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

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[S0002-7537(99)03401-0]

The following report covers the period from October 1997 through September 1998.

1. INTRODUCTION

Historically, the backbone of our expanding astronomy program has been space ultraviolet instrumentation and missions, and that portion of our program continues strong, with the rapid progress of both FUSE (Far Ultraviolet Spectroscopic Explorer, to be launched in early 1999) and ACS (Advanced Camera for Surveys, for Hubble Space Telescope, to be placed aboard HST in mid 2000). Our sounding rocket program continutes to train the experimentalists of the future, and our participation in the Sloan Digital Sky Survey continues to be vigorous. Theoretical astronomy and ground-based observing continue as major components of our balanced total astronomy and astrophysics program.

2. PERSONNEL

CAS visitors are S. Casertano, L. Dressel, B. R. Espey, M. Finkenthal, A. Fullerton, T. Hartquist, J. Najita, P. Rosati, W. Sparks, and M. Urry. Departed CAS is D. Hall (University of Colorado). On leave from CAS are: Professor R. Giacconi (Director, ESO); Associate Research Scientist C. P. Holmes (Program Executive for Science Operations, NASA Space MO& DA, NASA Headquarters); Professor C. W. Kim (President, Korean Academy of Sciences). CAS permanent staff are: Professors A. F. Davidsen, P. D. Feldman (Chair, Henry A. Rowland Department of Physics and Astronomy), H. C. Ford (Director, CAS), T. M. Heckman, R. C. Henry (Director, Maryland Space Grant Consortium), B. R. Judd, J. H. Krolik, H. W. Moos, D. Neufeld, D. F. Strobel, A. Szalay, E. T. Vishniac, and R. F. G. Wyse; GSFC Scientists R. Mushotzky and K. A. Weaver; STScI Scientists R. J. Allen, H. C. Ferguson, M. G. Hauser (Deputy Director, STScI), G. A. Kriss, M. Livio, M. Postman, and R. Williams; Associate Research Professor W. P. Blair; Principal Research Scientist L. Taff; Research Scientists L. Bianchi, R. Burg, S. Friedman, J. Kruk, S. McCandliss, J. Murthy, W. Oegerle, Z. Tsvetavov, A. Uomoto, H. Weaver, and W. Zheng; Associate Research Scientists B-G. Andersson, C. M Carollo, A. Connolly, I. Csabai, A. Dey, M. Dickinson, D. Golimowski, M. E. Kaiser, P. A. Knezek, G. Meurer, D. Sahnow, K. R. Sembach, D. Stutman, and A. Thakar; and Postdoctoral Fellows E. Agol, R. Brunner, M. Houdashelt, B. Jain, P. Kunszt, N. Levenson, T. Matsubara, E. May, E. Murphy, S. Ridgeway, R. Sankrit, D. Strickland, M. SubbaRao, P. Tozzi, J. Wiseman, and B. Wolven.

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 (905-1190 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 spring of 1999 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, B. G. Anderson, L. Bianchi, W. Blair, P. Chayer, A. Davidsen. P. Feldman, S. Friedman, A. Fullerton, 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, now scheduled for July of 2000. The ACS is being built by a collaboration between Ball Aerospace, the Johns Hopkins University, and the Goddard Space Flight Center. Members of the science team, led by the PI Holland Ford, are at JHU, the Space Telescope Science Institute, the University of Arizona, the University of California Santa Cruz, Leiden University, the European Southern Observatory, and the Goddard Space Flight Center. A list of science and engineering team members and information about the ACS can be found at http://adcam.pha.jhu.edu.

The ACS is undergoing final assembly and optical alignment at Ball. The instrument will be shipped to Goddard in November, 1998, for extensive thermal vacuum testing and calibration. The instrument will be shipped with the second flight build of the High Resolution Camera (HRC) and the first flight build of the Wide Field Camera (WFC). After testing at Goddard, the ACS will be returned to Ball for further work on the cameras. The HRC Build 2 camera will be disassembled to fix a problem with internal baffles. A third build of the WFC will then be installed in the ACS. The third build will include changes in the bonding of the two-stage thermoelectric coolers, and will have two 2k$\times$ 4k

CCDs that are superior to those in Build 2. After alignment of the cameras, the ACS will be returned to Goddard for final calibration and subsequent shipping to Cape Canaveral in preparation for launch.

5. RESEARCH AND ACTIVITIES

Luciana Bianchi is co-Investigator of the NASA SMEX mission GALEX (The Galaxy Evolution Explorer, P.I. C. Martin, Caltech). GALEX will be launched in 2001 to perform imaging and spectroscopic imaging and spectroscopic surveys of the sky in the ultraviolet. GALEX will produce an unprecedented, statistically powerful database of UV images and spectra of nearby and distant galaxies, stellar objects, and a UV map of the background. Luciana Bianchi is responsible for the GALEX science data archive. The ($\approx$ 3TB) GALEX science archive will contain an order of magnitude more objects than any previous catalog, and an unprecedented, background limited survey of the whole sky in two UV bands.

L. Bianchi continued her study of hot massive stars in Local Group galaxies based on HST and ground based data with analysis of WR stars. Two young star forming regions in NGC6822 were also resolved into their stellar content, revealing coeval populations only a few million years old.

R. Chandar (graduate student), L. Bianchi and H. Ford discovered a significant population of young, blue clusters in M33, and compiled the first unbiased, representative sample of star clusters for this galaxy, from HST WFPC2 multiband images. Only four of these objects were known as clusters before, and 11 were classified as extended objects. The study (Ph.D. thesis of Ms. Chandar) extends the parameter space of known M33 clusters in two ways: (i) detecting more peaked and intrinsically small objects (observable radii $\sim 1''$), which are not distinguishable from stellar objects in ground based studies; (ii) revealing the youngest clusters and measuring their ages by use of far-UV and U,B,V images. This study revealed that the clusters formed continuously in M33 from $\sim 10^6 - 10^{10}$ years. Combining the measured photometry and ages with theoretical M/L_V ratios cluster masses between $\sim 4 \times 10^2 M_\odot - 3 \times 10^5 M_\odot$ were derived. There is a correlation between the ages and masses of our clusters, the oldest objects being the most massive. The global properties of the M33 clusters are compared to other Local Group galaxy cluster systems. Clusters at all ages are found to have well relaxed density profiles which are reasonably well fit by King profiles.

William P. Blair is an Associate Research Professor in the Department of Physics and Astronomy. He is the Chief Mission Planning Scientist for the Far Ultraviolet Spectroscopic Explorer (FUSE) Project at JHU, in charge of development of the mission planning segment of the ground operations system. Blair is also involved in public outreach and education for FUSE, and oversees the FUSE project public web site (http://fuse.pha.jhu.edu). 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 the Hopkins Ultraviolet Telescope (HUT), the Hubble Space Telescope (HST), and ground-based optical observatories.

Although the HUT project has officially wound down this year, there is still much to be done with the data returned from the two Astro shuttle missions. This year, effort has concentrated on the interpretation of the FUV spectrum of the magnetic cataclysmic variable AM Herculis, including the short timescale variability seen during Astro-2. This effort, led by graduate student B. Greeley and including K. Long (STScI) and J. Raymond (SAO), has included in a detailed time variability analysis of both line and continuum components, and demonstrates the importance of coverage in the 900 - 1200 Å of these systems. Other HUT projects completed this year include a paper on Her X-1 (led by B. Boroson from CfA) and the Herbig-Haro object HH2 (led by J. Raymond). Work continues on an extensive HUT/IUE/optical data set for a shocked cloud in the Cygnus Loop with graduate student C. Danforth. HUT and IUE ultraviolet observations of supernova remnants were presented by Blair in invited talks at the final IUE conference in Seville, Spain, in 19987 November.

