a large sample of QSO spectra. The aim of this work is to obtain a database of line profile measurements for use in emission line studies. An advantage over previous work is the consistency of the database; previous papers on emission line properties used samples drawn from published results and have been limited in scope due to the adoption of different measurement techniques by the various authors.

Paul D. Feldman currently serves as Chair of the Department of Physics and Astronomy. He directs the NASA supported sounding rocket program, which has as its main focus the development of new instrumentation for far- and extreme-ultraviolet astronomy. Two rockets were lauched during the past year, one for the ultraviolet imaging of Jovian aurora, and the second as part of NASA's comet Hale-Bopp campaign. He has continued the analysis of the data obtained during the final year of an IUE comet program (in collaboration with M. F. A'Hearn of the University of Maryland and M. C. Festou of Toulouse) and maintained his collaboration with H. A. Weaver (JHU) in a program of HST observations of comet Hale-Bopp. He collaborated with D. T. Hall (now at the University of Colorado) and D. F. Strobel (JHU) in HST observing programs of Europa and Ganymede, and with A. Vidal-Madjar (IAP) in HST studies of CO and atomic carbon in the gaseous disk surrounding β Pictoris. He is a member of the science teams for the Far Ultraviolet Spectroscopic Explorer (FUSE) mission and for the Advanced Camera for Surveys for HST.

Holland Ford continues to concentrate his research in two areas, massive black holes in the nuclei of galaxies, and the stellar dynamics of galaxy halos. During the past year Ford gave three invited talks: a talk at the 1996 Port Douglas IAU Colloquium 163, ''Accretion Phenomena and Related Outflows,'' on the small ($r \sim 100-300$ pc) gaseous disks found in early type galaxies, a review of HST Observations of Massive Black Holes at the Kyoto IAU Symposium No.184 on ''The Central Regions of the Galaxy and Galaxies,'' and a review of HST Observations of the Nuclear Disk in M87 at the Ringberg Workshop on M87. H. Ford, L. Ferrarese (Caltech), and W. Jaffe (Leiden) used the 0.086″ aperture of the FOS spectrograph to measure the rotation of the ionized gas in the center of the $\sim$300 pc dusty disk in the center of the radio galaxy NGC 6251. They find that the mass enclosed within 40 pc is 7.5×10^8 $M_\odot$. A paper describing the results has been submitted to the ApJ.

Ford and K. Freeman (Mt. Stromlo Obs.) used the CTIO 4-m with the Argus spectrograph and the AAT fiber spectrograph to measure the radial velocities of planetary nebulae in the halo of Cen A out to projected distances of 50 kpc. Ford, M. Arnaboldi (Mt. Stromlo Obs.), and K. Freeman have begun a survey of the Virgo cluster using the CFHT 8k $\times$ 8k CCD camera to search for intracluster planetary nebulae.

Ford serves on NASA's Independent Science Review Panel, chaired by Malcolm Longair. The panel met twice, first to review plans for the Second HST Servicing Mission, and subsequently to recommend changes in HST scheduling in response to the shortened life of the NICMOS due to a thermal short in the dewar.

Scott D. Friedman is the Hopkins project scientist for the Far Ultraviolet Spectroscopic Explorer (FUSE) mission. FUSE will make observations in the critical 910–1195 Å region at a spectral resolving power of approximately 30,000. FUSE will address problems such as the abundance of primordial light elements, including the deuterium/hydrogen ratio and the distribution of intergalactic helium, the composition and dynamics of galaxies, and the origin and evolution of stars and stellar systems. Friedman's interests include studies of the interstellar medium, Big Bang nucleosynthesis, and astronomical instrumentation.

Along with A. Uomoto and P. Feldman, Friedman is also designing and constructing two fiber optic spectrographs as part of the Sloan Digital Sky Survey. Each spectrograph will record the spectra of 320 separate objects over a wide field of view. The spectrographs will be delivered to the dedicated 2.5-m telescope at Apache Point Observatory in New Mexico.

Timothy Heckman and collaborators have continued their studies of the galactic 'superwind' phenomenon: the galaxy-scale outflows associated with starburst galaxies and presumably driven by the collective effect of the energy and momentum input from massive stars and supernovae. He and M. Lehnert (Leiden) are analyzing ground-based spectra of the interstellar NaI 'D' doublet in a large sample of starbursts. He is also analyzing a smaller HST data-set that covers the major UV resonance lines. Outflows of gas (seen in absorption) are common among very luminous starbursts. The outflow speeds are typically a few hundred km s^{-1} and the associated kinetic energy represents a significant fraction of the energy injected by supernovae.

Heckman and collaborators L. Armus (Caltech), M. Dahlem (STScI), R. Della Ceca (Osservatorio di Brera), G. Fabbiano (Harvard-Smithsonian), D. Gilmore (STScI), R. Griffiths (CMU), M. Lehnert, J. Wang (JHU), and K. Weaver (JHU) have continued their analysis of ROSAT and ASCA X-ray data for a sample of a dozen starburst galaxies spanning a broad range in starburst luminosity. In all cases studied to date, the keV X-ray emission is resolved, and can be detected out to radii of tens-of-kpc (e.g. well beyond the optical isophotal radii). In the case of the edge-on galaxies, the X-ray emission is preferentially extended along the optical minor axis, strongly suggesting that much of the X-rays are produced by a galactic 'superwind.' The Fe-L emission complex has been detected in several, demonstrating that much of the keV X-ray emission comes from hot gas with a temperture of several million K. This gas represents a rate of mass outflux similar to the star-formation rate. It is hot enough to escape the potential wells of the dwarf galaxies, but its fate is unclear in the typical L^* galaxies.

C. Robert (Laval), R. Gonzalez-Delgado (STScI), C. Leitherer (STScI), and Heckman have constructed synthetic ultraviolet spectra of starbursts for a wide range in initial mass functions and star-formation histories. They are using these models to analyze HUT and HST UV spectra of starburst galaxies. The superior signal-to-noise and spectral resolution of these data (compared to IUE) have allowed them to compare the predicted and observed stellar wind lines in detail and provide powerful constraints on the initial mass function and burst history. The data also reveal strong, broad, and blueshifted interstellar absorption lines, indicating large column densities of turbulent, outflowing gas spanning a wide range in ionization states.

Heckman (with Robert and Leitherer) has analyzed the UV spectral properties of a large sample of starbursts observed with IUE. They find that dust has a profound effect on the amount and 'color' of the escaping UV light, that the UV line and continuum properties correlate strongly with the starburst's metallicity and luminosity, and with the mass/luminosity of the surrounding galaxy 'hosting' the starburst. These results have important implications for the interpretation of the rest-frame-UV spectra of star-forming galaxies at high-redshift. Heckman and Leitherer discuss the case of NGC 1705 in some detail, highlighting the dominant interstellar contribution to the UV resonance absorption-lines and the direct evidence that a starburst-driven outflow of metal-enriched gas is occurring. With G. Meurer (JHU) and D. Calzetti (STScI), Heckman is also emphasizing the role the dust plays in affecting measurements of the evolution of the star-formation rate with cosmic time. Surprisingly, they find that the bolometric surface brightnesses (star-formation rates per unit area) in local starbursts are quite similar to those in high-z galaxies (suggesting some 'feedback' process may be involved).

Heckman has continued to investigate the environments of high-redshift quasars. He and collaborators M. Lehnert, J. Lowenthal (Lick), G. Miley (Leiden), and W. van Breugel (IGPP Livermore), have used HST WFPC2 to obtain optical continuum (F555W) and narrow-band (redshifted Lyman Alpha) images of two samples of quasars at z = 2 to 3 (one radio-loud and the other radio-quiet). In contrast to the spatially-resolved structures seen around the radio-loud quasars, the radio-quiet quasars are mostly unresolved. The host galaxies of these radio-quiet quasars are therefore fainter by at least one to two magnitudes than are either the host galaxies of radio-quiet quasars or powerful radio galaxies at similar redshifts.

Heckman, with collaborators R. Gonzalez-Delgado, A. Kinney, A. Koratkar, and C. Leitherer (STScI), Krolik and Meurer (JHU), and A. Wilson (Maryland), has obtained HST images of the UV continuum in 10 of the brightest-known type 2 Seyfert nuclei. These images show that the UV continuum arises in extended (hundreds of pc to a kpc) structures that are morphologically complex. In many cases the morphology and photometric structure of the UV emitting-region is similar to what is seen in classical starburst galaxies. Spectroscopy in the near-UV (from the ground) and far-UV (using HST) shows that at least half of the type 2 Seyferts contain a prominent population of young, hot stars. These circumnuclear starbursts are evidently an energetically-significant part of the Seyfert phenomenon and may account for the heating source for the strong far-IR emission in Seyferts (and by extension - possibly quasars).

Richard C. Henry conducts research on the interstellar medium, cosmology, and ultraviolet background radiation. Henry is Principal Investigator for HUBE, the Hopkins Ultraviolet Background Radiation Explorer, which in 1996 April was selected by NASA as the MIDEX ''Alternate'' Astrophysics mission. An ''Alternate'' mission only goes forward, should the primary mission that was selected falter. As we do not expect MAP, the primary mission, to do anything other than succeed, we have used some of our MIDEX funding to conduct technical investigations, including studies of the possibility of implementing HUBE under the SMEX (Small Explorer) boundary conditions. The happy result was that we were indeed able to re-submit HUBE as a SMEX candidate, with what outcome we anxiously await to see. HUBE Co-Investigators are H. Ford, J. Kruk, J. Murthy, D. A. Neufeld (JHU), L. J. Paxton, K. Peacock (JHU/APL), J. Atkins, E. Hammond (Morgan State University), G. Carranza (Argentina), P. A. Charles (University of Oxford), M. Clampin (STScI), E. Conway (Sykesville Middle School), P. Jakobsen (ESTEC), R. A. Kimble (GSFC), R. W. O'Connell (U. VA), and C. Vaz (Portugal).

Henry presented two papers at the 1997 conference, ''Multifrequency Behaviour of High Energy Cosmic Sources,'' on the Island of Vulcano, Italy. The conference was organized by F. Giovannelli, and the papers will appear in Memorie della Societa Astronomica Italian. Titles were ''The Diffuse Ultraviolet Background,'' (Invited Paper), and ''Hopkins Ultraviolet Background Explorer'' (contributed).

Henry spent a substantial fraction of the past year in England: he was Keeley Visiting Fellow, University of Oxford, from October 1, 1996 to September 30, 1997. He spent several months working in the Department of Astrophysics, University of Oxford, where on 1997 June 17 he presented the Colloquium, ''The Cosmological Deuterium-to-Hydrogen Ratio.'' The observations on this topic carried out with HST by Andrew Dring, Jayant Murthy, and other colleagues, have resulted in a paper which is in press in the Astrophysical Journal.

