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This report covers the period October 1995 through September 1996.

1. INTRODUCTION

The years have seen the growth of a highly varied astronomy and astrophysics program in the Department of Physics and Astronomy at the Johns Hopkins University. A highlight of the past year was visits by most Hopkins astronomers to the Apache Point Observatory to achieve familiarity with the 3.5-meter telescope. Participation in the Sloan Digital Sky Survey continues to be strong, and there are many other projects that are moving forward: the Advanced Camera for Surveys *HST* project; Far-Ultraviolet Spectroscopic Explorer; Sounding Rockets (just renewed for a further three-year period); HUBE, the Hopkins Ultraviolet Background Explorer (selected by NASA in April 1996 as a MIDEX Alternate payload); Hopkins Ultraviolet Telescope (massive processing of the data); and many smaller projects. Our widespread work in theory, observation, and instrumentation continues apace. Visit http://www.pha.jhu.edu.

2. PERSONNEL

L. Bianchi and H. Weaver have joined CAS as Research Scientists. New post docs are M. Dickinson and E. Murphy. Hopkins' scientist-astronaut Sam Durrance has departed. Durrance is now Director of Science and Technology at Final Analysis, Inc. R. Griffiths left to go to Carnegie Mellon in Pittsburgh. A. Naim and K. Ratnatunga join R. Griffiths in Pittsburgh. N. Roche is now at University of Wales. G. Bowers left to take a position at NOAO, Tucson.

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. F. Strobel, A. Szalay, and R. Wyse, Professors; D. Neufeld, Associate Professor; W. P. Blair, and G. A. Kriss, Associate Research Professors; Wm. G. Fastie, Adjunct Research Professor; M. Finkenthal, Visiting Professor; L. Taff, Principal Research Scientist; R. Burg, S. McCandliss, S. Friedman, J. Kruk, J, Murthy, Z. Tsvetanov, and A. Uomoto, Research Scientists; M. Allen, A. Connolly, B. Espey, D. Golimowski, D. Hall, C. Holmes, E. Kaiser, Y. Pei, P. Rosati, D. Sahnow, K. Sembach, K. Weaver and W. Zheng, Associate Research Scientists; C. M. Carollo, J. Daniels, S. Doty, M. Martinez, G. Meurer, C. Mihos, E. Murphy, S. Regan, and M. Spaans, 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. RESEARCH AND ACTIVITIES

Luciana Bianchi is studying massive star populations in Local Group Galaxies (M31, M33, NGC 6822). *HST* (WFPC-2), UIT and ground-based photometry are used to detect the hottest, most massive objects in nearby galaxies, by comparison with evolutionary tracks and isochrones.

HST UV spectroscopy of a few O massive stars in each galaxy was obtained (O and B supergiants, LBV, W-R) and complemented with ground-based spectroscopy (KPNO WYIN and 4m, MMT, and the William Herschel Telescope 4.2-m at IAC, La Palma, Spain). The wind and photospheric lines of stars in M33, M31 and NGC 6822 are compared to stars of the same spectral type in the Milky Way and the Magellanic Clouds, to study how the mass loss rate and other stellar parameters depend on global parameters of the parent galaxy, such as metallicity and star formation history. Stellar quantities ($T_{\rm eff}$, log g, Lum, abundances, Mass loss rate, wind velocity, Radius) are derived by detailed modeling of the UV and optical line profiles. The derived stellar parameters are compared among ''similar'' stars in different galaxies, and to predictions from radiation pressure wind theory, and stellar evolution theories.