Work with HST continues to focus primarily on analysis of data for two young ''oxygen-rich'' supernova remnants in the Magellanic Clouds, with J. Morse (U. Col.), Raymond, Long, and others. HST imaging and spectroscopy have shed new light on the abundances, excitation mechanisms, and circumstellar environments of N132D in the LMC and 1E0102-7219 in the SMC. These results were presented at the fall 1997 ''TexMex'' conference and at the IUE conference mentioned above. The imaging portion of a cycle 7 HST program on nonradiative shocks in the Cygnus Loop was begun, but the spectroscopy portion has been delayed by programmatic concerns. New post-doctoral fellow R. Sankrit (previously from Arizona State Univ.) has joined Blair to work on this and other projects.

Two ground-based optical surveys of nearby galaxies have come to completion this year. With D. Matonick and R. Fesen (Dartmouth) and Long, 35 supernova remnants have been identified in the spiral galaxy NGC 2403, with 15 of them confirmed spectroscopically. In addition, with S. Gordon (Livermore), Long, and others, an extensive new study of supernova remnants in M33 has been published. The combined optical/radio technique used raised the total number of confirmed remnants in M33 to 98.

Arthur Davidsen directed the final year of the Hopkins Ultraviolet Telescope (HUT) project as principal investigator. Results from the Astro-1 mission (1990) and the Astro-2 mission (1995) have mostly now been published (primarily in the Astrophysical Journal), and the calibrated data from both missions have been deposited with the NSSDC. As of this writing, there have been 36 papers published in the refereed literature from HUT observations on Astro-1, and 47 HUT-related papers from Astro-2. Several more results are still in the process of being completed. A list of publications associated with HUT may be found at http://praxis.pha.jhu.edu/hut.html. Davidsen and his HUT colleagues, together with several astronomers at other institutions, prepared a proposal to NASA for the Small Explorer Program (SMEX) called HUTSPA, in which an improved version of HUT would be integrated with a SPARTAN 400 spacecraft to be developed by GSFC and launched from the space shuttle for a 2-year mission. The primary goal identified for HUTSPA is to measure the properties of ionized helium in the lowest-density regions of intergalactic space that fill most of the universe at redshifts from 2 to 3. Such data would provide new clues for understanding the evolution of structure from the earliest density fluctuations to the present-day galaxy distribution. Since this proposal has not yet been selected for development, however, it is likely that HUT will soon be transferred to the Smithsonian Institution, where it is expected to become a part of a new display on cosmology at the National Air and Space Museum.

After completing his service as interim dean of arts and sciences at Johns Hopkins, Davidsen spent a semester at the Center for Space Research at MIT during Fall 1997. He is now looking forward to the launch of the FUSE mission, which, it is hoped, may be capable of providing new results on intergalactic helium at redshifts 2-3 at higher resolution than was possible with HUT.

During the year **Brian R. Espey** moved to an appointment with the European Space Agency at the Space Telescope Science Institute, although he remains a visiting Associate Research Scientist at Hopkins. He continued his work on emission line spectroscopy of symbiotic binary stars and active galactic nuclei (AGN) spectra. In addition, Espey has further collaborated with the atomic physics group at the Queen's University of Belfast to develop improved diagnostics for nebular material using the most up-to-date atomic data. This latter work has led to the publication of a paper (Keenan *et al.* 1998), along with the submission of another. More papers are planned.

Espey continued his collaborations with 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. This work, which is part of Birriel's thesis effort, resulted in a paper on the efficiency of the Raman lines of OVI in the symbiotic binary Z Andromedae (Birriel *et al.* 1998), and two other papers are nearing completion. Further thesis work will study the statistical properties of Raman scattering in a sample of symbiotic systems observed with a variety of far-UV instruments, and aim to determine the parameters fundamental to enhanced scattering.

Espey led in the analysis of far-UV spectra of the Seyfert 1 galaxy NGC 4151 obtained during the Orfeus-II space astronomy mission in November/December 1996. The goal of this work was to study the variability in this enigmatic object by closely monitoring its spectrum at far-UV wavelengths. Absorption features of OVI are of too high an optical depth to permit accurate deblending and hence isolation of the relative variations in strength. However, variability of the SIV 1076Å and CIII* 1176Å absorption lines was found to anti-correlate with the continuum variations after a short lag of 1–2 days, as expected on the basis of photoionization models. The high ionization emission lines were also found to follow the continuum with a lag similar to that of the absorbing material. Results are published in Espey *et al.* (1998).

During the summer, work proceeded on the analysis of a large number of QSO spectra. Espey worked with undergraduates S. Andreadis and P. Maksym of Yale University to obtain a database of line profile measurements for use in emission line studies, in particular the so-called ''Baldwin Effect.'' By analysing the spectra in a consistent manner the large scatter in emission line parameters obtained by compilations of heterogeneous datasets will be much reduced. A review of part of this work was presented by Espey at the La Serena meeting on ''Quasars as Standard Candles in Cosmology.''

As part of the group responsible for the calibration of the Hopkins Ultraviolet Telescope (HUT) spectrograph, Espey collaborated with others in the HUT group on the definitive calibration paper for the HUT instrument as flown on the Astro-2 mission in March 1995. This paper is currently in press.

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. 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 continued his collaboration with H. A. Weaver (JHU) in a program of HST/STIS observations of comets Hale-Bopp and Hartley 2. He collaborated with H. W. Moos and D. F. Strobel (JHU) in HST/STIS observing programs of Io and Ganymede, and with A. Vidal-Madjar (IAP) and colleagues 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), the Advanced Camera for HST, the Alice ultraviolet spectrometer experiment for Rosetta, and the Comet Nucleus Tour Mission.

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. A paper by Y. Pei, H. Ford, Z. Tsvetanov, G. Kriss, and R. Harms submitted to the Ap.J reports strong evidence for a massive black hole in the fainter (P2) of the ''two'' nuclei in M31. The authors used the FOS to discover a strong asymmetry in the rotation curve along the major axis of the nucleus. The observed rotational curve approches a maximum of -270 km/s on the side of the faint peak and a maximum of +160 km/s on the side of the bright peak. The center of rotation does not coincide with either of the peaks but lies in between the two, at $0\farcs13$ from the faint peak. The observed velocity dispersion reaches a maximum of 300 km/s and occurs at the faint peak location to within $0\farcs03$. The kinematic data strongly support the hypothesis, suggested by Tremaine, that the nucleus of M31 is a thick stellar eccentric disk orbiting around a massive black hole. The bright peak is the position where the density of stars in the disk is highest due to slowing at the apoapsis of the eccentric disk. With simple exponential profiles for the disk model, they can fit nearly all of the photometric and kinematic data, yielding an estimate of mass of $(7.0 \pm 0.4) \times 10^7 M_\odot$ for the central black hole in the nucleus of M31.

Ford, E. Peng and K. Freeman used the CTIO 4-m and Argus spectrograph to measure the radial velocities of 224 planetary nebulae at projected distances up to 50 kpc in the halo of Centaurs A. The velocities show a slowly declining rotation curve beyond 20 kpc, with rotation persisting to 40 kpc. The velocity dispersion is constant or very slowly declining throughout the halo. Analysis using the Heisler, Tremaine, and Bahcall mass estimator shows that the mass of Cen A doubles between 10 and 40 kpc, and appears to be approaching an asymptotic limit at 50 kpc.

Ford is a member of the NOVA Instrument Steering Committee, a group that reviews instrument proposals and plans submitted by the consortium of four Dutch Universities that won a national competition for five years funding of targeted excellence. Ford has given several invited talks on the ACS, including talks at Leiden University, a ''Space Congress,'' and an Optical Society of America meeting.

Scott D. Friedman is the Hopkins project scientist for the Lyman Far Ultraviolet Spectroscopic Explorer (FUSE) mission. FUSE will make observations in the critical 910–1195Å 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.