The paper is an exploration of the local interstellar medium using GHRS, combined with a new determination of the local ISM deuterium-to-hydrogen ratio. Most of Henry's work in England, however, was the carrying out of studies on HUBE technical questions.

Analysis continued on data from the Mid-Course Space Experiment, MSX. The reader will find brief accounts of many results in BAAS volumes 28 and 29 and other conference proceedings (Universe at Low and High Redshift, May 1997 and IAU 179). Further information on MSX, including a map showing progress of the sky survey, may be found online at http://msx4.pha.jhu.edu/survey.html.

In 1996 Henry presented an invited paper, ''Stellar Evolution: From Protostars to Supernovae and Black Holes,'' at the seminar on ''Origins,'' at Amsie '96, American Association for the Advancement of Science. Henry was also a ''Mission HOME'' panelist with Joe Rothenberg and Apollo 13 Astronaut Jim Lovell; was elected to the National Council of Space Grant Directors Executive Committee; served on the Maryland State Department of Education High School Test Specifications Committee (Earth-Space Science); and served as a Consultant at Los Alamos National Laboratory.

Charles P. Holmes has taken a 2-year IPA assignment as Program Executive for Science Operations at the Office of Space Science, NASA Headquarters.

Patricia M. Knezek has just joined the staff at Johns Hopkins as an Associate Research Scientist after spending nearly two years employed as a Research Scientist for the Observatories of the Carnegie Institution of Washington, based at Las Campanas Observatory in La Serena, Chile. She will be working with Ken Sembach on the properties of dwarf galaxies, as well as the interstellar and intergalactic medium. She is currently collaborating with Eric Schulman, Morton Roberts, and David Hogg (NRAO) studying the properties of amorphous galaxies. She is also working with Joel Bregman (U. Michigan) on determining the absorption properties of intercluster and intergroup gas using AGNs as background light sources. She is directing an on-going study of the star formation properties of giant low surface brightness galaxies with Stephen Lawrence (Bowling Green State University) and Irene Cruz-Gonzalez (Universidad Nacional Autonoma de Chile). She is also part of a collaboration to determine the optical integrated spectral properties of a volume-limited sample of galaxies with Charles Liu (Columbia U.).

Gerard A. Kriss is an Associate Research Professor in the Department of Physics and Astronomy. During the past year Kriss has moved his efforts from the Hopkins Ultraviolet Telescope (HUT) project, where he was project scientist for the Astro-2 mission, to the Far Ultraviolet Spectroscopic Explorer (FUSE) mission, where he heads up the data reduction software development as Data Processing Scientist.

During the past year he was also occupied with two major proposal development efforts. He headed a team as principal investigator to develop a concept for a 2002 instrument for the Hubble Space Telescope (HST). Unfortunately, the proposal was not successful. ''LUCY'' was an integral-field spectrograph that would have provided HST with three-dimensional spectroscopy from the near-UV through visible and near-IR wavelengths. The LUCY team was a collaborative effort of JHU, the Space Telescope Science Institute, the Centre de Recherche Astronomique in Lyon, France, Ball Aerospace, and scientists from the University of Arizona, the University of Colorado, Leiden University in the Netherlands, the Observatoire de Paris in France, and the Observatoire Midi Pyrenees in Toulouse, France. JHU team members included Dr. Zlatan Tsvetanov as project scientist, Dennis McCarthy as project manager, and professors Holland Ford and Timothy Heckman.

The optical channel of LUCY used a 40×80 array of microlenslets to sample the HST focal plane at scales of either $0.05''$ or $0.10''$, thereby giving fields of view of $2''\times4''$ or $4''\times8''$. Independent spectra from each lenslet were to be detected with a red-optimized $2k\times4k$ SITe CCD from the Hubble Advanced Camera for Surveys program. Spectra with resolving power R$\sim$1500 covered the 3500–10,000 Å range in six overlapping bands. Higher resolution (R$\sim$3000 and 9000) was available in selected bands surrounding H β+[O III], the Mg I triplet, and Hα+[N II] through [S II].

The near-UV channel used a 10×20 array of fused silica microlenslets giving an angular scale of $0.10''$ per lenslet. Spectra covering 2000-4000 Å with R$\sim$500 could be obtained at every $0.1''$ point in the $1''\times2''$ field of view. A UV-optimized 1024×1024 CCD coated by M. Lesser of the University of Arizona served as the detector.

With the improved CCDs, AR-coated optics, and overcoated silver mirrors in the visible, LUCY's throughput was a factor of two better than the Space Telescope Imaging Spectrograph (STIS) at visible wavelengths, and a factor of 7 better at 2500 Å. With factors of 10–40 in spatial multiplexing advantage, LUCY would have provided a gain of $\sim$ 80 relative to STIS for spectroscopy of compact, spatially complex objects— a common feature in objects imaged at HST resolution. LUCY would have had rich applications for observations of star clusters, both in our own galaxy and in other galaxies out to the distance of the Virgo cluster; galactic and extragalactic supernova remnants and H II regions; compact planetary nebulae; gravitational lenses; high-redshift radio galaxies; merging galaxies at intermediate redshifts. The LUCY team's science program concentrated on dynamical studies of the nuclei of normal and active galaxies. 300 orbits of the GTO program were to be devoted to observations of over 100 normal and active galaxies spanning all Hubble types. This would have provided a definitive sample for studying the demographics of black holes and helped discern their influence on galaxy formation and evolution.

As Deputy Principal Investigator, Kriss helped develop a small explorer proposal– the Hopkins Ultraviolet Telescope Spartan (HUTSPA) explorer (Arthur Davidsen, PI). HUTSPA starts with HUT, upgrades its spectrograph to provide 0.5 Å resolution spectra covering 900–1400 Å, and adds new delay-line anode detectors from the University of California, Berkeley, to achieve an effective area of $\sim150\ cm^2$. This is an improvement of a factor of 5 over the Astro-2 version of HUT, and more than $2\times$ the throughput of FUSE. The key advantage over FUSE, however, is the $10\times$ lower background that comes from the lower dispersion– HUTSPA is optimized for observing He II Lyman α absorption in the intergalactic medium (IGM) by looking at faint, $z=2-3$ QSOs. QSOs as faint as one tenth the FUSE background level ($\sim3\times10^{-16}$ ergs $cm^{-2}s^{-1}Å^{-1}$) can be observed at high S/N with little systematic error in background subtraction. The renovated HUT is to be mounted on a long-duration Spartan 400 platform being developed by Goddard Space Flight Center. This platform is lofted into orbit aboard the space shuttle, and then deployed for 12–18 months before being retrieved. In this time HUTSPA would obtain high S/N spectra of ~30 $z=2-3$ QSOs, compared to the single one (HS1700+64) observed during Astro-2. HUTSPA would be sensitive to discrete He II Lyman α absorption lines with rest-frame equivalent widths of <0.05 Å. The most recent models of the IGM find that He II traces the lowest density regions of the IGM, and it is very sensitive to the evolution of structure in the universe. By studying the He II forest, its evolution with redshift, and comparing it with the H I Lyα forest, we will be able to constrain models for the gravitationally mediated evolution of structure in the universe and determine the sources of ionizing radiation at high redshift.

Kriss is also continuing analysis of the far-ultraviolet spectra of more than a dozen AGN from the Astro-2 mission. Statistics of the frequency of intrinsic, sharp Lyman limits provides an interesting test of unified models for AGN. Four of thirteen objects – NGC 1068, NGC 4151, NGC 3516 and NGC 3227 – have intrinsic Lyman limit absorbers. All four also have extended narrow-line regions with bi-polar morphologies. All AGN with no absorption are Seyfert 1s with compact NLRs. These observations support geometrical shadowing as the means for collimating the ionizing radiation in unified models of AGN, most likely in a photoionized atmosphere above the obscuring torus.

Analysis of the absorption-line variations in the six NGC 4151 observations obtained during Astro-2 with HUT offers key insights into the location of the UV-absorbing gas. The opacity of the Lyman limit is observed to decrease markedly in response to a rise in the continuum flux, and then rise again with an e-folding time of roughly 10 days after the continuum decreases in intensity. The 60% change in flux together with the 10-day timescale implies rather low density gas is involved, $\sim10^3\ cm^{-3}$, and that it lies at a distance of ~60 pc from the nucleus. This suggests an association with either the narrow-line region or with a wind outflowing from the surface of the obscuring torus.

Further monitoring observations of NGC 4151 at wavelengths shortward of 1200Å were also performed during the ORFEUS/SPAS II mission in November 1996. The 12 higher resolution (R$\sim$5000) spectra we obtained resolve the O VI and Lyβ absorption complex. Components similar to those observed at high resolution with the GHRS by Weymann *et al.* in C IV are clearly seen. Unfortunately, individual components in the density-sensitive C III λ1176 line are blended by the high velocity widths. Variations in the continuum flux, the O VI emission line, and the neutral hydrogen column were also observed, but these were more chaotic than those seen with HUT during Astro-2, and the interpretation is not straightforward.

Knox S. Long is an adjunct professor at JHU and an astronomer at STScI. Long pursues research topics in the ultraviolet characteristics of cataclysmic variables, supernova remnants, and the properties of the interstellar medium in nearby galaxies. He remains an active co-investigator in the Hopkins Ultraviolet Telescope project, analyzing data from Astro-1, which was flown in 1990 December and Astro-2, in 1995 March.

Long and postdoc C. Knigge (STScI) in collaboration with Wade (PSU) and Horne (St. Andrews) have completed the analysis of two sets of high time resolution FOS spectra of the novalike variable UX UMa. The eclipse light curves obtained are qualitatively consistent with the gradual occultation of an accretion disk with a radially decreasing temperature distribution. The integrated spectra are not particular well fit with model spectra constructed for steady state accretion disks. Better spectral fits are obtained if optically thin component, perhaps associated with a transition region between the disk and fast wind, is included. In the first set of data, low amplitude, coherent 29-s oscillations are also detected. The spectra of these oscillations are quite blue compared to the time-averaged spectra, suggesting that the ultimate source of the oscillations is a hot, compact region near disk center.

Long and R. Knigge are also developing a Monte Carlo spectral synthesis program which models the spectra of high state cataclysmic variables in the far and extreme ultraviolet. Beginning with a kinematic description of the wind, the ionization state of the wind is then determined, followed by a synthesis of the spectrum. In an initial application of the program, Long and Knigge are able to create spectra which mimic the observed spectrum of U Gem in outburst with EUVE, which supports the hypothesis that most of the features in this spectrum are created by scattering in the wind.