William P. Blair is an associate research professor in the Department of Physics and Astronomy. He is completing his duties as deputy project scientist for the Hopkins Ultraviolet Telescope (HUT) Project this year, and is in transition to the Far Ultraviolet Spectroscopic Explorer (FUSE) Project as planning and scheduling scientist. With the successful two-week flight of HUT on the Astro-2 space shuttle mission (STS-67) in 1995 March, HUT data reduction and analysis have dominated this year's activities. Blair has participated in numerous HUT papers on supernova remnants, cataclysmic variable stars, and other related topics that have either been published or are in press. Specific results include the first FUV spectra of the supernova remnants Puppis A (with K. S. Long, J. C. Raymond [SAO], and G. A. Kriss) and SN 1006 (with Raymond and Long), HUT spectra of classical novae (with JHU graduate student B. W. Greeley and Long) and dwarf novae U Gem (with Long and Raymond), VW Hyi (with Long, Raymond, and I. Hubeny [NASA/GSFC]), and Z Cam (with C. Knigge [STScI], Long, and R. Wade [PSU]), and a paper on the search for Fe III absorption in a star located behind SN 1006 (with Raymond and Long). Numerous other HUT results are still in preparation for publication.

In addition, Blair has continued independent research on galactic and extragalactic supernova remnants using both ground-based telescopes and space-based instruments. *Hubble Space Telescope* imagery of the supernova remnant N132D in the Large Magellanic Cloud, a member of the ''oxygen-rich'' class of remnants, was carried out this year, in conjunction with J. Morse (U. CO) and a host of coauthors. These images show the structure of the nebulosity in exquisite detail and demonstrate the stratification of the supernova ejecta and the interaction of the blast wave with the surrounding ISM. These data have been followed by FOS spectroscopy of three filaments, which are undergoing analysis now. Also, a *Hubble* paper on narrow band images of the Crab Nebula has been submitted, with K. Davidson (U. MN), R.A. Fesen (Dartmouth), and several other collaborators.

Two papers are in press dealing with surveys of nearby galaxies for supernova remnants. With S. Gordon (LLNL), Long, and others, an extensive survey of M33 has pushed the number of remnant candidates in that galaxy to 98. This is the largest optical sample known in any galaxy. A deep X-ray survey of M33 was also completed with Long, P. A. Charles (Oxford), and Gordon. With Long, Blair has completed an emission-line survey of two nearby Sculptor group galaxies, NGC 300 and NGC 7793, finding 28 strong candidate objects in each galaxy, many of which were confirmed with spectroscopy. This is the first such survey to push beyond the Local Group of galaxies. A similar survey is in progress for the more distant face-on spiral M83.

Brian R. Espey continued his work analyzing symbiotic and active galactic nuclei (AGN) spectra from the HUT Astro-2 mission. This work has led to a number of papers published in the current year including one on far-UV diagnostic emission lines of NeV and NeVI in collaboration with the atomic physics group at the Queen's University of Belfast (Espey *et al.* 1996). In addition, he has collaborated on several papers concerning the UV and X-ray spectrum of the low redshift AGN NGC 3516 (Kriss *et al.* 1996a; Kriss *et al.* 1996b).

Espey holds an adjunct position of research assistant professor at the University of Pittsburgh, and has continued his collaboration with co-I R. Schulte-Ladbeck, and graduate student J. Birriel on the analysis of Astro-2 and ground-based data of symbiotic star systems. A poster paper containing new results on the far-UV opacity of atomic and molecular material in the atmosphere of two giant star components in two symbiotic binaries was presented at the summer AAS meeting in Madison. Two more papers of symbiotic binary results are being prepared for submission to ApJ.

In addition to his work with Schulte-Ladbeck, Espey has also collaborated with D. Turnshek of Pittsburgh on a review of the ionizing spectra and structure of Broad Absorption Line QSOs (BALQSOs) (Turnshek *et al.* 1996), and has recently submitted a paper on [OIII] emission from these objects, as well as one on the dusty sightlines towards the gravitational lens H1413+1143.