David Golimowski is an associate research scientist who splits his time between searching for very low mass (VLM) companions to nearby stars and evaluating CCDs for the Advanced Camera for Surveys (ACS) program. His searches for substellar (brown dwarf) companions are both ground- and space-based. Together with Caltech collaborators Ben Oppenheimer and Shri Kulkarni, Golimowski uses JHU's Adaptive Optics Coronagraph and Palomar Observatory's 60-inch telescope to perform a search for brown-dwarf companions to stars within 8 pc of the Sun. This search led to the identification the first unambiguous brown dwarf, Gliese 229B, in late 1995.

Following the discovery of Gliese 229B, the JHU/Caltech team was awarded time to observe the brown dwarf with the Hubble Space Telecope (HST). Direct images of Gliese 229B were recorded at three epochs spanning one year using the Wide Field and Planetary Camera 2 (WFPC2). These images produced the first R-band detection of Gliese 229B and revealed the first evidence of the brown dwarf's orbital motion about Gliese 229A. This motion shows that Gliese 229B has an elliptical orbit, which suggests that Gliese 229B has a binary rather than planetary origin. The broadband WFPC2 images also indicate that a strong source of optical continuum opacity exists in the photosphere of Gliese 229B. No other companions to the Gliese 229 system were detected.

Golimowski and Daniel Schroeder (Beloit College) are wrapping up a direct imaging survey of 24 of the nearest stars using WFPC2. Although no new VLM companions have been found in this sample of stars, Golimowski and Schroeder have obtained optical photometry for two nearby VLM objects which has been so far unachievable from ground-based observation. Images of Proxima Centauri showed no evidence of the possible brown-dwarf companion previously reported by Schultz *et al.* from their images obtained with HST's Faint Object Spectrograph. The final results of this WFPC2 survey are currently being prepared for publication.

Along with co-principal investigator Todd Henry (Harvard-Smithsonian Center for Astrophysics), Golimowski was awarded time to observe up to 265 of the stars within 10 pc of the Sun using HST's NICMOS Camera 2. If completed, this four-bandpass survey will be the largest and most sensitive volume-limited search for VLM and brown dwarf companions so far undertaken. At present, the survey (as awarded) is 45% complete. The survey has permitted extensive study of the imaging performance of NICMOS Camera 2. Images from the survey revealed a probable time-dependent misalignment of the camera's cold mask with HST's pupil obscurations. An analysis of this misalignment and its effect on the appearance and subtraction of the camera's point-spread function (PSF) was published in a paper principally authored by team member John Krist (Space Telescope Science Institute). Preliminary scientific results will be reported at the January 1999 meeting of the American Astronomical Society (AAS).

Golimowski joined the ACS program in December 1995 both as a member of the science team and as an evaluator of CCD performance. Much of the last year has been spent simulating the effects of cosmic radiation upon the charge transfer in the ACS Wide Field Camera CCDs. These devices are irradiated at the University of California at Davis's Crocker Nuclear Laboratory and then evaluated at JHU's ACS CCD test facility, which is managed by Golimowski.

On the side, Golimowski has worked with John Krist, Holland Ford (JHU), and Chris Burrows (STScI) promoting and investigating the design requirements for an optical camera aboard the Next Generation Space Telescope (NGST). This activity has primarily involved simulating of optical PSFs for the various proposed telescope designs and assessing the impact of these PSFs on both low and high dynamic range imaging with NGST. This work has also identified some of the technological challenges which must be addressed to make operation of a CCD camera feasible in the harsh environment in which NGST is to be placed. Results from this effort were presented by Golimowski at the June 1998 meeting of the AAS.

Richard C. Henry conducts research on the interstellar medium, cosmology, and ultraviolet background radiation. Henry is Principal Investigator for the NASA MIDEX Astrophysics Alternate Mission, ''Hopkins Ultraviolet Background Explorer,'' HUBE. HUBE, now re-named ''Hot Universe Background Explorer,'' has been re-submitted (1998 August) to NASA for the second MIDEX competition. The HUBE proposal has been greatly strengthened over the previous submission, through inclusion of powerful additional instruments that are capable of even more deeply characterizing the high-energy diffuse background radiation. Some of these new instruments have been provided by Dr. David N. Burrows, and by Drs. Jeffrey J. Bloch, Barham W. Smith, and John M. Harlander. An expanded team of 42 Co-Investigators will conduct the scientific work of HUBE in the happy event that HUBE should be implemented by NASA.

The new HUBE was presented at the 1997 June meeting of the American Astronomical Society by Henry, Jayant Murthy, Holland Ford, Keith Peacock, David Burrows, Barham Smith, and Jeffrey Bloch (BAAS, 30, 926). Henry also presented the new HUBE concept as part of his invited paper, ''Diffuse Ultraviolet Background Radiation,'' at IAU Colloquium No. 171, ''The Low Surface Brightness Universe,'' at Cardiff, Wales, 1998 July 9. Henry continues his outreach activity as Director of Maryland Space Grant Consortium, and was elected Chair of the National Council of Space Grant Directors for the term 1998 - 2000.

Mary Elizabeth Kaiser, an associate research scientist in the Department of Physics and Astronomy, is a co-investigator with the Space Telescope Imaging Spectrograph (STIS) Investigation Definition Team (IDT). Her formal duties as the STIS Calibration Scientist culminated in the determination of the on-orbit signal-to-noise (S/N) capabilities of the STIS 1024 $\times$ 1024 ultraviolet MAMA detectors. Collaborating on this effort were Bohlin (STScI), Lindler (ACC), Argabright (BASG), Gilliland (STScI), and Kimble (GSFC). For the long slit FUV modes (115 - 170 nm), a S/N of $\sim$ 130 per spectral resolution element is achieved for a single point source spectrum of GD 153 with counting statistics of $\sim$ 165. In the NUV (165 - 310 nm), a single point source spectrum of GRW+70°5824 with counting statistics of $\sim$ 200 yields a S/N of $\sim$ 150 per spectral resolution element. An even higher S/N capability is realized in the echelle modes with the use of fixed pattern (FP) split slits. Using the multiple spectra of BD 28°4211 to solve for the stellar spectrum and flat field yields a S/N of $\sim$390 in the FUV and $\sim$ 380 in the NUV over a narrow spectral region which may not reflect the S/N capability over the full detector. However, applying flat fields to these echelle spectra yields a S/N of $\sim$ 205 in the FUV and $\sim$ 290 in the NUV over an extended spectral region.

In addition to instrument performance verification for STIS, Kaiser and collaborators have been pursuing research activities on the kinematics of Seyfert galaxies, the dynamics of the near-nuclear regions of normal galaxies, optical jet structure in 3C radio sources, and cluster mass determinations from gravitational lensing. Kaiser is also a member of the HDF-S working group.

Kaiser and collaborators Hutchings (DAO), Bradley (JHU), Crenshaw (CUA), Gull (GSFC), Kraemer (CUA), Nelson (UNLV), Ruiz (CUA), Weistrop (UNLV) have kinematically mapped the full NLR of NGC4151 using medium resolution STIS slitless spectroscopy of the emission line regions. These data exhibit a set of clouds with velocities well in excess of those predicted by pure rotation in a gravitational field for this object. Another physical process, such as wind-driven outflow, must be responsible for these velocities.

Kaiser and collaborators Hutchings (DAO), Baum (STScI), Weistrop (UNLV), Nelson (UNLV), and Gelderman (WKU) have obtained *HST* STIS spatially resolved spectra of the near-nuclear optical jets of a sample of 3C galaxies. Of the four targets observed, two reveal clumpy emission-line structures that indicate outward motions of of a few hundred kilometers per second. The other targets have jets which are consistent with their proposed synchrotron origin. **P. Knezek** continues her research on the evolution of galaxies. She is collaborating with K. Sembach (JHU) and J. Gallagher (Univ. of Wisconsin) in a project to study the properties of dwarf ''transition'' galaxies with mixed morphologies in an effort to understand the evolutionary history of such systems. The first paper is in press in ApJ.