Long and F. Gilliland (STScI) are completing an analysis of a set of HST/GHRS spectra in U Gem in quiescence, spectra which are dominated by emission from the white dwarf. The observations permit very accurate determination of the orbital parameters of the U Gem system as well as a direct measurement of the surface gravity. An abundance analysis shows evidence of CNO processing of material now on the surface of the WD.

Long and Winkler (Middlebury) have completed an analysis of X-ray and optical observations of the bright galactic SNR SN1006. Their improved Hα images show the existence of non-radiative Balmer-dominated filaments around most of the periphery and also across the face of the SNR. They have also identified a quasar behind SN1006, a second UV light bulb, that can be used to probe high velocity, unshocked gas from the SN explosion.

Long, Dubus (Paris), and P. Charles (Oxford) have begun the analyzing a multi-year set of ROSAT HRI observations of the nearby galaxy M33. They have identified a total of 39 point sources in these images. A detailed study of the nuclear source X-8, the brightest point source in the Local Group, reveals a 156 day periodicity which suggests that the object is a binary black hole system, rather than a mini-quasar or collection of discrete sources. A similar timing analysis of X-7 confirmed the 3.45-d periodicity known from earlier observations and revealed a 0.31-s pulse period, implying that this system has a neutron star as it's compact object.

Stephan R. McCandliss is presently involved with the post-flight calibration and analysis of the long slit spectrum of Comet Hale-Bopp recorded on April 5, 1997 at 21:00 MST during NASA Sounding Rocket launch 36.156UG from White Sands Missile Range in New Mexico. This work is being carried out with graduate student Jason McPhate and Paul Feldman (JHU/CAS). The long slit ($\approx$ 300″×7″) spectrum of Comet Hale-Bopp has 4Å resolution and shows cometary emission lines of C, O, S, and CO in the 1250–1850 Å spectral bandpass. Planning is underway for the next sounding rocket where the instrument will be a long slit spectrograph with a holographic astigmatism corrected SiC grating with a KBr coated micro-channel plate detector and double-delay line readout. This instrument will be used in the windowless FUV to record nebular emissions from 912–1300 Å from the environments around hot stars. A follow-on instrument is also under development; a dual order spectrograph that will double the effective area by using both $\pm$ orders of a holographically ruled concaved grating.

McCandliss continues his work, along with J. Kruk and C. Pankratz, on a vacuum UV Ar arc lamp, which is presently being configured to record a flat field of the Hale-Bopp spectrograph. In addition to the Ar arc lamp they are working on a windowless H_2 getter lamp. Both of these lamps use very small pinholes ($\sim$ 1 – 10 μm) and differential pumping systems for work in the windowless FUV. He also is continuing his work of developing calibration techniques for windowless vacuum UV CCDs. Work is in progress on his analysis with N. Walborn (STScI) of Astro-2 Hopkins Ultraviolet Telescope data of LMC and SMC O3 III star extinction and H absorptions and various other hot star topics.

Gerhardt R. Meurer is an Associate Research Scientist (promoted from postdoctoral research associate) working with T. Heckman. Meurer with collaborators Heckman, Lehnert (Leiden), Leitherer (STScI), and Lowenthal (UC Santa Cruz), completed a study of the integrated effective surface brightnesses S_e of starbursts. They find a consistent 90th percentile upper limit $S_e \leqslant 2.0\times10^{11} L_\odot \mathrm{kpc}^{-2}$ to the distribution of S_e for samples of starbursts observed in: 1. the rest frame ultraviolet (UV), 2. the far-infrared and Hα, and 3. 21cm radio continuum emission. There is very little variation of this upper limit with effective radii over two orders of magnitude ($R_e \sim 0.1-10$ kpc), and little evolution out to redshifts $z\approx3$. The lack of a strong dependence of this starburst intensity limit on wavelength, and its consistency with the pressure measured in strong galactic winds, argue that it corresponds to a *global* star formation intensity limit ($\dot{\Sigma}_e \leqslant \sim 45\, \mathscr{M}_\odot \mathrm{kpc}^{-2}\, \mathrm{yr}^{-1}$) rather than being an opacity effect. This result implies that there is a robust physical mechanism limiting starburst intensity, and that normal elliptical galaxies and spiral bulges can plausibly be built with maximum intensity bursts, while normal spiral disks can not. Indeed the high redshift ($z \sim 3$) galaxies observed in the Hubble Deep Field have all the properties expected of bulges and elliptical galaxies undergoing their formative burst of star formation.

One key aspect of this study was the exploitation of a tight empirical relationship between UV reddening and extinction. We demonstrated that in local starbursts this method recovers the UV flux that is absorbed by dust and reradiated in the far infrared. Application of the same algorithm to high-*z* galaxies indicates that the UV obscuration of high-*z* galaxies is significant (a factor of ~ 10 at $\lambda = 1600$Å), implying that star formation in the early universe is moderately obscured. After correcting for extinction, the observed metal production rate at $z \sim 3$ agrees well with independent estimates made for the epoch of elliptical galaxy formation. Meurer, with Heckman and Calzetti (STScI) are continuing to improve the calibration of high-*z* star formation rates using local starbursts as templates.

Warren Moos is the Principal Investigator for the Lyman Far Ultraviolet Spectroscopic Explorer. Warren Moos also participates as a Co-Investigator in the definition of the Space Telescope Imaging Spectrograph; M. E. Kaiser is the STIS Calibration Scientist. Moos is also Principal Investigator of the DOE-supported ‘‘XUV Diagnostics Based on Layered Synthetic Microstructures for Magnetically Confined Fusion Plasmas.’’ M. Finkenthal is Principal Research Scientist, D. Stutman is Associate Research Scientist and M. May a Post-doctoral Fellow on this grant.

David Neufeld’s research interests lie primarily in molecular astrophysics. With collaborators M. Harwit (NASM), G. Melnick, M. Kaufman (NASA/Ames), and JHU graduate student W. Chen, he has been continuing to plan, analyse and interpret far-infrared observations of water that have been carried out using the Infrared Space Observatory (ISO) toward warm molecular gas in circumstellar outflows and shocked interstellar regions. This program, which last year led to the first detection (in W Hydrae) of thermal water emission from a circumstellar outflow, will test theoretical models which predict that far-IR water emissions will dominate the emission line spectrum of warm, dense molecular gas.

Neufeld is the Principal Investigator on another ISO observing program that led to the discovery of interstellar hydrogen fluoride. The J=2-1 transition of HF near 121.7 microns was detected in absorption toward the bright far-infrared source Sagittarius B2. The discovery of HF marks the first time that a molecule containing fluorine has been detected in an interstellar gas cloud and the first time that a new interstellar molecule has been detected by means of observations in the far-infrared spectral region. Hydrogen fluoride is unique among diatomic interstellar hydrides in being more strongly bound than molecular hydrogen; thus direct reactions of fluorine atoms with hydrogen molecules are expected rapidly to incorporate all gas-phase fluorine nuclei into HF. Measurements of the HF abundance therefore provide a valuable probe of the fluorine depletion and imply that 98 percent of the fluorine nuclei along the line-of-sight to Sgr B2 are locked up in dust grains.

With J. Stone (Maryland), Neufeld has been investigating the effect of the well-known Wardle instability upon the emission line spectrum of C-type shocks in dense molecular gas. Stone’s numerical simulations of the non-linear evolution of the Wardle instability showed that it has profound effects upon the density distribution in the shocked gas, yet the effect on the overall emission line spectrum was found to be surprisingly small. The explanation of this negative result is that the strongest emission from the shocked gas occurs upstream of the region where the effects of the Wardle instability are felt. Neufeld and Stone’s results on the emission line spectrum justify previous studies in which the observed emission from C-type shocks was interpreted using one-dimensional shock models in which the Wardle instability was not included.

With JHU postdoctoral fellow M. Spaans, Neufeld has been constructing three-dimensional models of diffuse molecular clouds. The goal of this study is to interpret cospatial observations of HI 21 cm line emission and IRAS 100 micron emission from such clouds, the intensity ratio of these emissions providing a probe of the molecular content. Spaans and Neufeld found that three-dimensional models yield a better fit to the observations than earlier plane-parallel slab models, allowing the thickness of the cloud along the line-of-sight to be estimated.

With JHU postdoctoral fellow S. Doty, Neufeld completed an extensive theoretical study of the physical and chemical conditions within dense molecular cloud cores that are heating from within by an embedded protostar (i.e. ‘‘hot cores’’). The resultant model yields predictions for the submillimeter and far-infrared molecular line spectra of such sources, and is successful in explaining recent ISO observations of absorption in the 6 micron vibrational band of water toward several hot core regions.

Neufeld continues to serve as a co-investigator on the Submillimeter Wave Astronomy Satellite, a NASA Small Explorer mission now scheduled for launch in 1998. SWAS will probe the chemistry and thermal balance within star-forming molecular clouds by carrying out pointed observations of submillimeter emissions from H_2O, $H_2^{18}O$, O_2, C, and ^{13}CO.

David Sahnow continues as instrument scientist for the Far Ultraviolet Spectroscopic Explorer. During the past year, he has participated in the construction and testing of the FUSE detectors with the UC Berkeley Experimental Astrophysics Group. He has also assisted with the integration and test of the FUSE spectrograph at the University of Colorado. Analysis of the data obtained during spectrograph integration and test will be used to predict on-orbit instrument performance.

Kenneth R. Sembach is an Associate Research Scientist working with the Far Ultraviolet Spectroscopic Explorer

(FUSE) project. His primary project responsibilities include coordinating the science team investigation of the D/H ratio in the Milky Way and the comprehensive team study of hot gas processes that control the evolution of galaxies. He has given several FUSE related presentations this year, including poster displays and write-ups for the *International Origins Conference* in Estes Park in May and the 13^{th} IAP Colloquium in Paris in July. Sembach and Blair (JHU) have been named the science press liaisons for the FUSE activities at Johns Hopkins.

Murphy (JHU) and Sembach have conducted a large survey of the Galactic H I 21cm emission in the direction of approximately 500 quasars, active galactic nuclei, and radio sources using the NRAO 140-ft radio telescope. Much of this data was obtained this year, and a re-analysis of existing data sets has been completed. The data compilation will be used to assess the sight line velocity structure for many extragalactic continuum sources that will be observed with FUSE. Data from this project will be made available electronically and will be submitted for publication in the fall of 1997.