Recent work with A. Cooke (ROE) and R. Carswell (IoA) has resulted in a paper on the ionizing UV background at moderate to high redshift, and this 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 also continued 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 collaborations with A'Hearn, H. A. Weaver, M. R. Combi (U. MI) and G. P. Tozzi (Arcetri) in various programs of *HST* observations of comets that included comets Hyakutake and Hale-Bopp as well as periodic comets Schwassmann-Wachmann 1 and Kopff. He collaborated with D. T. Hall and D. F. Strobel 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 beta Pictoris. He is a member of the science teams for the Far Ultraviolet Spectroscopic Explorer (FUSE) mission and for the Advanced Camera for Surveys. Through 1995 he served as a member of the *HST* Users Committee, and is currently a member of NASA's Small Bodies Science Working Group and Sounding Rocket Users Group.

Holland Ford, in collaboration with Ball Aerospace and colleagues from JHU, the STScI, the University of Arizona, the University of California at Santa Cruz, Leiden University, and the Goddard Space Flight Center, continued work on the Advanced Camera for Surveys (ACS) for the *Hubble Space Telescope*. During the past year all the filters, prisms, and grism have been specified in detail. Orders have been placed for the majority of the filters. The mirrors for the ACS will be delivered to Ball Aerospace by Tinsley Optics in December 1996. The mirrors for the High Resolution Camera (HRC) and the Solar Blind Camera will be coated with $Al+MgF_2$ at Goddard. The Wide Field Camera (WFC) Mirrors will be coated with silver at Denton Vacuum. The graphite epoxy optical bench has been designed and ordered, and will be delivered to Ball in late December 1996 or early January 1997. Two lots of 2K×4K CCDs have been produced by SITe, and two more lots are in fabrication. There are six flight candidate 2K×4K CCDs in lot 2 with excellent cosmetic quality. SITe will deliver four 1K×1K CCDs to Ball, and four thinned 1K×1K CCDs to Mike Lesser at Steward Observatory for custom backside coating to enhance the quantum efficiency between 200 nm and 350 nm. An engineering model of the evacuated thermal housing for the two WFC 2K×4K CCDs is presently being tested. Engineering models of the WFC and HRC corrector mechanisms and the filter wheel are being tested. NASA accepted a proposal to build an aberrated coronagraph consisting of a field stop at the circle of least confusion and a pupil mask over the HRC aberration-correcting mirror. At 800 nm the coronagraph will suppress the wings of the HST diffraction-limited PSF by approximately two magnitudes, and will provide more than 2.5 magnitudes suppression relative to the present WFPC2.

Ford gave an invited talk on ''Hubble Space Telescope Observations of the Centers of Elliptical Galaxies,'' at Nobel Symposium 98, held at the Stockholm Observatory in Saltsjobaden, Sweden. The primary thrust of Ford's research during the last year has been the study of gaseous nuclear disks in the centers of elliptical and E/S0 galaxies. The kinematics of these disks measured with the Faint Object Spectrograph on *HST* provide a very efficient means of measuring the galaxy mass within the central 100 to 200 parsecs. New measurements of the rotation within the disks in M87 and NGC 4261 lead to central masses of 2×10^9 $M_\odot$ and 5×10^8 $M_\odot$ within radii of 7 and 14.5 parsecs. The corresponding visual mass-to-light ratios are $(M/L)_V \sim 3000$ M

$_{\odot}$/L$_{\odot}$ and $(M/L)_V \sim 2100$ M$_{\odot}$/L$_{\odot}$, leading us to the conclusion that these galaxies host massive black holes. Surveys conducted by Ford and others are showing that small ($r \sim 100$–200) gaseous nuclear disks are common in early type galaxies. The disks are in themselves interesting. Study of these disks will lead to a better understanding of the fueling of black holes, and will provide an efficient means for measuring the central masses of the host galaxies.

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

Along with A. Uomoto, S. Smee, 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.

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 T. Nakajima, S. Kulkarni, and B. Oppenheimer, and with former JHU research scientist S. Durrance, Golimowski uses JHU's Adaptive Optics Coronagraph and Palomar Observatory's 60-inch telescope to perform a search for brown-dwarf companions to young ($\sim$ 1 billion years old), nearby (within 20 pc) stars. Last year the group reported the detection of a VLM companion to the astrometric binary Gliese 105A that is believed to have a mass of 0.084 $M_{\odot}$, which is just above the minimum necessary for stable hydrogen burning.