She is involved in a project to study the interstellar media in the outer regions of elliptical galaxies, as well as the intergalactic media in clusters and groups of galaxies with J. Bregman and E. Miller (Univ. of Michigan). They use background quasars as continuum light sources and search the UV with HST for absorption lines. The paper detailing the results from the first HST spectra has been submitted.

She is continuing her work with S. Lawrence (Columbia University) and I. Cruz-Gonzalez (Universidad Nacional Autonoma de Mexico) to study the optical and NIR properties of gas-rich low surface brightness properties. They will determine the underlying star formation history of these poorly understood systems.

She is collaborating with J. Bregman (Univ. of Michigan), S. Snowden (NASA/Goddard) and D. Kelson (Carnegie/DTM) to understand the detailed structure of interstellar medium of the Milky Way by comparing detailed HI and X-ray maps of an 8x8 degree region of the galactic plane with models.

She is involved in an international project to survey the entire southern hemisphere in HI using the Parkes Telescope in Australia. She is providing over half the optical follow-up observations on HI detections which have no cataloged counterparts. The survey is now over half-way complete, and optical follow-up continues.

Jeffrey Kruk is presently the System Scientist for the Far Ultraviolet Spectroscopic Explorer (FUSE) project at JHU, and is responsible for scientific oversight of the satellite design, integration, test, and flight operations. He is also responsible for designing and implementing the FUSE on-orbit calibration plan. Following conclusion of satellite testing, he will assume responsibilty for the processing of scientific data from FUSE and for its archiving and dissemination to the astonomical community.

Kruk served as the technical liason to the Canadian Space Agency (CSA), which is a partner in the FUSE project and has provided the FUSE Fine Error Sensors (FES). The FES provides star-field images and fine guiding information for FUSE. Following delivery of the FESs by CSA, Kruk has been responsible for their integration into FUSE and for their environmental and functional testing.

Klaus Werner and Kruk have analyzed spectra of PG 1159 stars obtained with the Hopkins Ultraviolet Telescope. This analysis has confirmed the previously suspected absence of He in H1504+65, demonstrating that this star is a pure C/O stellar core. This study also uncovered the presence of N in PG 1707+427 and possibly also in PG 1159-035. The presence of nitrogen is an important clue to the nature of mixing processes during the course of the final helium flash in such stars. The comparison of spectra from the pulsator/non-pulsator pair PG 1707+427, PG 1424+435 indicates that the red edge of the GW-Vir instability strip is determined by removal of C and O from the stellar envelope by gravitational settling, and that the GW-Vir pulsation phenomenon is restricted to stars with masses very close to $0.6 M_{\odot}$. Kruk will continue his collaboration with Klaus Werner and Stefan Dreizler on the study of PG 1159 stars using the Far Ultraviolet Spectroscopic Explorer following its launch.

Stephan R. McCandliss is presently involved with the pre-flight preparation and calibration of an FUV windowless long slit spectrograph and telescope. The telescope is scheduled to be launched in the early winter of 1999 from White Sands Missile Range on NASA Sounding Rocket 36.136 UG. The target for the observation is the central star and surrounding reflection nebula of NGC 2023 in the Orion Constellation. We intend to study on intermediate angular scales ($\approx 200'' \times 12''$) how the scattering and absorption of the stellar energy flux, which peaks in our spectral bandpass (912 – 1400 Å), regulates the ionization and chemical balance in the nebular gas and dust. Work is also underway on the design of a high dynamic range dual order spectrograph. This spectrograph will double the effective area normally realized in a low scattered light Rowland circle design by using both $\pm$ orders of a holographically ruled concaved grating. It achieves high dynamic range through the use of a MCP detector in one order and a UV sensitive CCD in the other. This work is being carried out with Eric Burgh and Paul Feldman.

McCandliss has recently published his identification of a new type of reflection grating ghost, termed a narcissistic ghost, whereby a diffracted line from a Rowland grating reflects off of a detector surface and is reimaged by the grating zero order back onto the detector. This work was performed with Jason McPhate and Paul Feldman.

McCandliss continues to work on characterizing the output of his vacuum FUV pinhole lamps: the Ar arc lamp for ground based absolute flux calibrations and a flyable H_2 getter lamp. Both of these lamps use very small pinholes (~ 1 – 10 μm) and differential pumping systems for work in the windowless FUV. Along with Brian Espey and co-investigators he was recently granted guest investigator time on FUSE to study FUV absorption lines created by cool star atmospheres that eclipse hot white dwarf companions in symbiotic binary systems. He also is continuing his work on a variety of hot star topics.

Warren Moos is the Principal Investigator for the Lyman Far Ultraviolet Spectroscopic Explorer. Warren Moos also participates as a Co-Investigator in the analysis of data from 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 continues to work primarily in the field of molecular astrophysics. In collaboration with M. Harwit, G. Melnick and former JHU graduate student M. Kaufman, he is analysing and interpreting infrared observations carried out using the Infrared Space Observatory (ISO). An ISO observing program to study interstellar water has revealed a high abundance of water vapor in shocked gas within the Orion Molecular Cloud. The line strengths measured by Neufeld and his collaborators for eight far-infrared rotational transitions of water are in excellent agreement with specific predictions made in the Hopkins PhD thesis of M. Kaufman, and are entirely consistent with chemical models which predict that water vapor will be the dominant reservoir of gas-phase oxygen in warm interstellar regions.

Subsequent theoretical work carried out with E. Bergin and G. Melnick suggests that the enhanced water abundance generated within shock waves will likely persist for $\sim 10^5$ years, long enough for the water vapor to freeze out onto the surfaces of cold interstellar dust grains. This result suggests a new mechanism for the formation of icy grain mantles, and – since dust grains appear to suffer relatively little processing in entering a protostellar nebula – a possible origin for water in the solar system.

Neufeld and collaborators have also reported ISO observations of molecular hydrogen in the outflow source HH 54. The observed strengths of the S(1) through S(5) pure rotational lines of H_2 indicate a gas temperature ~ 700 K and an ortho-to-para ratio ~ 1.2, a value far smaller than the equilibrium value of 3 expected at gas temperatures above 200 K. This is the first time that an astronomical source has been shown to have a non-equilibrium ortho-to-para H_2 ratio. The small ratio measured in HH 54 is presumably the legacy of an earlier stage in the thermal history of the gas when the temperature was less than ~ 90 K, and is consistent with the notion that the emitting gas has been heated recently by a shock wave.

Related theoretical work with A. Sternberg has revisited the question of the ortho-to-para H_2 ratio in photon dominated regions (PDRs). There appears to be a widespread confusion in the literature between the ortho-to-para ratio in excited vibrational states of H_2 and the true ortho-to-para ratio for H_2, a misunderstanding that has led to the erroneous suggestion that observations of H_2 vibrational emissions in PDRs imply non-equilibrium ortho-to-para ratios. Sternberg and Neufeld showed that the ortho- to para-H_2 ratios measured for excited vibrational states do not require *true* ortho- to para-H_2 ratios smaller than 3 but are simply a consequence of optical depth effects in the fluorescent pumping of the observed vibrational emissions

Neufeld and collaborators have also searched for water in the diffuse interstellar medium, by means of absorption line observations carried out with the Hubble Space Telescope. Negative results, interpreted with the use of chemical models developed by former JHU postdoctoral fellow M. Spaans, place interesting constraints upon the chemistry.

Neufeld has continued to serve as a co-investigator on the Submillimeter Wave Astronomy Satellite, a NASA Small Explorer Mission scheduled for launch in December 1998. SWAS will probe the chemistry and thermal balance within star-forming molecular clouds by carrying out pointed observations of 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 taken part in spectrograph integration and test at the University of Colorado, and instrument integration and test at the Applied Physics Laboratory. Final pre-launch satellite testing is now under way at Goddard Space Flight Center. Using data obtained during these tests, he is proceeding with his work modeling the expected on-orbit performance of the satellite.