Sembach, Savage (U. Wisconsin), Lu (Caltech) and Murphy (JHU) are using data from the Goddard High Resolution Spectrograph (GHRS) aboard the Hubble Space Telescope (HST) to characterize the ionization properties of high velocity clouds at large distances from the Galactic plane. The discovery of highly ionized high velocity clouds in the direction of Mrk 509 in 1995 led to further investigations of these clouds and others toward PKS 2155-304. In both cases, the ionization properties of the clouds inferred from absorption line studies of many ions are more similar to those of the high ionization metal line systems seen toward quasars than they are of gas in the disk and low halo of the Galaxy. Ionization models incorporating an ionizing flux from metagalactic background radiation are able to reproduce the observed ratios. These highly ionized high velocity clouds are within a few degrees of H I HVCs mapped by the investigators with the NRAO 140-ft telescope. This suggests that the highly ionized gas traces the outer boundaries of H I clouds located at large distances from the Galactic plane. Studies of such clouds provide new information about the distribution, kinematics, and ionization of gas at large distances from the Sun.

Savage and Sembach continue their work on understanding the elemental abundances of Milky Way halo gas. Their 1996 Annual Reviews article describes much of the recent work in this field. A new result obtained this year in conjunction with Lu and Wakker (U. Wisconsin) provides an accurate metallicity measurement for a high velocity cloud and the first evidence for dust in a HVC. The cloud, HVC 287.5+22.5+240 in the direction of NGC 3783, probably originated within the Magellanic Cloud system and was tidally stripped during a passage of the Magellanic Clouds near the Milky Way. Sembach has presented reviews of these results at the Goddard High Resolution Spectrograph Symposium in December 1996 and at the Santa Cruz Workshop on Galactic Halos in August 1997.

Sembach, Savage, and Howk (U. Wisconsin) are using the Space Telescope Imaging Spectrograph (STIS) in its highest resolution mode to determine how the highly ionized gas traced by Si IV, C IV, and N V is produced and how it is related to lower ionization gas. The work builds on results presented in a paper earlier this year that indicates that large scale structures in the ISM, such as radio loops and old supernova remnants, may contain significant amounts of these highly ionized species. Understanding the impact of these structures on the observed absorption profiles is necessary if a complete description of the hot gas distribution within the Milky Way is to be developed.

Sembach, in collaboration with Walborn (STScI), Danks, (Hughes STX), Bohlin (STScI), and Jenkins (Princeton), has completed an analysis of a STIS early release observation of a hot star behind the Carina Nebula. The data clearly show many different kinds of interstellar regions along the sight line, including a large expanding H II region, high velocity gas within the Carina nebula, and diffuse clouds in the solar neighborhood. The properties of these regions and initial results from the study will appear in a special ApJ issue devoted to EROs from the recently installed HST instrumentation.

Sembach, Keenan (QUB), and collaborators at the Queen's University in Belfast, Northern Ireland are using data from the GHRS to study the properties of the intermediate-high velocity cloud in the direction of HD 203664. This cloud is known to lie within 1.5 kiloparsecs of the Galactic disk and contains gases that have a wide range of ionization states. It provides an environment for testing models of conductive interfaces between hot and cool gases, and it serves as a benchmark for comparisons with high velocity clouds located at large distances from the Galactic plane. Additional work in this collaboration includes determining the distances to other high velocity clouds in the sky and a Cycle 7 HST proposal to study the physical properties and elemental abundances of gas in the Magellanic Bridge.

Sembach, Jenkins, Danks, and Raymond (SAO) are analyzing GHRS echelle observations of the ultraviolet absorption produced by a variety of species in the high velocity gas in the Vela supernova remnant. Four sight lines have been studied, and all exhibit absorption at velocities exceeding $|v| \sim 100$ km s^{-1}. The primary objectives of this study are to understand the observational signatures of the thermal instabilities and elemental abundances in the shocked gas. Results from the study will be used to refine shock ionization models and will be compared to the ionized gas properties found for other sight lines within the Galactic disk and halo.

Along with graduate student Cha (JHU), Sembach is investigating the velocity structure of approximately 60 sight lines in the the direction of the Vela SNR through optical absorption line spectroscopy. The data, which were obtained at the ESO Coudé Auxiliary Telescope and have high S/N (>100) and high resolution (~ 4 km s^{-1}), provide the highest quality measurements to date of the Ca II and Na I profiles in this region of the sky. The investigation is designed to yield an accurate distance to the remnant and will provide information about time variability of the absorption features. The velocity structure and time variability information obtained from this study will be used to plan follow-up observations with HST and FUSE.

Sembach, Knezek (JHU), and Gallagher (U. Wisconsin) are investigating the ionized gas content of dwarf galaxies in fields outside of the Virgo cluster as part of Sembach's Long Term Space Astrophysics grant to study the diffuse ionized gas in galactic environments. Data were recently obtained at the 1.3 meter Michigan-Dartmouth-MIT telescope to determine how the morphological properties and the ionized gas content of the dwarf galaxies are related. Broad-band as well as Hα images were obtained under excellent conditions and the initial results of the investigation will be presented at the January 1998 AAS meeting.

Reprints of recent journal articles and conference proceedings can be found on the world wide web at http://violet.pha.jhu.edu/~sembach/.

Alex Szalay has been working on novel methods of analyzing the large scale distribution of galaxies. A technique, based upon the Karhunen-Loeve transform is expected to yield improvements over a factor of three in comparison to other existing methods. The goal of this research is to give an early measurement of single most interesting cosmological quantity today: the shape of the power spectrum on 100+ Megaparsec scales. This will be the technique used in the analysis of the early Sloan redshift survey.

Another major area of his research has been into how to create and organize Terabyte size databases. The technical challenge posed by the SDSS data set is formidable and a substantial amount of original research is required. Here Szalay's research has been also quite successful. With his coworkers they developed a novel idea on how to speed up the data access times of very large databases. Their results have been presented at several astronomy and computer science conferences. They created a pilot demo system, which searches astrophysical data substantially faster than other astrophysical databases.

He has also pioneered a new unified sky subdivision scheme, which can make the integration of the next generation of astronomical archives much easier. This technique has been adopted by the SDSS and GSC-II catalogs, and is under active consideration by several others (eg. 2MASS).

Laurence G. Taff and colleagues from the Ukraine presented a paper at the I.A.U. General Assembly in Kyoto, Japan this Summer. They discussed their most recent work regarding the long-standing problem of systematic errors in the region of the North Celestial Pole. Both ''pole stars'' and north polar cap star catalogues remain of considerable importance in astrometry because of the year-round accessibility of the north polar region to most optical observatories. Data from the HIPPARCOS catalogues is also being used to explore this issue despite the correlations in the parallaxes and proper motions deduced from the space-based observations. Star positions within the polar cap contain at least two kinds of unusual systematic errors; a general dependence on right ascension which is not analytically simple and a near-two-hour periodicity depending on right ascension in both equatorial coordinates. The reason for these peculiarities could not be clarified until the creation of a special north polar cap catalogue of 4272 stars. This novel star catalogue was compiled using all the existing visual and photographic catalogues covering the last one and a half centuries. Taff's method of infinitely overlapping circles was the key standardization technique. In addition, we have intercompared our north polar cap catalogue with the TYCHO catalogue (thanks to ESA for providing the data), the U. S. Naval Observatory ACRS star catalogue, and the German PPM catalogue.

The importance of deterimining the Geminga pulsar X-ray and gamma-ray pulsar distance trigonometrically with Caraveo, Bignami, Mignani has been stressed in a paper. Moreover, they are pursuing the firm establishment of a distance to the Vela pulsar. In this way the theorists can make meaningful model comparisons because absolute fluxes will be known.

More standard HST observing on double stars came to a significant intermediate point with the publication of the results comibining HST Fine Guidance Sensor meausrements with ground-based lunar occulatation data observations with Simon and Holfeltz. This work is ongoing. Taff and Hershey are winding down their analysis of the sub-brown dwarf candidtate L722-22. The ground-based orbit on this barely resolvable system has been shown to be severely in error leading to an underestimate of the secondary's mass. Employing the full suite of HST FGS capabilities, along with specially designed observing techniques, a complete kinematical and dynamical solution for this system will be available soon. This orbit will be the only one completely defined by HST measurements.

Classical star catalogue work has continued to a logical conclusion with two STScI Research Associates. Finally, a two-dimensional version of the full three-dimensional problem of kinematical state determination has been published. It has applications to sonar detection since that situation is analytically identical to the passive reception of light from moving stars. The numerical complexity of the three-dimensional problem will be dealt with this year.

Ani Thakar has joined the development team for the Science Archive of the Sloan Digital Sky Survey as a postdoctoral fellow. He is also using numerical simulations to study the formation of massive counterrotating disks in spiral galaxies. His models can select between two types of gas dynamics: ''sticky particles'' and Smoothed Particle Hydrodynamics (SPH). Results with sticky particles have established the viability of secular, adiabatic gas infall (for early and late-type spirals) and gas-rich dwarf mergers (early-type spirals only) as producers of counterrotating disks when the infall or merger occurs on a retrograde orbit with respect to the rotation of the spiral's disk. SPH simulations, which are still in progress, are shedding light on the structure and dynamics of the counterrotating disks formed. They are comparable in size but are considerably thinner and kinematically colder than the corresponding primary stellar disks. Exponential radial profiles (similar to the primary disk profiles) are not a natural byproduct of the formation processes investigated, and require the initial conditions to be just right. The presence of primordial prograde gas in the primary disk has a dramatic effect on the dynamics of the counterrotating gas, indicating that the primary disk needs to have little or no prograde gas for a counterrotating disk to form successfully. The addition of star formation to these models is likely to yield more insight into these processes.

Zlatan Tsvetanov along with E. Neilsen (grad. student, JHU) and H. Ford (JHU) has used the surface brightness fluctuations (SBF) method applied to HST archival images to estimate distances to M87 and several of its close neighbours in the Virgo cluster and to measure some of the properties of their globular cluster populations. The measured distance to M87 is 15.8 +/- 1 Mpc and it is shown that three of the closest neighbours are at the same distance, while one (NGC 4476) is about 5 Mpc further behind. This work has revealed that the red fraction of the bimodal color distribution of the M87 Globular Cluster population is much more concentrated toward the center. The blue GC population extends much further out and there are indication that at least part of the curent GC population in M87 has been stripped from its smaller neighbors.

With M. Dopita (Australian National University) and M. Allen (grad. student, ANU and JHU) developed a set of line diagnostic diagrams for separating shock excitation from nuclear photoionization in narrow emission line regions of AGN. The key idea is the usage of electron temperature sensitive high ionization potential UV line transitions. The set of UV diagnostic diagrams was used to study phisical conditions in a small collection of nearby AGN. The most striking example is M87 (with M. Dopita, M. Allen, H. Ford and collaborators), where it was shown that the gaseous nuclear disk in M87 is shock excited.