This year, the JHU/Caltech group announced an even greater discovery: a bona fide brown dwarf companion to the M1 dwarf Gliese 229. Although many good brown dwarf candidates have been recognized, Gliese 229B is the first unambiguously identified brown dwarf. Multibandpass observations from 0.6 to 10.5 microns reveal that Gliese 229B has a bolometric luminosity of $5\times10^{-6}L_{\odot}$, or 20 times less than the faintest previously identified brown dwarf candidate, GD 165B. Near-infrared spectra of Gliese 229B reveal strong absorption by water and methane, which is not seen in late M dwarfs but resembles the reflected-light spectrum of Jupiter. Preliminary models of Gliese 229B's spectrum by other groups suggest that Gliese 229B has an effective temperature of 900–1000 K and a mass 40–55 times that of Jupiter. With an observed binary separation of 7.7″, the brown dwarf presently lies at least 45 AU from the primary star, or about the same distance as Pluto from our Sun. Thus, Gliese 229B takes at least 450 years to orbit its larger companion. The JHU/Caltech group was subsequently awarded four orbits of *HST* Director's Discretionary Time to measure the parallax and proper motion of Gliese 229B as well as to search for other companions to the system. Results from these observations will be published in early 1997.

Following up the earlier JHU/Caltech detection of the VLM star Gliese 105C, Golimowski, *HST* Guaranteed Time Observers W. Fastie (JHU) and D. Schroeder (Beloit), and A. Uomoto published the first WFPC2 observations of Gliese 105C. V- and I-band measurements suggest the star to have a spectral type of M7V. This preliminary spectral classification supports the empirically derived assertion that the end of the hydrogen-burning main sequence may occur as early as spectral type M7. Although the observed separation and position angle of Gliese 105C are not consistent with astrometric predictions, the WFPC2 observations do not reveal any other companions that may account for the astrometric perturbation of Gliese 105A. More WFPC2 observations of the Gliese 105 system, as well as 23 other nearby stars, are planned following the February 1997 *HST* servicing mission.

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 ten months has been spent developing a clean facility at JHU for long-term studies of ACS CCD performance and for ACS ramp-filter calibration. Equipment for the calibration and test facility is either en route or in house, and routine operation is expected by year's end. Golimowski and ACS team members M. Clampin (STScI) and Z. Tsvetanov will be jointly responsible for characterizing the CCDs and filters at the JHU facility.

During August 1995, planetary scientist **Doyle Hall** used the *Hubble Space Telescope* Faint Object Spectrograph to observe Saturn very near the time when the Earth crossed Saturn's ring plane, and measured the density and distribution of hydroxyl molecules in the tenuous atmosphere that enshrouds the icy ring system. His continuing observations of Europa and Ganymede using the *HST* Goddard High Resolution Spectrograph indicates that both of these moons emit far-UV oxygen line emissions and that each has a thin atmosphere containing oxygen gas. During the summer of 1996, he also acquired *Extreme Ultraviolet Explorer* observations of Jupiter and its Io plasma torus, scheduled to coincide with the *Galileo* spacecraft's most intensive UV Jupiter scans. The ongoing analysis of the two data sets promises a unique stereoscopic view of the Jupiter system at extreme-UV wavelengths. He and J. Murthy are continuing their analysis of cosmic background and heliospheric UV emissions detected by the *Voyager* spacecraft.

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 spectra of the interstellar NaI D doublet in a large sample of starbursts. 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. In a related vein, he has collaborated with C. Norman (JHU), and

D. Bowen, C. Blades, and L. Danly (all STScI) to use the FOS on-board *HST* to study the absorption-line properties of starburst outflows at large galactocentric radii (several Holmberg radii) by using background quasars as probes. The results to date imply that starburst galaxies probably have significantly larger absorbing cross-sections than typical galaxies. This may be due to the superwind and/or the tidal debris produced by a starburst-triggering galaxy interaction.