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 investigations of the D/H ratio in the Milky Way and hot gas processes that control the evolution of galaxies. He has given several FUSE related presentations this year, including talks at the Boulder *Ultraviolet-Optical Space Astronomy Beyond HST Conference* and the *High Velocity Cloud Workshop* in Canberra. Sembach and Blair (JHU) continue as science press liaisons for the FUSE activities at Johns Hopkins.

Sembach, Savage (U. Wisc), Lu (Caltech) and Murphy (JHU) have published their results on the ionization properties of high velocity clouds at large distances from the Galactic plane. 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.

Sembach, Savage (U. Wisc), and Hurwitz (UC-Berkeley) have obtained high ionization absorption line data for the sight line to E141-55. The high ion profiles from HST (Si IV, C IV, and N V) are being compared with O VI from the ORFEUS-II mission. The data reveal strong high ion absorption, indicating substantial amounts of hot gas along the sight line. There is also H_2 along the sight line, which has a reddening of less than 0.10 magnitudes.

Knezek (JHU), Sembach, and Gallagher (U. Wisc) 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. They have recently completed their first study of three ''transition'' dwarfs (see description by Knezek).

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 lies within 1.5 kpc of the Galactic disk and contains gases with a wide range of ionization properties. The data can be used to test models of conductive interfaces between hot and cool gases. The cloud serves as a benchmark for comparisons with high velocity clouds located at larger distances from the Galactic plane. Additional work in this collaboration includes determining the distances to other high velocity clouds in the sky and a study of the physical properties and elemental abundances of gas in the Magellanic Bridge.

Sembach, Jenkins (Princeton), Raymond (CfA) and Danks (Raytheon/STX) 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.

Cha (JHU), Sembach, and Danks (Raytheon STX) are finishing an investigation of 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.

Murphy (JHU) and Sembach continue their work on 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. The data compilation will be used to assess the sight line velocity structure for many extragalactic continuum sources that will be observed with FUSE.

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

A. R. Thakar continues his investigation of massive counterrotating disks in spirals using a Smoothed Particle Hydrodynamics / N-body code. His simulations have established the viability of the retrograde gas infall model for producing such disks in cold and hot primaries. Gas-rich dwarf mergers, which have produced mixed results thus far (see last year's report) are still under investigation, as are further models of gas infall. Spherical infalling gas shells are able to produce counterrotating rings but not disks. The effect of preexisting prograde gas in the primaries will be fully investigated when star formation models are incorporated into the simulations. Exponential counterrotating disks (such as the one observed in NGC 4550) are difficult to produce with any model tested to date, and require special initial conditions. Thakar is currently also investigating models of satellite mergers that will yield kinematically decoupled bulges in early-type spirals.

Alan Uomoto works on instrumentation for the Sloan Digital Sky Survey, a project to map 1/4 of the sky near the north galactic pole in five broadband colors and to measure redshifts of one million galaxies. The JHU group has built two fiber optic spectrographs, each capable of measuring 320 objects at once and is contributing to the broadband CCD photometer to be used on the 20-inch SDSS photometric telescope at Apache Point Observatory.

Harold Weaver is a Research Scientist and is also working half-time as the deputy to the NASA *FUSE* Project Scientist, George Sonneborn (GSFC). In February 1998, Weaver completed his HST observing program on comet Hale-Bopp using the Space Telescope Imaging Spectrograph (STIS). The principal results were: the comet was slightly less active post-perihelion compared to pre-perihelion, the OH spatial brightness profile showed anomalous flattening near the nucleus (possibly due to the presence of icy grains in the coma), and the observed OH excitation was consistent with the predictions of a fluorescence equilibrium model. Weaver also used STIS to investigate comet 103P/Hartley 2 in early January 1998, but the activity levels were about 3 times lower than expected and no CO emissions were detected. With Paul Feldman and others, Weaver is continuing to analyze previously-obtained HST spectroscopic data on comets Hyakutake and Schwassmann-Wachmann 1, and they expect to submit papers on those results during the coming year. In an HST program being led by Philippe Lamy (LAS/Marseille), Weaver has been measuring the sizes, shapes, and rotational periods of cometary nuclei. They have already obtained excellent results on eight comets and hope that future observations will allow them to characterize the physical properties of cometary nuclei as a population, thereby yielding insights into their origin and evolution.

Weaver has been also been actively pursuing an infrared program on comets, in collaboration with several colleagues. In late January and early February 1998, they observed comets 55P/Tempel-Tuttle and 103P/Hartley 2 from the NASA *IRTF*. These comets were pushing the sensitivity limits of the *IRTF*, and a full analysis of the data has not yet been completed. Weaver and his team are continuing their analyses of the excellent *IRTF* spectra they took on comets Hyakutake and Hale-Bopp in 1996 and 1997, which show emissions from many molecules including CO, OH, CH_4, and C_2H_6. The first paper on the Hale-Bopp results is in press, and papers on CH_4 and C_2H_6 are in preparation.

R. Wyse continued her work into the formation and evolution of galaxies, including the Milky Way. Together with graduate student Annette Ferguson (now a postdoctoral fellow at the Institute of Astronomy, University of Cambridge) she discovered massive star formation in the extreme outer regions of nearby disk galaxies, far beyond previous data and expectations. The best explanation for the variation they observe in the star formation across the face of the galaxies is gravitational instability in flaring (as opposed to constant thickness) gas disks.

Wei Zheng's main research interest is in the spectra of active galaxies and quasars. He continues his work on the quasar spectra in the extreme UV band. In collaboration with G.A. Kriss, A.F. Davidsen, and R.C. Telfer (graduate student), he will soon complete the collection of archival HST FOS spectra of quasars. With a larger sample size, they hope to improve the signal-to-noise level at the intrinsic wavelengths below 600 Å and produce the composite quasar spectra for different redshift ranges. This will allow a study of the cosmic evolution of the intrinsic quasar spectra.

He continues to analyze the far-UV spectra of Seyfert galaxies obtained with the Hopkins Ultraviolet Telescope (HUT). The spectra of Mrk 478 and PG1211+14 show a rising UV continuum that can be extrapolated to match the luminosity in the soft X-ray band. These two objects may belong to a group of narrow-line Seyfert galaxies that show extremely strong soft X-ray excess and peculiar emission-line properties. The high-ionization lines, such as O VI λ1034 and He II λ1640, are exceptionally strong. In another object, PG1351+64, an opposite trend is seen: the soft X-ray luminosity is very low, and the high-ionizaiton lines are very weak. These results suggest that the intensity of high-ionization lines are indicative of high-energy photons in the largely unobservable extreme UV band.

Zheng, Kriss and Davidsen carried out extensive simulations of the absorption lines produced by the intergalactic medium. They conclude that the absorbing mass associated with the Lymanα lines that have been identified cannot account for all the He II opacity that was recently measured. They suggest the existence of a large amount of intergalactic mass with hydrogen column density below 10^{12} cm^{-2} whose properties are to be explored.

In collaboration with L.-Z. Fang (U. Arizona), Zheng studies the emission line intensities of He II Lyman α and Hα. The intensity ratio of these two lines is found to be much lower than the canonical value in one quasar, suggesting possible severe reddening in the line-emitting region.

6. ACKNOWLEDGEMENTS

The CAS Director is indebted to Professor Richard Henry and Ms. Connie Fliegel for preparation of this report.

PUBLICATIONS

Bergin, E., Neufeld, D.A., and Melnick, G.J. 1998. ‘‘The Postshock Chemical Lifetimes of Outflow Tracers and a Possible New Mechanism to Produce Water Ice Mantles,’’ ApJ, 499, 777.