With R. Morganti (Australian Telescope National Facility) and T. Ooosterloo (ATNF) have completed a detailed radio (continuum and HI) study of the sourthern Seyfert 2 galaxy IC 5063. The HI measurements reveal a fast gaseous outflow (700 km/s), quite untypical for a Seyfert 2 galaxy. On a larger scale the observation show a warped HI disk with a velocity curve indicating a large dark mass.

With H. Ford, M. Allen, and G. Kriss Tsvetanov has used a detailed set of dithered HST WFPC2 images to build a fully sampled Halpha image of the gaseous nuclear disk in M87. The morphology of the disk is dominated by a three arm spiral with a large number of small ''arclets.'' The orientation and inclination are consistent, to a first order, with the disk being perpendicular to the famous synchrotron jet.

With H. Ford and G. Kriss (JHU) he has used HST FOS to obtain a large wavelength range spectrum of the nuclear source in M87. The FOS spectrum reveales a series of blueshifted absorption lines indicative of an outflow of neutral and/or slightly ionized gas. In addition, the smooth continuum spectrum can not be represented by a simple power law with a single spectral index.

Alan Uomoto is the Spectrograph Scientist for the Sloan Digital Sky Survey, which will map the northern sky in five broadband colors and obtain redshifts for the brightest million galaxies and 100,000 quasars. The spectroscopic portion of the survey uses two identical fiber optic spectrographs to record up to 640 spectra in each field at a resolution of approximately 3 Angstroms. The spectrographs will be delivered to Apache Point Observatory near Sunspot, New Mexico in 1998 for installation on the specially built 2.5 m wide field survey telescope.

Harold Weaver is a Research Scientist and recently joined the FUSE project to work on Guest Investigator issues. During the past year, he has continued to lead the HST investigation of comet Hale-Bopp. These observations allow a detailed study of the sublimation behavior of the comet over a large range in heliocentric distance, from which we have learned that water and carbon monosulfide ices apparently vaporize independently of each other and that neither of these species drove the prodigious dust production observed in Hale-Bopp at large heliocentric distances. The HST images of Hale-Bopp enabled us to estimate that Hale-Bopp's nucleus had an effective diameter of ~30-40 km, making it one of the largest cometary nuclei ever measured. Serendipitously, HST caught the comet during a large outburst in activity in September 1996, at which time the dust production rate increased by at least a factor of ~10 over its quiescent value, indicating that rather violent activity must be occuring on the surface of the nucleus. The post-perihelion HST observations of Hale-Bopp were successfully begun in late-August 1997 using the newly-commissioned Space Telescope Imaging Spectrograph (STIS), and returned 2-dim ensional spectral information that will allow the team to determine whether some of the assumptions they made in analyzing the pre-perihelion 1-dim ensional data were valid.

Weaver also led an infrared investigation of Hale-Bopp from the NASA IRTF. His team searched for a variety of previously undiscovered molecules, emphasizing those not having permanent electric dipole moments (and, thus, cannot be probed at radio wavelengths) and having high predicted abundances in ISM or solar nebula models. Several unidentified emissions were detected and analysis of them is proceeding. In addition, the team detected some new transitions of water in the 4.7 μm region and emissions from CO, OH, CH_4, and C_2H_6. The rich harvest of IRTF results on comets Hale-Bopp and Hyakutake (observed during the spring of 1996) will keep the team busy for quite awhile and will help to refine observing strategies during future infrared observations of comets.

In a program being led by his French colleague, P. Lamy, Weaver has continued to study the nuclei of active comets. Using HST's high spatial resolution imaging capability, the team has demonstrated that cometary nuclei can be ''photometrically resolved'' even in the presence of a strong dust coma. The physical properties of cometary nuclei (e.g., size, shape, and rotational period) as a population are essentially unknown, and we hope to perform a statistically significant sampling of nuclei over time. In addition, these HST observations provide important probes of special comets that are the targets of future NASA and ESA space missions.

Kimberly A. Weaver is an associate research scientist who conducts X-ray studies of active galactic nuclei and starburst galaxies. One of the current ''hot'' topics in AGN research is the origin of the iron K-alpha fluorescence line. Using data from the *ASCA* satellite with collaborators J. Nousek (PSU), T. Yaqoob and R. Mushotzky (NASA/GSFC), and I. Hayashi and K. Koyama (Japan), Weaver has discovered a complex, multi-peaked iron line in the Seyfert 1.9 galaxy MCG−5-23-16. The primary component of the line is narrow with a FWHM of less than 6,600 km s^{-1} and the secondary component is broad with a FWHM of 90,000 km s^{-1}. The majority of the line is consistent with arising from an accretion disk viewed at high inclination (60−80°); however, the data do not constrain the shape of the high-energy continuum, which impacts the detailed modeling of the iron line profile. With collaborators J. Krolik (JHU) and E. Pier (NASA/GSFC), Weaver has recently used the Rossi X-ray Timing Explorer RXTE to detect the signature of Compton reflection in this galaxy and to confirm the broadness of the iron line. The RXTE data provide the first independent confirmation that broad iron K lines in Seyfert galaxies are physical (resulting from gravitational and Doppler effects) and are not merely an artifact of how the continuum is modeled. Ongoing work involves using simultaneous observations with RXTE and ASCA to study time variability of the iron line and Compton reflection in MCG−5-23-16 and other Seyfert galaxies.

Weaver, with collaborators T. Heckman (JHU) and M. Dahlem (ESTEC, StScI), is continuing an analysis of ROSAT and ASCA X-ray data for a sample of edge-on starburst galaxies, resulting in one paper recently submitted and several others in preparation.

In December 1996, Weaver was one of six NASA-supported scientists selected by President Clinton to receive the Presidential Early Career Award for Scientists and Engineers (PECASE).

The assistance of Dr. Richard Henry and Ms. Susanne Marier was appreciated in compiling this report.

PUBLICATIONS

Acosta-Pulido, J.A., Vila-Vilaró, A., Pérez-Fournon, I., Wilson, A.S., and Tsvetanov, Z.I. 1996. ''Towards an Understanding of the Seyfert Galaxy NGC 5252: A Spectroscopic Study,'' ApJ, 464, 177

Arnaboldi, M., Freeman, K. C., Mendez, R. H., Capaccioli, M., Ciardullo, R., Ford, H.C., Gerhard, O., Hui, X., Jacoby, G. H., Kudritzki, R. P., and Quinn, P. J. 1996, ''The Kinematics of the Planetary Nebulae in the Outer Re gions of NGC 4406,'' ApJ, 472, 145

Baptista, R., Horne, K., Hubeny, I, Long, K., Mauche, C. W., Rutten, R. G. M., and Wade, R. A. 1996. ''Spectrally Resolved Maps of Optically Thick Accretion Disks,'' in IAU Colloq. 158 Cataclysmic Variables and Related Objects, ed. A. Evans and J. H. Wood (Dordrecht: Kluwer), 17

Bertschinger, E., Bower, R., Doroshkevich, A., Kaiser, N., Petitjean, P., Steinmetz, M., Szalay, A.S., Wambsganss, J. and White, S.D.M. 1997. ''How Did Galaxies Form?,'' Dahlem Workshop on 'The Evolution of the Universe,' eds: G. Börner and S. Gottlöber, 275

Bi, H.-G., and Davidsen, A.F. 1997. ''Evolution of Structure in the Intergalactic Medium and the Nature of Galazies of the Lyα Forest,'' ApJ, 479, 523.

Bianchi, L. Vassiliadis, E., and Dopita, M., 1997. in ''Different Parent Galaxies: The Stellar Winds of Three Planetary Nebula Nuclei in the Large Magellanic Cloud,'' ApJ, 480, 290

Bianchi, L. 1997. '' and spectroscopy,'' B.I. SEA, 6, 28

Bianchi, L., Clayton, G., Hutchings, J.B., Massey, P., and Bohlin, R. 1996. 203

Blair, W.P., Davidson, K., Fesen, R., Uomoto, A., MacAlpine, G., and Henry, R. 1997. ''Observational Overview,'' ApJS, 109, 473

Blair, W.P., and Long, K.S. 1997. in the ''Sculptor Group Galaxies NGC 300 and NGC 7793,'' ApJS, 108, 261

Borkowski, K.J., Harrington, J.P., and Tsvetanov, Z.I. 1995. ''Interaction of Stellar Wind with Clumpy Stellar Ejecta in A30,'' ApJ, 449, L143

Bower, G., Heckman, T., Wilson, A., and Richstone, D. 1997. ''The Ionized Gas in the Nucleus of the Radio Galaxy M 84,'' ApJL, 483, L33

Brunner, R.J., Connolly, A.J., Szalay, A.S. and Bershady, M.A. 1997. ''Towards More Precise Photometric Redshifts: Calibration via CCD Photometry,'' APJ, 482, L21

Brunner, R.J., Csabai, I., Szalay, A.S., Connolly, A., Szokoly, G.P. and Ramaiyer, K. 1996. ''The Science Archive for the Sloan Digital Sky Survey,'' in Proc. ADASS Conference, 5, 493

Caraveo, P.A., Bignami, G.F., Mignani, R., and Taff, L. G. 1996. ''Geminga in the Space Telescope Era,'' A&AS,120, 65

Caraveo, P.A., Bignami, G.F., Mignani, R. and Taff, L.G. 1996. ''Parallax Observations with the Hubble Space Telescope Yield the Distance to Geminga,'' AJ 461, L91

Carollo, C.M., Franx, M., Forbes, D.A., and Illingworth, G.D. 1997. '' ApJ, 710

Clarke, J.T., Ballester, G.E., Trauger, J., Evans, R., Connerney, J., Stapelfeldt, K., Crisp, D., Feldman, P.D., Burrows, C.J., Casertano, S., Gallagher, J.S., Griffiths, R.E., Hester, J.J., Hoessel, J.G., Holtzman, J.A., Krist, J.E., Mould, J.R., Scowen, P. A., Watson, A.M., and Westphal, J.A. 1996. '' 'footprint' with the Hubble Space Telescope Wide Field Planetary Camera 2,'' Sci, 274, 404–408

Colbert, E.J.M., Baum, S.A., Gallimore, J.F., O'Dea, C.P., Lehnert, M.D., Tsvetanov, Z.I., Mulchaey, J.S., and Caganoff, S. 1996. ''Galactic Winds in Edge-on Seyfert Galaxies. I. Optical Emission-Line Imaging and Optical Spectroscopy,'' ApJS, 105, 75

Connolly, A.J., Szalay, A.S., Dickinson, M., SubbaRao, M.U., and Brunner, R.J. 1997. ''Measured from the Hubble Deep Field,'' ApJ, 486, L11

Connolly, A.J., Szalay, A.S., Koo. D.C., Romer, A.K., Holden, B., Nichol, R.C. and Miyaji,T. 1996. ''Superclustering at Redshift z=0.54,'' APJ, 473, L67