Heckman and collaborators L. Armus (Caltech), M. Dahlem (STScI), R. Della Ceca (JHU), G. Fabbiano (Harvard-Smithsonian), D. Gilmore (STScI), R. Griffiths (JHU), M. Lehnert (Leiden), J. Wang (JHU), and K. Weaver 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 a few cases, demonstrating that much of the keV X-ray emission comes from hot gas with a temperature of several million K. There is also spectroscopic evidence for a much harder component that can be fit as either thermal emission with kT $>>$ few keV or as a hard power-law.

Heckman has also participated in several other studies of starburst galaxies. Heckman and Lehnert have emission-line images and rotation curves of their sample of starburst galaxies to show that: 1) the observed correlation between dust temperature and IR surface brightness is consistent with a simple foreground screen model for the dust 2) starbursts have a maximum surface-brightness, suggesting that some type of feedback is occurring between the massive stars and the interstellar medium 3) the starburst is located within the central region of the galaxy where the rotation curve indicates solid body rotation 4) typical starburst galaxies have masses ranging from a few percent to about 100 percent that of the Milky Way. 5) In some extreme cases, starbursts appear to be forming stars at the maximum rate allowed by causality (viz. turning all the gas into stars in one orbital time).

C. Robert (U. Laval), 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 *HST* FOS and GHRS 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 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 WFPC2 on-board the *HST* to obtain optical continuum (F555W) and narrow-band (redshifted Lyman-α) 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), J. Krolik and G. Meurer (JHU), and A. Wilson (U. MD), has obtained *HST* images of the UV continuum in ten 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 Explorer. In April of 1996, NASA selected HUBE as a MIDEX ‘‘Alternate’’ Mission. An Alternate Mission undergoes pre-phase-A study, and undergoes a Definition Phase, should the primary mission not succeed in its own definition phase. Since the primary mission, Goddard Space Flight Center’s MAP mission, will no doubt succeed in its definition phase, HUBE is being refined in hopes that it will be selected as primary mission in the next SMEX or MIDEX round. HUBE Co-Investigators are: A. F. Davidsen, P. D. Feldman, H. Ford, J. Kruk, J. Murthy, D. A. Neufeld (JHU), L. J. Paxton, K. Peacock (JHU/APL), J. Atkins, E. Hammond (Morgan State U.), G. Carranza (Córdoba, Argentina), P. A. Charles (Oxford), M. Clampin (STScI), E. Conway (Sykesville Middle School), P. Jakobsen (ESTEC), R. A. Kimble (GSFC), R. W. O’Connell (U. VA), A. Sandage (Carnegie), and C. Vaz (U. Algarve, Portugal).

Henry presented an invited poster paper on HUBE at ‘‘Stellar Ecology,’’ a meeting held in Elba, Italy, in June of 1996, in honor of Professor Icko Iben’s 65th birthday. Murthy and Henry’s graduate student, A. Dring, continued work on the 28-orbits’ worth of *HST* data on the local interstellar medium that their team (Henry, PI; W. Landsman, deputy PI; Murthy, Linsky, Vidal-Madjar, Audouze) obtained during 1996. With Murthy, Henry continues work on the *Voyager* body of observations of the cosmic ultraviolet background radiation. They continue to find many locations where the cosmic background is <100 photons cm^{-2} s^{-1} sr^{-1} Å^{-1}. Finally, a major new activity has begun with the successful launch on April 24, 1996, of the Mid-Course Space Experiment, MSX. Henry is a co-investigator on the Celestial

Backgrounds Experiment. In particular, co-I L.J. Paxton and Henry are in charge of the analysis of celestial backgrounds data obtained with the UVISI instruments, which consist of two visible imagers, two ultraviolet imagers, and five imaging spectrometers, 130–900 nm. CAS participants in the analysis of the UVISI data include J. Murthy, M. Allen, J. Daniels, and JHU graduate students A. Dring and R. Newcomer. It is expected that several papers on UVISI data will be presented at the Toronto meeting of the American Astronomical Society in January 1997.