Bianchi, L. 1997. ‘‘The Ultraviolet Universe at Low and High Redshift: Probing the Progress of Galaxy Evolution,’’ eds. W. H. Waller, M. N. Fanelli, J. E. Hollis, & A. C. Danks, AIP Conference Proceedings 408, ‘‘Hot Massive Stars in M33: HST UV Spectroscopy and Photometry’’ p.135.

Bianchi, L.1998. ‘‘UV Astrophysics beyond the IUE Final Archive,’’ eds. R. Gonzalez-Riestra, W.Wamsteker and R.A. Harris, ESA SP-413, ‘‘Characterizing the Young Stellar Populations in Nearby Galaxies: What Do We Learn From UV Data?’’ p.553.

Birriel, J.J., Espey, B.R., & Schulte-Ladbeck, R.E. 1998. ‘‘Near-Simultaneous Observations of Direct and Raman Scattered Lines in the Symbiotic Star Z Andromedae,’’ ApJ 507, L75.

Blair, W. P. 1998. ‘‘A New View of Interstellar Shock Waves and Supernova Remnants,’’ ESA SP-413, ed. by R. Gonzalez-Riestra, W. Wamsteker, & R.A. Harris, p. 441.

Blair, W. P. 1998. ‘‘An Overview of Results from the Hopkins Ultraviolet Telescope,’’ ESA SP-413, ed. by R. Gonzalez-Riestra, W. Wamsteker, & R.A. Harris, p. 763.

Boroson, B., Blair, W. P., Davidsen, A. F., Vrtilek, S. D., Raymond, J. Long, K. S., & McCray. R. 1997. ''Hopkins Ultraviolet Telescope Observations of Her X-1,'' ApJ, 491, 903.

Bower, G.A., Green, R.F., Danks, A.C., Gull, T.R., Heap, S.R., Hutchings, J.B., Joseph, C., Kaiser, M.E., Kimble, R.A., Kraemer, S.B., Weistrop, D.E., Woodgate, B.E., Lindler, D., *et al.* (7 additional authors), 1998. ''Kinematics of the Nuclear Ionized Gas in the Radio Galaxy M84 (NGC 4374),'' ApJ., 492, L111.

Combi, M. R., Brown, M. E., Feldman, P. D., Keller, H. U., Meier, R. R. and Smyth, W. H., 1998. ''Hubble Space Telescope ultraviolet imaging and high resolution spectroscopy of water photodissociation products in comet Hyakutake (C/1996 B2),'' ApJ494, 816.

Dierks, A., Deutsch, E., Castandar, F., Corson, C., Gilmore, G., Lamb, D. Turner, E. & Wyse, R., 1998. ''The Optical afterglow of GRB971214: Further Evidence for a Varied Population,'' ApJ., 503, L105.

Doty, S.D., and Neufeld, D.A. 1997. ''Models for Dense Molecular Cloud Cores,'' ApJ, 489, 122.

Dring, A. R., Linsky, J., Murthy, J., Henry, R. C., Moos, H. W., Vidal-Madjar, A., Audouze, J., and Landsman, W. 1997. ''Lyman Alpha Absorption and the D/H Ratio in the Local Interstellar Medium,'' ApJ, 488, 760.

Espey, B.R., Kriss, G.A., Krolik, J., Zheng, W., Tsvetanov, Z., & Davidsen, A.F. 1998. ''Far-UV observations of NGC4151 during the Orfeus-II mission,'' ApJ 500, L13.

Espey, B. R., Kriss, G. A., Krolik, J., Zheng, W., Tsvetanov, Z., and Davidsen, A. F. 1998. ''Far-UV Observations of NGC 4151 During the ORFEUS-SPAS II Mission,'' ApJ, 500, L13.

Ferguson, A.M.N., Gallagher, J. & Wyse, R.F.G., 1998. ''Star Formation in the Extreme Outer Disks of Spiral Galaxies: HII region Spectroscopy,'' AJ, 116, 673.

Ferguson, A.M.N., Wyse, R.F.G., Gallagher, J.S. and Hunter, D., 1998. ''Discovery of Star Formation in the Extreme Outer Regions of Disk Galaxies,'' ApJ 506, L19.

Gallagher, J. S., Han, M. and Wyse, R. F. G, 1997. ''Structures of Dwarf Elliptical Galaxies in Rich Clusters.'' Invited talk, in ''Dark and Visible Matter in Galaxies,'' ASP Conf Ser. 117, eds. M. Persic & P. Salucci, p. 66-73.

Gilmore, G. & Wyse, R.F.G., 1998. ''Element Ratios and the Formation of the Stellar Halo,'' AJ 116, 748.

Golimowski, D. A., Burrows, C. J, Kulkarni, S. R., Oppenheimer, B. R., and Brukardt, R. A. 1998. ''Wide Field Planetary Camera 2 Observations of the Brown Dwarf Gliese 229B: Optical Colors and Orbital Motion,'' AJ, 115, 2579.

Golimowski, D. A., and Schroeder, D. J. 1998. ''Wide Field Planetary Camera 2 Observations of Proxima Centauri: No Evidence of the Possible Substellar Companion,'' AJ, 116, 440.

Gordon, S. M., Kirshner, R. P., Long, K. S., Duric, N., Blair, W. P., & Smith, R. C., 1998. ''A New Optical Sample of Supernova Remnants in M33,'' ApJS, 117, 89.

Greeley, B. G., Blair, W. P., & Long, K. S. 1998. ''FUV Spectroscopy of Magnetic Cataclysmic Variables and Preliminary Results from ORFEUS-II,'' 13th North American Workshop on Cataclysmic Variables, ASP Conference Series 137, ed. by S. Howell, E. Kuulkers, & C. Woodward, p. 444.

Hall, D. T., Feldman, P. D., McGrath, M. A. and Strobel, D. F., 1998. ''The far-UV airglow of Europa and Ganymede,'' ApJ499, 475.

Harwit, M., Neufeld, D.A., Melnick, G.J., and Kaufman, M.J. 1998. ''Thermal Water Vapor Emission from Shocked Regions in Orion,'' ApJ, 497, L105.

Heap, S.R., Brown, T., Hubeny, I., Landsman, W., Yi, S., Fanelli, M., Gardner, J.P., Lanz, T., Maran, S., Sweigart, A., Kaiser, M.E., and 9 additional authors, 1998. ''Ultraviolet Spectral Dating of Stars and Galaxies,'' ApJ 492, L131.

Heap, S.R., Brown, T.M., Hubeny, I., Lansman, W., Fanelli, M., Yi, S., Gardner, J.P., Lanz, T., Maran, S.P., Seigart, A., Kaiser, M.E., Linsky, J., Timothy, J.G., Lindler, D., Beck, T., Bohlin, R.C., Clampin, M., Grady, J., Loiacono, J., Krebs, C., and Moos, H.W. (1998). ''Ultraviolet Spectral Dating of Stars and Galaxies,'' ApJ, 492, L131.

Hogg, D. E., Roberts, M. S., Schulman, E. and Knezek, P. M. 1998. ''The Amorphous Galaxy NGC 2777: H I Evidence for Tidal Interaction with a Faint Companion,'' AJ, 115, 502.

Hutchings, J.B., Baum, S.A., Weistrop, D., Nelson, C., Kaiser, M.E., Gelderman, R.F., 1998. ''Spatially Resolved Spectra of 3C Galaxy Nuclei,'' AJ,116, 634.

Hutchings, J.B., Crenshaw, D.M., Kaiser, M.E., Kraemer, S.B., Weistrop, D., Baum, S., Bowers, C.W., Feinberg, L.D., Green, R.F., Gull, T.R., Hartig, G.F., Hill, G., Lindler, D.J., 1998. ''Gas cloud kinematics near the nucleus of NGC 4151,'' ApJ, 492, L115.