Cooke, A.J., Espey, B.R., and Carswell R.F. 1997. ''Ionizing Flux at High Redshifts,'' MNRAS, 284, 552

Crenshaw, D. M., *et al.* 1996. ''Multiwavelength Observations of Short Time-scale Variability in NGC 4151. I. Ultraviolet Observations,'' ApJ, 470, 322

Csabai,I., Szalay, A.S. and Brunner, R., 1997. ''Multidimensional Index For Highly Clustered Data With Large Density Contrasts,'' in Statistical Challenges in Astronomy II, eds. E. Feigelson and A. Babu, Wiley, 447

Dahlem, M., Petr, M., Lehnert, M., Heckman, T., and Ehle, M. 1997. ''Evidence for a New Superwind Galaxy: NGC 4666,'' A&A, 320, 731

Della Ceca, R., Griffiths, R., and Heckman, T. 1996. ''ASCA Observations of Star-Forming Dwarf Galaxies,'' in Rontgenstrahlung from the Universe, eds. H. Zimmerman, J. Trumper, and H. Yorke, MPE Report 263, 369

Della Ceca, R., Griffiths, R., Heckman, T., and MacKenty, J. 1996. ‘‘ASCA Observations of Starbursting Dwarf Galaxies: The Case of NGC 1569,’’ ApJ, 469, 662

Della Ceca, R., Griffiths, R., and Heckman, T. 1997. ‘‘Starbursts and Outflows in Low Luminosity Galaxies: ASCA and ROSAT Observations of NGC 4449,’’ ApJ, 485, 581

Deltorn, J.M., Le Fèvre, O., Crampton, D., and Dickinson, M. 1997. ‘‘Massive Cluster of Galaxies at $z = 0.996$,’’ ApJ, 483, 21L

Dickinson, M. 1997. ‘‘High Redshift Universe,’’ eds. N. Tanvir, A. Aragon-Salamanca, and J.V. Wall, World Scientific, 207

Dickinson, M. 1997. ‘‘Galaxy Scaling Relations: Origins, Evolution and Applications,’’ eds. L. da Costa & A. Renzini, (Springer: Berlin), 215

Dickinson, M. 1997. ‘‘Universe with the VLT, ed. J. Bergeron’’ (Springer: Berlin), 274

Dickinson, M., and Steidel, C.C. 1996. ‘‘Absorption–Selected Galaxies at High Redshift,’’ in New Light on Galaxy Evolution, eds. R. Bender & R. Davies, (Dordrecht: Kluwer), 295

Dickinson, M. 1996. ‘‘Absorption–Selected Samples,’’ in The Universe at High-z, Large Scale Structure and the Cosmic Microwave Background, eds. E.Martinez–Gonzalez & J.L. Sanz, (Springer: Berlin), 3

Dopita, M.A., Koratkar, A.P., Allen, M.G., Tsvetanov, Z.I., Ford, H.C., Bicknell, G.V., and Sutherland, R.S. 1997. ‘‘The LINER Nucleus of M87: A Shock-Excited Dissipative Accretion Disk,’’ ApJ, 490, Nov 20

Dopita, M. A., Vassiliadis, E., Wood, P. R., Meatheringham, S. J., Harrington, J. P., Bohlin, R. C., Ford, H.C., Stecher, T. P., and Maran, S. P. 1997. ‘‘Hubble Space Telescope Observations of Planetary Nebulae in the Magellanic Clouds. V. Mass Dependence of Dredge-up and the Chemical History of the Large Magellanic Cloud,’’ ApJ, 474, 188

Edelson, R. A., *et al.* 1996. ‘‘Multiwavelength Observations of Short Time-scale Variability in NGC 4151. IV. Analysis of Multiwavelength Continuum Variability,’’ ApJ, 470, 364

Ford, H.C., Feldman, P., Golimowski, D., Tsvetanov, Z., Bartko, F., Crocker, J., Bely, P., Brown, R., Burrows, C., Clampin, M., Hartig, G., Postman, M., Rafal, M., Sparks, W., White, R., Broadhurst, T., Illingworth, G., Kelly, T., Woodruff, B., Cheng, E., Kimble, R., Krebs, C., Neff, S., Lesser, M. and Miley, G. 1996, ‘‘The Advanced Camera for the Hubble Space Telescope,’’ SPIE, 2807, 184

Ford, H.C., Tsvetanov, Z., Ferrarese, L., Kriss, G., Jaffe, W., Harms, R., and Dressel, L. 1997. ‘‘Gaseous Disks in the Nuclei of Elliptical Galaxies,’’ in Accretion Phenomena and Related Outflows, IAU colloquium 163, eds. D. T. Wickramasinghe, G. V. Bicknell, and L. Ferrario (ASP Conference Series)

Feldman, P., Festou, M., Tozzi, G., and Weaver, H. 1997. ‘‘CO_2/CO abundance ratio in 1P/Halley and several other comets observed by IUE and HST,’’ ApJ, 475, 829–834

Ferrarese, L., Freedman, W. L., Hill, R. J., Saha, A., Madore, B. F., Kennicutt, R. C., Jr., Stetson, P. B., Ford, H. C., Graham, J. A., Hoessel, J. G., Han, M., Huchra, J., Hughes, S. M., Illingworth, G. D., Kelson, D., Mould, J. R., Phelps, R., Silbermann, N. A., Sakai, S.,Turner, A., Harding, P., and Bresolin, F. 1996. ‘‘The Extragalactic Distance Scale Key Project. IV. The Discovery of Cepheids and a New Distance to M100 Using the Hubble Space Telescope,’’ ApJ, 464, 568

Ferrarese, L., Freedman, W. L., Hill, R. J., Saha, A., Madore, B. F., Kennicutt, R. C., Jr., Stetson, P. B., Ford, H. C., Graham, J. A., Hoessel, J. G., Han, M., Huchra, J., Hughes, S. M., Illingworth, G. D., Kelson, D., Mould, J. R., Phelps, R., Silbermann, N. A., Sakai, S., Turner, A., Harding, P., and Bresolin, F. 1997. ‘‘The Extragalactic Distance Scale Key Project. IV. The Discovery of Cepheids and a New Distance to M100 Using the Hubble Space Telescope: Erratum,’’ ApJ, 475, 853.

Gonzalez-Delgado, R., Leitherer, C., Heckman, T., and Cervino, M. 1997. ‘‘Are the Super Star Clusters in NGC 1569 Post-Starbursts?’’ ApJ, 483, 705

Gonzalez-Delgado, R., Leitherer, C., Heckman, T., Ferguson, H., and Lownethal, J. 1997. ‘‘Far-Ultraviolet Spectra of Starburst Galaxies,’’ in Starburst Activity in Galaxies, Rev. Mex Astron Astrofis, 6, 67

Graham, J. A., Phelps, R. L., Freedman, W. L., Saha, A., Ferrarese, L., Stetson, P. B., Madore, B. F., Silbermann, N. A., Sakai, S., Kennicutt, R. C., Harding, P., Bresolin, F., Turner, A., Mould, J. R., Rawson, D. M., Ford, H. C., Hoessel, J. G., Han, M., Huchra, J. P., Macri, L. M., Hughes, S. M., Illingworth, G. D., Kelson, D. D. 1997, ‘‘The Hubble Space Telescope Extragalactic Distance Scale Key Project. VII. The Discovery of Cepheids in the Leo I Group Galaxy NGC 3351,’’ ApJ, 477, 535

Greeley, B.G., Blair, W.P., Long, K.S., and Knigge, C. 1997. ‘‘ Far-Ultraviolet Spectrum of the Intermediate Polar EX Hya,’’ ApJ, 488, 419

Harrington, J.P., Borkowski, K.J. and Tsvetanov, Z.I. 1995. ‘‘GHRS Observations of Mass-Loaded Flows in Abell 78,’’ ApJ, 439, 264

Heckman, T. 1996. ‘‘Outflows from Barred Galaxies,’’ in Nobel Symposium No. 98: Barred Galaxies and Circumnuclear Activity, ed. A. Sanqvist and P. Lindblad (Springer: Berlin), 263

Heckman, T. 1997. ‘‘Starburst-Driven Outflows’’ in Starburst Activity in Galaxies, Rev Mex Astron Astrofis, 6, 156

Heckman, T., and Leitherer, C. 1997. ‘‘Kinematics of the Interstellar Medium in NGC 1705: Implications for Distant Star- Forming Galaxies,’’ AJ, 114, 69

Heckman, T., Gonzalez-Delgado, R., Leitherer, C., Meurer, G., Krolik, J., Wilson, A., Koratkar, A., and Kinney, A. 1997. ‘‘A Powerful Nuclear Starburst in the Seyfert Galaxy Mrk 477: Implications for the Starburst-AGN Connection,’’ ApJ, 482, 114

Henry, R.C. 1997. ‘‘Capabilities of HUBE, the Hopkins Ultraviolet Explorer,’’ in Proceedings of the Ickofest, ed. R. Rood (Cambridge University Press: Cambridge) 337

Henry, R.C. 1995. Review of ‘‘At Home in the Universe,’’ by J.A. Wheeler, Foundations of Physics, 25, 1637

Huang, C.H., Munn, J., Yanny, B., Kent, S., Petravick, D., Pordes, R., Szalay, A.S., Brunner, R., 1996. ''Object-Oriented Modeling and Design for Sloan Digital Sky Survey Retained Data,'' in Proc. ADASS Conference, 5, 289

Kelson, D. D., Illingworth, G. D., Freedman, W. F., Graham, J. A., Hill, R., Madore, B. F., Saha, A., Stetson, P. B., Kennicutt, R. C., Jr., Mould, J. R., Hughes, S. M., Ferrarese, L., Phelps, R., Turner, A., Cook, K. H., Ford, H.C., Hoessel, J. G., Huchra, and J. 1997, ''The Extragalactic Distance Scale Key Project. III. The Discovery of Cepheids and a New Distance to M101 Using the Hubble Space Telescope: Erratum,'' ApJ, 478, 430

Knigge, C. Long, K.S., Blair, W.P., and Wade, R.A. 1997. ''and Veiling Curtains: Dissecting the Ultraviolet Spectrum of the Dwarf Nova Z Cam in Outburst,'' ApJ, 476, 291

Koo, D.C., Vogt, N.P., Phillips, A.C., Guzman, R., Wu, K.L., Faber, S.M., Gronwall, C., Forbes, D.A., Illingworth, G.D., Groth, E.J., Davis, M., Kron, R.G., Szalay, A.S. 1996. ''Redshift z approx1imately 1 Field Galaxies Observed with the Keck Telescope and the Hubble Space Telescope,'' ApJ, 469, 535