Gerard A. Kriss is an associate research professor in the Department of Physics and Astronomy. As project scientist for the Hopkins Ultraviolet Telescope, he is continuing analysis of the far-ultraviolet spectra of more than a dozen AGN from the Astro-2 mission, including six observations of NGC 4151 and two observations of NGC 3516 which were performed simultaneously with *ASCA* X-ray observations. Applying the warm absorber models of Krolik and Kriss (1995) to the NGC 3516 observations shows that the X-ray and UV-absorbing regions in NGC 3516 have distinctly different ionization states and column densities. The absorbing medium thus appears to be complex and highly stratified. Analysis of the absorption-line variations in the six NGC 4151 observations may offer further 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 ten 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, $\sim 10^3$ 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 1200 Å to be performed during the ORFEUS/SPAS-II mission in late 1996 should provide additional constraints at higher spectral resolution.

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, in collaboration with C. Mauche (LLNL), P. Szkody (U. WA), J. Raymond (SAO), and J. Mattei (AAVSO) obtained the first spectra of U Gem in the extreme ultraviolet. The observations, which were made with *EUVE*, cover the peak and decline of a normal outburst. The (75–225 Å) spectra are complex, and there is an eclipse of the continuum source near orbital phase 0.7. At outburst maximum, the effective temperature of the continuum, is about 140,000 K and the effective size of the emitting region is about that of the white dwarf in the system. The eclipse spectrum, which is most likely associated with a wind emerging from the vicinity of the white dwarf, is dominated by emission lines, expected in a relatively cool ($T < 160{,}000$ K) photoionized plasma. The EUV lines arise from the dominant state of the wind, and their strengths suggest that the wind mass loss rate, at least in U Gem, is a substantial fraction of the white dwarf accretion rate. In other studies of U Gem, Szkody, Long, E. Sion (Villanova), and Raymond used *ASCA* to show that there was also a partial eclipse of the X-ray source in U Gem near orbital phase 0.7 during optical quiescence, and Long, Blair and Raymond showed that the FUV (820–1840 Å) spectra of U Gem far from outburst were well-modeled in terms of a white dwarf with a T of 30,000 degrees, with the possible exception of the region below 950 Å, where there is excess emission.

Long, Blair and Raymond observed a number of quiescent dwarf novae, including SS Cyg, YZ Cnc, WX Hyi, and VW Hyi, on Astro-2. Only U Gem (mentioned above) and VW Hyi show the broad Lyman profiles and narrow metal lines expected from a white dwarf salted with material accreted from the secondary star. And Long, Blair, I. Hubeny (NASA/GSFC) and Raymond found that although the spectrum of VW Hyi could be modeled as an approx. 17,000 K white dwarf with subsolar abundances, a better fit could be obtained from the combination of a white dwarf with near-solar abundances and an accretion disk. In the other systems, it seems likely that the disk is dominant, a suggestion which Long, Mauche, Ko (U. MI) and T. Kallman (NASA/GSFC) are following up in an ongoing *HST* investigations of WX Hyi and SS Cyg.

Long and C. Knigge (STScI) have also continued earlier efforts to analyze the outburst spectra of dwarf novae observed with HUT. Specifically, Knigge, Long, Blair and R. Wade (PSU) have recently completed an analysis of the spectrum of Z Cam as observed on Astro-2. They were able to approximate the overall spectrum in terms of a steady state accretion disk with $\dot{m}$ of 3×10^{17} g s^{-1}. They also succeeded in reproducing the profiles of five high ionization resonance lines in the Z Cam spectrum using a Monte Carlo radio transfer code and a description of the geometry, density and velocity profile for the wind which had been used earlier by Knigge to model C IV in the novalike variable UX UMa.