Ibata, R., Wyse, R.F.G., Gilmore, G., Irwin, M. and Suntzeff, N., 1997. ''The Orbit and Survival of the Sagittarius Dwarf Galaxy,'' AJ, 113, 634.

Jenkins, E.B., Tripp, T.M., Fitzpatrick, E.L., Lindler, D., Danks, A.C., Beck, T.L., Bowers, C.W., Joseph, C.L., Kaiser, M.E., Kimble, Randy A., Kraemer S.B., Robinson, R.D., Timothy, J.G., Valenti, J.A., Woodgate, B.E., 1998. ''UV Absorption Lines from High-Velocity Gas in the Vela Supernova Remnant: New Insights from STIS Echelle Observations of HD72089,'' ApJ, 492, L147.

Jolly, A., McPhate, J. B., Lecavalier, A, Lagrange, A.-M., Lemaire, J. L., Feldman, P. D., Vidal-Madjar, A., Ferlet, R., Malmasson, D. Rostas, F.,1998. ''HST-GHRS observations of CO and C I in the βPictoris circumstellar disk,'' A&A329, 1028.

Kaiser, M.E., Bohlin, R.C., Lindler, D.J., Gilliland, R.L., Argabright, V.S., Kimble, R.A., 1998. ''STIS Signal-to-Noise Capabilities in the Ultraviolet,'' PASP, 110, 978.

Keenan, F.P., Aller, L.H., Bell, K.L., Espey, B.R., Feibelman, W.A., Hyung, S., McKenna, F.C., & Ramsbottom, C.A. 1998. ''Emission Lines of [NeIV] in the Optical and Ultraviolet Spectra of Planetary Nebulae,'' MNRAS 295, 683.

Kimble, R.A., Woodgate, B.E., Bowers, C.W., Kraemer, S.B., Kaiser, M.E., Gull, T.R., Heap, S.R., Danks, A.C., Boggess, A., Green, R.F., Hutchings, J.B., Jenkins, E.B., Joseph, C.l., Linksy, J.L., Maran, S.P., Moos, H.W., Roesler, F., Timothy, J.G., Weistrop, D.E., et al. (68 additional authors), 1998. ''The On-Orbit Performance of the Space Telescope Imaging Spectrograph,'' ApJ, 492, L83.

Knezek, P. M. and Bregman, J. N. 1998. ''The Identification of Quasars Behind Elliptical Galaxies and Clusters of Galaxies,'' AJ, 115, 1737.

Krist, J. E., Golimowski, D. A., Schroeder, D. J., and Henry, T. J. 1998. ''Characterization and Subtraction of Well Exposed HST/NICMOS Camera 2 Point-Spread Functions for a Survey of Very Low Mass Companions to Nearby Stars,'' PASP, 110, 1046.

Kruk, J. W., Werner, K., 1998. ''Far Ultraviolet Spectroscopy of PG 1159 Stars with the Hopkins Ultraviolet Telescope,'' ApJ 502, 858.

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 Far Ultraviolet Calibration Standards,'' ApJ 482, 546.

Kruk, J. W., 1997. ''Review of the Ultraviolet Flux Calibration,'' in Fundamental Stellar Properties: The Interaction Between Observation and Theory, ed. T.R. Bedding, A.J. Booth and J. Davis, IAU Symposium 189 (Dordrecht:Kluwer), 67.

Kupperman, D. G., Paxton, L. J., Carbary, J., Romick, G. J., Anderson, D. E., Meng, C.-I, and Feldman, P. D., 1998. ''On the sodium tail of comet Hale-Bopp (C/1995 O1),'' Geophysics Research Letters25, 3261.

Lagrange,A.-M., Beust, H., Mouillet, D., Deleuil, M., Feldman, P.D., Ferlet, R., Hobbs, L., Lecavalier des Etangs, A., Lissauer, J. J., McGrath, M. A., McPhate, J. B., Spyromilio, J., Tobin, W. and Vidal-Madjar, A., 1998. The βPictoris circumstellar disk. XXIV. Clues to the origin of the stable gas, A&A, 330, 1091.

Lamy, P. L., Toth, I., & Weaver, H. A. 1998. ''Hubble Space Telescope observations of the nucleus and inner coma of comet 19P/Borrelly,'' A&A, 337, 945.

Lamy, P. L., Toth, I., Jorda, L., Weaver, H. A. & A'Hearn, M. F. 1998, ''The nucleus and inner coma of comet 46P/Wirtanen,'' A&A, 335, L25.

Matonick, D. M., Fesen, R. A., Blair, W. P., & Long, K. S. 1997. ''An Optical Search for of Supernova Remnants in NGC 2403,'' ApJS, 113, 333.

May, M.J. Finkenthal, M., 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, 36, 881.

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, 1333.

May, M.J., Regan, S.P., Soukhanovskii, V.A., Fikenthal, M., Moos, H.W., Goetz, J.A., Lipschultz, B., Terry, J.L., West, P., Allen, S., Brooks, N. 1997. ''Diagnostics for Local Spectroscopic Measurements in the Divertor Region of the Alcator C-Mod and DIII-D Tokamaks,'' Rev. Sci. Instrum, 68, 1047.

McCandliss, S. R., McPhate, J. B., and Feldman, P. D., 1998. ''Narcissistic ghosts in Rowland-mounted concave gratings with $\beta = 0°$: a cautionary note,'' Appl. Opt., 37, 5070.

McGrath, M. A., Courtin, R., Smith, T. E., Feldman, P. D., and Strobel, D. F., 1998. ''The ultraviol*et al.*bedo of Titan,'' Icarus 131, 382.

Moos, W.H., Sembach, K., Bianchi, L. (1998). ''Far Ultraviolet Astronomy and Origins: The Far Ultraviolet Spectroscopic Explorer (FUSE) Mission,'' Origins, C.E. Woodward, T.M. Shull, and H.A. Thronson eds., ASP, 148, 304.

Moos, H.W., et. al. (1998). ''The On-Orbit Performance of the Space Telescope Imaging Spectrograph,'' ApJ, 492, L83.

Morse, J. A., Blair, W. P., & Raymond, J. C. 1998. ''HST Observations of Oxygen-rich Supernova Remnants in the Magellanic Clouds,'' RMAASC, 7, 21.

Neufeld, D.A., Zmuidzinas, J., Schilke, P., and Phillips, T.G. 1997. ''Discovery of Interstellar Hydrogen Fluoride,'' ApJ, 488, L141.

Neufeld, D.A., Melnick, G., and Harwit, M. 1998. ''Infrared Space Observatory Observations of Molecular Hydrogen in HH 54: Measurement of a Nonequilibrium Ratio of Ortho- to Para-H_2,'' ApJ, 506, L75.

Ohl, R.G., Barkhouser, R.H., Kennedy, M.J., and Friedman, S.D.,1998. ''Assembly and Test-Induced Distortions of the FUSE Mirrors - Lessons Learned,'' Astronomical Telescopes and Instrumentation, SPIE Proceedings 3356, 854.

Omont, A., Caillaud, B., Fouque, P., Gilmore, G., Ojha, D., Perault, M., Seguin, P. M., Simon, G., Wyse, R. F. G. and the ISOGAL-DENIS team, 1998. ''Mass-losing AGB Stars and Young Stats in the ISOGAL Survey.'' Invited review, ''The Impact of Near-Infrared Sky Surveys on Galactic and Extragalactic Astronomy,'' ed N. Epchtein (Kluwer, Dordrecht) p. 49.

Price, S. D., Tedesco, E. F., Cohen, M., Walker, R. G., Henry, R. C., Moshir, M., Paxton, L. J., and Witteborn, F. C. 1997. ''Astronomy on the Midcourse Space Experiment,'' in Proceedings of IAU Symposium 179, New Horizons from Multi-Wavelength Sky Surveys, ed. B. J. McLean, D. A. Golombek, J. J. E. Hayes, and H. E. Payne, 115.