Krasnopolsky, V.A., Mumma, M.J., Abbott, M., Flynn, B.C., Meech, K.J., Yeomans, D.K., Feldman, P.D., and Cosmovici, C.B. 1997. ''soft X-rays and a sensitive search for noble gases in comet Hale-Bopp (C/1995 O1),'' Sci, 277, 1488

Kriss, G., Krolik, J., Grimes, J., Tsvetanov, Z., Zheng, W., and Davidsen, A.F. 1996. ''HUT Observations of the Lyman Limit in AGN: Implications for Unified Models,'' in IAU Colloquium 159, Emission Lines in Active Galaxies: New Methods and Techniques, eds. B.M. Peterson, F.-Z. Cheng, & A.S. Wilson (Astronomical Society of the Pacific: San Francisco), 113, 453

Kruk, J. W., Kimble, R. A., Buss, Jr., R. H., Davidsen, A. F., Durrance, S. T., Finley, D. S., Holberg, J. B., & Kriss, G. A. 1997. ''Final Astro-1 Calibration of the Hopkins Ultraviolet Telescope: A Test of White Dwarf Model Atmospheres as FUV Calibration Standards,'' ApJ, 482, 546

Lagrange, A.M. *et al.* 1996. ''GHRS Observations of the Extrasolar Protoplanetary System b Pictorus,'' in Science with the Hubble Space Telescope, P. Benvenuti, F.D. Macchetto and E.J. Schrier eds., STScI, 532

Laming, J.M., Raymond, J.C., McLaughlin, B.M., and Blair, W.P. 1996. ''SN1006,'' ApJ, 472, 267

Landy, S.A., Szalay, A.S., Koo, D.C. 1996. ''Strong Angular Clustering of Blue Galaxies,'' ApJ, 460, 94

Le Fèvre, O., Deltorn, J.M., Crampton, D., and Dickinson, M. 1996. ''Clustering around the Radio Galaxy MRC 0316-257 at $z=3.14$,'' ApJ, 471, 11L

Lehnert, M., and Heckman, T. 1996. ''On the Nature of Starburst Galaxies,'' ApJ, 472, 546

Levenson, N.A., Graham. J.R., Aschenbach, B., Blair, W.P., Brinkmann, W., Busser, J.-U., Egger, R., Fesen, R.A., Hester, J.J., Kahn, S.M., Klein, R.I., McKee, C.F., Petre, R., Pisarski, R., and Raymond, J.C. 1997. ''Rosat-HRI X-Ray Survey of the Cygnus Loop,'' ApJ, 484, 304

Lipari, S., Tsvetanov, Z., and Macchetto, F. 1997. ''Luminous Infrared Galaxies. II. NGC 4945: A Nearby Obscured Starburst/Seyfert Nucleus,'' ApJS, 111, 369

Long, K. S. 1996, ''Far Ultraviolet Observations of Dwarf Novae Made with the Hopkins Ultraviolet Telescope'' in IAU Colloq. 158 Cataclysmic Variables and Related Objects, ed. A. Evans & J. H. Wood (Dordrecht: Kluwer), 233

Macchetto, F.D., and Dickinson, M. 1997. '' Universe,'' Scientific American, 276, 5, 92

Madau, P., Ferguson, H.C., Dickinson, M., Giavalisco, M., Steidel, C.C., and Fruchter, A. 1996. ''Colour Selection and Star Formation History to $z=4$,'' MNRAS, 283, 1388

Marlowe, A., Meurer, G., Heckman, T., and Schommer, R. 1997. ''The Taxonomy of Blue Amorphous Galaxies,'' ApJS, 112, 285

Marshall, H. L., Carone, T. E., Peterson, B. M., Clavel, J., Crenshaw, D. M., Korista, K. T., Kriss, G. A., Krolik, J. H., Malkan, M. A., Morris, S. L., O'Brien, P. T., and Reichert, G. A. 1997. ''The Variability and Spectrum of NGC 5548 in the Extreme Ultraviolet,'' ApJ, 479, 222

Massey, P., Bianchi, L., Hutchings, J.B., Stecher, T. 1996. ''UV-Brightest Stars of M33 and its Nucleus: Discovery, Photometry, and Optical Spectroscopy,'' ApJ, 469, 629

May, M.J., Finkenthal, Regan, S.P., Moos, H.W., Terry, J.L., Goetz,J.A., Graf, M.A., Rice, J.E., Marmar, E.S., Fournier, K.B., and Goldstein, W.H. 1997. ''The Measurement of Intrinsic Impurities in the Alcator C-Mod Tokamak Plasma using Low Resolution Spectroscopy,'' Nuclear Fusion, 37

May, M.J., Regan,S.P., Soukhanovskii, V.A., Finkenthal, M., Moos, H.W., Goetz, J.A., Lipschultz, B., Terry, J.L., West, W.P., Allen, S.L., and Brooks, N.H. 1997. ''A Multilayer Mirror Diagnostic for Monitoring XUV Impuity Emission in the Divertor of Alcator C-Mod,'' Rev. Sci. Instrum., 68, 1047

McCall, M.L., Straker, R.W., and Uomoto, A.K. 1996. ''Automatic Determination of Unbiased Luminosity Functions for HII Regions,'' AJ, 112, 1096

McPhate, J. B., McCandliss, S. R., Feldman, P. D., Burgh, E. B., and Pelton, R. 1997. ''Rocket Borne Long-slit UV Spectroscopy of Comet Hale-Bopp,'' DPS, 29, 3724

Meurer, G.R., 1996. ''The Ultraviolet Structure of Starbursts,'' in The Interplay between Massive Star Formation, The ISM and Galaxy Evolution, D. Kunth, B. Guiderdoni, M. Heydari-Malayeri, & T.X. Thuan, eds. (Editions Frontières: Paris), 333

Meurer, G.R., 1997. ''The Dark Blue Compact Dwarf Galaxy NGC 2915,'' PASAU, 14, 77

Meurer, G., Heckman, T., Leitherer, C., Lowenthal, J., and Lehnert, M. 1997. ''The Panchromatic Limit to Starburst Intensity at Low- and High-Redshift,'' AJ, 114, 54

Miyaji, T., Connolly, A.J., Szalay, A.S. and Boldt, E., 1997. ''Soft X-Ray Emission and Optical Multicolors of Faint QSOs in the Selected Area 57,'' AA, 323, L37

Moos, H.W. 1997. ''FUSE: A Different Approach to Lowering the Cost.'' in Proc. 1997 IEEE Aerospace Conference, 3, 299

Morrison, J.E., Roser, S., Lasker, B.M., Smart, R.L., and Taff, L.G. 1996. ''A Schmidt Plate Coma-Like Term,'' AJ, 111, 1405

Morrissey, P.F., Feldman, P.D., Clarke, J.T., Wolven, B.C., Strobel, D.F., Durrance, S.T., and Trauger, J.T. 1997. ''imaging of the Jovian aurora with the Hopkins Ultraviolet Telescope and the Hubble Space Telescope,'' ApJ, 476, 918

Mulchaey, J., Wilson, A., and Tsvetanov, Z. 1996. ''An Emission-Line Imaging Survey of Seyfert Galaxies of Early Morphological Type,'' ApJS, 102, 309

Mulchaey, J., Wilson, A., and Tsvetanov, Z. 1996. ''An Emission-Line Imaging Survey of Early-Type Seyfert Galaxies. II. Implications for Unified Schemes,'' ApJ, 467, 197

Murthy, J., Hall, T.D., Henry, R.C., and Holberg, J.B. 1996. ''Voyager Observations of Dust Scattered Starlight,'' in New Extragalactic Perspectives in the New South Afric, ed. D.L. Block and J.M. Greenberg (Dordrecht: Kluwer) 549

Neilsen, E.H., Jr., Tsvetanov, Z.I., and Ford, H.C. 1997. ''The Surface Brightness Fluctuations and Globular Cluster Population of NGC 4478,'' ApJ, 483, 745

Neufeld, D. A., Chen, W., Melnick, G. J., De Graauw, T., Feuchtgruber, H., Haser, L., Lutz, D., and Harwit, M. 1996. ''Detection of far-infrared rotational lines of water vapour toward W Hydrae,'' AA, 315, L237

Neufeld, D.A., and Hollenbach, D.J. 1996. ''Free-Free Emission from Accretion Shocks,'' ApJ, 471, L45

Neufeld, D.A., and Spaans, M. 1996. ''Red Fluorescent Line Emission from Hydrogen Molecules in Diffuse Molecular Clouds,'' ApJ, 473, 894

Noll, K. S., Johnson, R. E., Lane, A. L., Domingue, D. L., and Weaver, H. A. 1996. ''Detection of Ozone on Ganymede,'' Science, 273, 341

Norman, C., Bowen, D., Heckman, T., Blades, J.C., and Danly, L. 1996. ''HST Observations of Absorption Lines Associated with Starburst Galaxy Outflows,'' ApJ, 472, 73

Raymond, J. C., Blair, W. P., Long, K. S., Vancura, O., Edgar, R. J., Morse, J., Hartigan, P., and Sanders, W. T. 1997. ''Spectrum of a Face-On Shock Wave in the Vela Supernova Remnant,'' ApJ, 482, 881

Regan, S.P., May, M.J., Fikenthal, M., and Moos, H.W. 1996. ''Multilayer Mirror Based Monitors for the Impurity Controls in ITER,'' Diagnostics for Experimental Thermonuclear Fusion Reactors, ed. P.E. Stott, (Plenum Press: New York), 315

Regan, S.P., May, M.J., Fikenthal, M., Moos, H.W., Diebold, D.A., Hershkowitz, N., Wang, E.Y., Wang, X., Doczy, M., Edgell, D., Intrator, T., Kant, G., Oliva, S., Sorensen, J., Vukovic, M., Winz, G.R., Wukitch, S., Breun, R., Brouchous, D.A., Cekic, M., Cui, B., Kishinevsky, M., Meyer, J.A., and Prober, P.H. 1997. ''Impurity Transport Measurements of Biased H-modes in Hydrogen and Deuterium Plasmas on the Phaedrus-T Tokamak,'' Nuclear Fusion, 37, 657

Regan, S.P., May, M.J., Fournier K.B., Soukhanovskii, V.A., Finkenthal, M., Moos, H.W. 1997. ''How to Beat the Low Resolution of Multilayer Mirror Spectra,'' Rev. Sci. Instrum., 68, 1002

Regan, S.P., May, M.J., Soukhanovskii, V., Fikenthal, M., and Moos, H.W., Farnum, E.H., and Clinard, Jr., F.W., Tarrio, C., and Watts, R. 1997. ''An Evaluation of Muultilayer Mirrors for the Soft X-ray and Extreme Ultraviolet Wavelength Range that were Irradiated with Neutrons,'' Rev. Sci. Instrum., 68, 757