Long, Raymond and Blair also used HUT to obtain FUV spectra of a number of supernova remnants, including SN1006, Vela, Puppis and the Cygnus Loop. Due to the availability of slits as large as $18''\times120''$ and due to the fact that the HUT wavelength range includes O VI 1035 which is not accessible to *HST* or *IUE*, HUT is extremely useful for such studies. With HUT, Raymond, Blair and Long were able to detect the non-radiative filament on the NW rim on SN1006 for the first time and to show that in this 2300 km s^{-1} shock the velocities of different ions are independently randomized in the shock. Plasma turbulence is not effective in equilibrating temperatures among different ion species and is unlikely to be effective in equilibrating electron-ion temperatures. This result is consistent with conclusions being obtained by P. F. Winkler (Middlebury College) and Long from *ROSAT* HRI imagery showing that X-ray emission peaks about 7 arcsec inside the optical rim on SN1006 in the NW. Blair, Long and Raymond have also completed an analysis of the spectrum obtained of the Schweitzer-Middleditch star which lies behind SN1006, in which they confirm earlier detections of absorption from Fe II due to SN ejecta, and constrain the total amount of Fe III, in an attempt to inventory the total amount of iron ejected by the SN explosion.

Long, Charles (Oxford), Blair, and Gordon (LBNL) completed their analysis of a 50 ks *ROSAT* PSPC observation of M33 in which they identified 50 sources, many of which are associated with Pop I tracers in M33. There are ten sources which are positionally coincident with supernova remnants identified in a companion optical/radio survey of M33 carried out by Gordon, R. Kirshner (Harvard), Long, Duric (New Mexico), Blair, and Smith (U. MI). From a spectral analysis of the PSPC data, it is quite likely that a number of the other sources in the X-ray survey are also supernova remnants. Long and Charles are also continuing the effort to characterize X-ray source populations in M33 as they analyze a large amount of HRI data on this object.

Stephan R. McCandliss is currently preparing two NASA Sounding Rockets (NSR) for launch. The first NSR 36.115UG is a mission to simultaneously image atomic and molecular hydrogen UV emissions from the Jovian aurorae with 1″ resolution. The high throughput design uses an f/24 telescope with a curved LiF prism in the converging beam for the dispersing element and a thinned backside charged SITE (formerly Tektronics) CCD as the imaging device. Fine guidance is accomplished with an articulating secondary mirror and position feedback from a quadrant tracker. This work is being carried out with P. Morrissey and P. Feldman. The launch is scheduled for October 20 at 2100 MDT from White Sands Missile Range (WSMR). The second NSR 36.156UG is a mission to obtain a long slit ($\approx 330'' \times 7''$) spectrum of Comet Hale-Bopp at 5 Å resolution of cometary emission lines of C, O, S, and CO in the 1250–1850 Å spectral bandpass. This launch is scheduled for April of 1997 from WSMR.

McCandliss continues his work on developing techniques for calibration of windowless vacuum UV CCDs. He is also developing, along with J. Kruk, a windowless vacuum UV Ar arc lamp, which will find use as a continuum source in spectroscopic applications below 1150 Å. He continues to work on various hot star topics such as: the two-dimensional classification of WN type Wolf-Rayet stars; determining the interstellar absorption of molecular H and the FUV extinction in a pair of LMC O3V stars observed by N. Walborn (STScI) on Astro-2 with the Hopkins Ultraviolet Telescope; and the time variability of WR-134.