Putman, M. E., Gibson, B. K., Staveley-Smith, L., Banks, G., Barnes, D. G., Bhatal, R., Disney, M. J., Ekers, R. D., Freeman, K. C., Haynes, R. F., Henning, P., Jerjen, H., Kilborn, V., Koribalski, B., Knezek, P., Malin, D. F., Mould, J. R., Oosterloo, T., Price, R. M., Ryder, S. D., Sadler, E. M., Stewart, I., Vaile, R., Webster, R., and Wright, A. E. 1998. ''The Disruption of Nearby Galaxies by the Milky Way,'' Nature, 394, 752.

Raymond, J. C., Blair, W. P., & Long, K. S. 1998. ''Ultraviolet H_2 Emission from HH2,'' RMAASC, 7, 7.

Raymond, J. C., Blair, W. P., & Long, K. S. 1997. ''Hopkins

Ultraviolet Telescope Observations of H_2 Emission from HH2,'' ApJ, 489, 314.

Sahnow, D.J., Friedman, S.D., Moos, H.W., Green, J.C., and Siegmund, O.H.W., 1998. ''Preliminary Performance Estimates for the Far Ultraviolet Spectroscopic Explorer (FUSE) Satellite,'' Astronomical Telescopes and Instrumentation, SPIE Proceedings 3356, 552.

Sahnow, D. J., Friedman, S. D., Moos, H. W., Green, J. C., and Siegmund, O. H. W. 1998. ''Preliminary performance estimates for the Far Ultraviolet Spectroscopic Explorer (FUSE) satellite,'' Proc. SPIE, 3356, 552.

Sahnow, D. J. 1998. ''Two dimensional simulation of Far Ultraviolet Spectroscopic Explorer spectra,'' Proc. SPIE, 3356, 1011.

Sahu, K.C., Shaw, R.A., Kaiser, M.E., Baum, Stefi A., Ferguson, H.C., Hayes, J.J.E., Gull, T.R., Hill, R.J., Hutchings, J.B., Kimble, R.A., Plait, P., Woodgate, B.E., 1997. ''Imaging and spectroscopy of arcs around the most luminous X-ray cluster RXJ 1347.5-1145,'' ApJ, 492, L125.

Schultz, A.B., Allardm F., Clampin, M., McGrath, M., Bruhweiler, F.C., Valenti, J.A., Plait, P., Hulbert, S., Baum, S., Woodgate, B.E., Bowers, C.W., Kimble, R.A., Maran, S.P., Moos, H.W., and Roesler, F. (1998). ''First Results from the Space Telescope Imaging Spectrograph: Optical Spectra of Gliese 229B'' ApJ, 492, L181.

Sembach, K.R., Moos, H.W., Friedman, S.D., Sonneborn, G., and the FUSE Science Team, ''A New Window on the Far Ultraviolet Universe: Science with the Far Ultraviolet Spectroscopic Explorer (FUSE),'' Proceedings of the 13th IAP Colloquium (Paris), Structure and Evolution of the Intergalactic Medium from Quasar Absorption Line Systems, July 1-5, 1997, page 446.

Sonneborn, G., Pun, C.S.J., Kimble, R.A., Gull, T.R., Lundqvist, P., McCray, R., Plait, P., Boggess, A., Bowers, C.W., Damks, A.C., Grady, J., Heap, S.R., Kraemer, S., Lindler, D., Loiacono, J., Maran, S.P., Moos, H.W., and Woodgate, B.E. (1998). ''Spatially Resolved STIS Spectroscopy of SN 1987A: Evidence for Shock Interaction with Circumstellar Gas,'' ApJ, 492, L139.

Sorkhabi, O., Blunt, V. M., Lin, H., A'Hearn, M. F., Weaver, H. A., Arpigny, C., & Jackson, W. M., 1997. ''Using photochemistry to explain the formation and observation of C_2 in comets,'' Planet Space Sci., 45, 721.

Spaans, M., Neufeld, D.A., Lepp, S., Melnick, G. and Stauffer, J. 1998. ''Search for Interstellar Water in the Translucent Molecular Cloud toward HD 154368,'' ApJ, 503, 780.

Stern, S. A., Slater, D. C., Gibson, W., Scherrer, J., A'Hearn, M. F., Bertaux, J. L., Feldman, P. D. and Festou, M. C., 1998. ''ALICE — An ultraviolet imaging spectrometer for the *Rosetta* mission,'' Adv. Space Res. 21, No. 11, 1517.

Stern, S. A., Parker, J. W., Festou, M. C., A'Hearn, M. F., Feldman, P. D., Schwehm, G., Schulz, R., Bertaux, J. L. and Slater, D. C. Slater, 1998. ''Mid-ultraviolet spectroscopy of 46P/Wirtanen during its approach to perihelion in 1996–1997,'' A&A335, L30.

Stutman, D., *et al.* (1997). ''MLM Based Line Emission Tomography for Spherical Tokamaks,'' Rev. Sci. Instrum. 68, 1055.

Stutman, D. *et al.* (1997). ''Line Emission Tomography for CDX-U using filtered diodes,'' Rev. Sci. Instrum. 68, 1059.

Tozzi, G. P., Feldman, P. D., and Festou M. C., 1998. ''Origin and production of $C(^1D)$ atoms in cometary comae,'' A&A 330, 753.

Wilkinson, E., Green, J. C., Osterman, S. N., Brownsberger, K. R., and Sahnow, D. J., 1998. ''Integration, alignment and initial performance results of the Far Ultraviolet Spectroscopic Explorer (FUSE) spectrograph,'' Proc. SPIE, 3356, 18.

Wolven, B. C. and Feldman, P. D., 1998. ''Self-absorption by vibrationally excited H_2 in the Astro-2 Hopkins Ultraviolet Telescope spectrum of the Jovian aurora,'' Geophysics Research Letters 25, 1537.

Wolven, B. C. and Feldman, P. D., 1998. ''GHRS observations of solar Lyman-α induced fluorescence of H_2 and CO in comets and planetary atmospheres,'' in *The Scientific Impact of the Goddard High Resolution Spectrograph*, ed. J. C. Brandt, T. B. Ake, III & C. C. Petersen, ASP Conference Series, Volume 143, p.373.

Wyse, R.F.G., Gilmore, G., & Franx, M., 1997. ''Galactic Bulges,'' ARA&A, 35, 637.

Wyse, R.F.G., 1997. ''The IntraCluster Medium: An Invariant IMF,'' ApJ, 490, L69.

Wyse, R.F.G., 1998. ''Phase Space Density Constraints on the Formation of Bulges from Disks,'' MNRS, 293, 429.

Wyse, R.F.G., Ferguson, A.M.N., Gallagher, J.A. & Hunter, D.A., 1998. ''Star Formation in Disk Galaxies,'' PASP, 15, 118.

Wyse, R.F.G. ''Constraints on the early IMF from Chemical Evolution'' 1998. Invited review, 38th Herstmonceux Conference, ''The Stellar Initial Mass Function'' ASP Conference Series 142, eds G. Gilmore & D. Howell, (ASP, San Francisco) p89.

Wyse, R.F.G. ''From Proper Motions to Galaxy Formation and Evolution,'' 1997. Invited talk, Meeting in honor of the 100th Anniversary of Astronomy at U MInnesota, ASP Conference Series 127, eds R. Humphreys (ASP, San Francisco) p183.

Zheng, W., and Fang, L.-Z. 1998. ''Lyα/Hα Ratio of Singly Ionized Helium in Quasars,'' ApJ, 505, 512.

Zheng, W., Davidsen, A. F., and Kriss, G. A. 1998. ''The He II Opacity of the Lymanα Forest and the Intergalactic Medium,'' AJ, 115, 391