Regan,S.P., May, M.J., Soukhanovskii, V., Finkenthal, M., and Moos, H.W., Farnum, E.H., and Clinard, Jr., F.W., Tarrio, C. and Watts, R. 1997. ''An Evaluation of Mutilayer Mirrors for Soft X-ray and Extreme Ultraviolet Wavelength Range that were Irradiated with Neutrons,'' Rev. Sci. Instrum., 68, 1055

Regan, S.P., May, M.J., Fournier, K.B., Soukhanovskii, V.A., Finkenthal, M., Moos, H.W. 1997. ''How to Beat the Low Resolution of Multilayer Mirror Spectra,'' Rev. Sci. Instrum., 68, 1002

Rodríguez-Pascual, P.M., *et al.* 1997. ''Steps Toward Determination of the Size and Structure of the Broad-Line Region in Active Galactic Nuclei. IX. Ultraviolet Observations of Fairall 9,'' ApJS, 110, 9

Rix, H.W., de Zeeuw, P.T., Cretton, N., van der Marel, R.P., Carollo, C.M. 1997. ''Elliptical Galaxy NGC 2434,'' ApJ, 488, 702

Ryans, R.S.I., Keenan, F.P., Sembach, K.R., and Davies, R.D. 1997. ''Optical and H I Studies of High and Intermediate Velocity Gas Towards Complex A,'' MNRAS, 289, 986

Ryans, R.S.I., Keenan, F.P., Sembach, K.R., and Davies, R.D. 1997. ''The Distance to Complex M and the Intermediate Velocity Arch,'' MNRAS, 289, 83

Ryans, R.S.I., Sembach, K.R., and Keenan, F.P. 1996. ''UHRF Observations of the Interstellar Medium Towards Two Stars in the Galactic Halo,'' A&A, 314, 609

Sambruna, R. M., George, I. M., Madejski, G., Urry, C. M., Turner, T. J., Weaver, K. A., Maraschi, L., and Treves, A. 1997. ''An X-ray Absorption Feature in the BL Lacertae Object H1426+428,'' ApJ, 483, 774

Sahnow, D., Friedman, S., Oegerle, W., Moos, H.W., Green J., Siegmund, O. 1996. ''Design and Predicted Performance of the Far Ultraviolet Spectroscopic Explorer,'' SPIE, 2807, 2

Sahnow, D.J., VanDyke, C.M., Gong,Q., Bremer,J., Kennedy, M.J., ''Optical Performance Budget for the Far Ultraviolet Spectroscopic Explorer,'' SPIE, 2863, 27

Savage, B.D., Sembach, K.R., and Lu, L. 1997. ''Absorption By Highly Ionized Interstellar Gas Along Extragalactic and Galactic Sight Lines,'' AJ, 113, 2158)

Savage, B.D. and Sembach, K.R. 1996. ''Interstellar Abundances from Absorption Line Observations with the Hubble Space Telescope,'' ARA&A, 34, 279

Savage, B.D. and Sembach, K.R. 1996. ''Interstellar Gas-Phase Abundances and Physical Conditions Toward Two Distant High-Latitude Halo Stars,'' ApJ, 470, 893

Sembach, K.R., Savage, B.D., and Tripp, T.M. 1997. ''High Resolution Ultraviolet Observations of the Highly Ionized Interstellar Gas Toward Radio Loops I and IV,'' ApJ, 480, 216

Silbermann, N., Harding, P., Madore, B., Kennicutt, R., Saha, A., Stetson, P., Freedman, W., Mould, J., Graham, J., Hill, R., Turner, A., Bresolin, F., Ferrarese, L., Ford, H.C., Hoessel, J., Han, M., Huchra, J., Hughes, S., Illingworth, G., Phelps, R., and Sakai, S. 1996, ''The Hubble Space Telescope Key Project on the Extragalactic Distance Scale. VI. The Cepheids in NGC 925,'' ApJ, 470, 1S

Simon, M., Holfeltz, S.T., and Taff, L.G. 1996. ''Measurement of T Tauri Binaries Using the Hubble Space Telescope Fine Guidance Sensors,'' AJ 469, 890

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

Spaans, M., Carollo, C.M., 1997. ''a Function of Redshift: The Role of the Multi-Phase ISM,'' ApJ, 482, L93

Sparks, W.B., Carollo, C.M., Macchetto, F. 1997.

Steidel, C.C., Dickinson, M., Meyer, D., Adelberger, K., and Sembach, K. 1997. ''Spectroscopy in the Field of 3C 336,'' ApJ, 480, 568

Steidel, C.C., Giavalisco, M., Dickinson, M., Adelberger, and Kurt L. 1996. 352

Steidel, C.C., Giavalisco, M., Pettini, M., Dickinson, M., and Adelberger, K.L. 1996. ''Forming Galaxies at Redshifts $z>3$,'' ApJ, 462, 17

Stern, D., Spinrad, H. and Dickinson, M. 1996. ''Radio Galaxy MG 1136+1346 ($z=1.003$),'' AJ,111, 102

Stiavelli, M., Peletier, R.P., and Carollo, C.M. 1997. ''Counter-Jet Region of M87 in the Near-Infrared,'' MNRAS, 285, 181

Stutman, D., Hwang, Y.S., Ono, M., Finkenthal, M., Moos, H.W. 1996. ''Spectroscopic Diagnostics on Low Aspect Tokamaks,'' Journal of Electron Spectroscopy and Related Phenomena, 80, 249

SubbaRao, M.U., Connolly, A.J., Szalay, A.S. and Koo, D.C., 1996. ''Luminosity Functions from Photometric Redshifts I: Techniques,'' AJ, 12, 929

Szalay, A.S., 1997. ''Novel Statistical Aspects of Large Scale Structure,'' in Proc. Int. School of Astrofundamental Physics, Erice, eds. N. Sanchez, 538

Szalay,A.S., 1997. ''The Large Scale Structure of the Universe; in Proc. of the Erice School on Astrophyics; eds D.N. Schramm and P. Galeotti, Kluwer Academic Publishers, 538

Szalay, A.S. and Brunner, R.J., 1997. ''Exploring Terabyte Archives in Astronomy,'' in Proc. Wide Field Spectroscopy, Athens, eds. M.Kontizas and D. Morgan, 95

Szapudi, I. and Szalay, A.S. 1996. ''Effects of Sampling on Measuring Galaxy Count Probabilities,'' ApJ, 459, 504

Szapudi,I. and Szalay, A.S., 1997. ''Cumulant Correlators from the APM,'' ApJ, 481, L1

Szkody, P., Vennes, S., Sion, E. M., Long, K. S., and Howell, S. B. 1997. ''Extreme Ultraviolet Photometry and Spectroscopy of BL Hydri,'' ApJ, 487, 916

Taff, L.G. 1997. ''Target Localization from Bearings-Only Observations,'' IEEE Trans. Aerospace and Electronic Systems, 33, 1

Taff, L.G., Pesto, S., Tel'nyuk-Adamchuk, V.V., and Molotaj, O.A. 1997. ''Compiled Catalogue of Positions and Proper Motions of 4272 Stars North of Declination 80,'' Kinematics and Physics of Celestial Bodies, 13, 7

Taff, L.G., Tel'nyuk-Adamchuk, V.V., and Molotaj, O.A. 1997. ''NPC, A New Combined Position Catalogue of Stars in the Northern Pole Region,'' in Dynamics and Astrometry of Natural and Artificial Celestial Bodies, eds. I. M. Wytrzyszczak, J. H. Lieske, and R. A. Feldman, (Dordrecht: Kluwer), 499

Tsvetanov, Z.I., and Petrosian, A.R. 1995. ''HII Region Populations in Seyfert Galaxies. I. Database,'' ApJS, 101, 287

Turnshek, D.A., Lupie, O., Espey, B.R., and Rao, S. 1997. ''Observations of the Gravitationally Lensed Cloverleaf Broad Absorption Line QSO H1413+1143: Imaging,'' ApJ, 485, 100

Turnshek, D.A., Monier, E., Sirola, C.J., and Espey, B.R. 1997. ''HST-FOS Survey for Broad Absorption Lines in a Sample of Low-Redshift Weak-[OIII] QSOs,'' ApJ, 476, 40

Wang, J., Heckman, T., Weaver, K., and Armus, L. 1997. ''An X-ray and Optical Study of the Infrared-Luminous Galaxy Merger Mrk 266,'' ApJ, 474, 659

Weaver, H. 1997. ''The Impact of Comet D/Shoemaker-Levy 9 with Jupiter,'' in Molecules in Astrophysics: Probes and Processes, in Proc. of IAU Symposium 198, E. F. van Dishoeck (ed.), Kluwer, 205

Weaver, H., Feldman, P., McPhate, J., A'Hearn, M., Arpigny, C., Brandt, J. C., Festou, M., Stern, S., and Tozzi, G. 1997. ''the nucleus of comet Hale-Bopp, Sci, 275, 1900

Weaver, K. A., Yaqoob, T., Mushotzky, R. F., Nousek, J., Hayashi, I., and Koyama, K.1997. ''Iron K-alpha Evidence for Two X-ray Reprocessors in MCG−5-23-16,'' ApJ, 474, 675

Williams, R.E., Blacker, B., Dickinson, M., Dixon, Van Dyke Dixon, W., Ferguson, H.C., Fruchter, A.S., Giavalisco, M., Gilliland R.L., Heyer, I., Katsanis, R., Levay, Z., Lucas, R.A., McElroy, D.B., Petro, L., Postman, M., Adorf, H.-M., and Hook, R.N. 1996. ''observations, data reduction, and galaxy photometry,'' AJ, 112, 1335

Willmer, C.N.A., Koo, D.C., Ellman, N., Szalay, A.S., Kurtz, M.J., 1996. ''A Medium Deep Redshift Survey of a Mini−Slice at the North Galactic Pole, II. The Data,'' ApJS, 104, 199

Winkler, P. F., and Long, K. S. 1997. ''A Second UV Light Bulb Behind the SN1006 Remnant,'' ApJ, 486L, 137

Vogeley, M.S. and Szalay, A.S., 1996. ''Eigenmode Analysis of Galaxy Redshift Surveys, Theory and Methods,'' ApJ, 465, 34

Wolven, B. C., Feldman, P. D., Strobel, D. F., and McGrath, M. A. 1997. ''post-SL9 impact site on Jupiter,'' ApJ, 475, 835–842

Zheng, W., Kriss, G. A., Telfer, R. C., Grimes, J. P., and Davidsen, A. F. 1997. ''A Composite HST Spectrum of Quasars,'' ApJ, 475, 469

Holland C. Ford