Gerhardt R. Meurer is a postdoctoral associate working with T. Heckman. Meurer, and collaborators C. Carignan (Montréal), S. F. Beaulieu (MSSSO), and K. C. Freeman (MSSSO) completed a detailed study of the neutral hydrogen (HI) properties of the galaxy NGC 2915. While in the optical continuum this galaxy appears to be an inconspicuous blue compact dwarf galaxy with a Holmberg radius (where the *B* band surface brightness is 26.6 mag arcsec^{-2}) of 3 Kpc, in the 21 cm radio emission of HI it appears five times larger, and has spiral arms—with no detected optical counterpart. Analysis of its HI dynamics shows that NGC 2915 has several outstanding properties. The rotation curve shows that dark matter (DM) dominates the mass distribution at nearly all radii. The total mass to blue light ratio is 76 within the last measured point on the rotation curve, which makes NGC 2915 one of the darkest disk galaxies known. The core of the DM halo is also unusually dense ($\rho_0 \sim 0.1 M_\odot \mathrm{pc}^{-3}$) about a factor of ten denser than typically found in disk galaxies. The neutral gas component, with mass $M_g = 1.3\times10^9 M_\odot$ is probably more massive than the stellar disk. NGC 2915 does not obey the Tully-Fisher (1977) relation, being underluminous for its $V_{\mathrm{rot}} = 88$ km s^{-1} by a factor of nine. Although the HI properties of NGC2915 are extreme relative to normal galaxies they appear less extreme in comparison to other BCDS, many of which have similar radial profiles of HI density and velocity dispersion, as well as HI extending well beyond the optical disk.

Chris Mihos has been using numerical models to study the dynamical evolution of galaxies, with an emphasis on galaxy collisions and dark matter in galaxies. The effect of dark matter halos on the formation of tidal tails in merging galaxies was studied with J. Dubinski and L. Hernquist (U. CA, Santa Cruz). It was found that massive dark matter halos prevented the formation of the long tidal tails observed in many merging galaxies, an indication that dark matter halos may not be as massive as commonly believed. With S. S. McGaugh (Carnegie Inst.) and W. J. G. de Blok (Groningen), the dynamical stability of low surface brightness disk galaxies is being explored. Because of their low surface mass density, LSB disks prove more stable against bar formation than do normal galaxies. Rather than driving central starbursts, interactions may elevate the global star formation rate throughout LSB disks, raising the surface brightness of the galaxy. This effect may explain the isolated environments in which LSB galaxies are found, as LSB galaxies in group environments may have been transformed into ''normal'' disk galaxies via interactions.

Mihos and G. Bothun (U. OR) have observed several interacting and merging galaxies with the Rutgers Imaging Fabry-Perot at CTIO, to obtain the morphology and kinematics of galaxies at different stages of merging. Observations of the nearby barred spiral NGC 2442 show that star formation is coincident with strong compression and shocks along tidal arms, and modeling of the system is consistent with the star formation activity having been triggered by a collision with a nearby companion. Such interactions are probably rather typical in the evolutionary history of galaxies in groups.

With C. Norman (JHU), S. Sigurdsson (Cambridge), and L. Hernquist (U. CA, Santa Cruz), Mihos is using parallel supercomputers to investigate the influence of massive back holes on the structure of elliptical galaxies. Preliminary results suggest that black holes may scatter stars off the box orbits which support triaxiality in ellipticals, causing galaxies to become rounder. Accordingly, it may be possible to use the isophotal shapes of ellipticals as a constraint on the presence of central black holes.

Warren Moos is the principal investigator for the Lyman Far Ultraviolet Spectroscopic Explorer. Also participating in this activity are: W. Blair, A. F. Davidsen, P. D. Feldman, S. Friedman, C. Holmes, J. Kruk, G. Kriss, R. Murphy, W. Oegerle, D. Sahnow and K. Sembach. 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 and S. Regan a postdoctoral fellow on this grant.

David Neufeld continues to study the interstellar medium, star formation, and astrophysical masers. With M. Harwit (ISO mission scientist), G. Melnick (CfA), and JHU graduate student W. Chen, he has been reducing and analyzing early data from the *Infrared Space Observatory* (*ISO*). Observations carried out during the performance verification phase of the *ISO* mission have resulted in the detection of several far-infrared rotational transitions of water toward the evolved star W Hydrae; this is the first detection of thermal water vapor emission from a circumstellar outflow. Using a theoretical model developed by Chen and Neufeld, Neufeld and collaborators have been deriving constraints upon the physical conditions in the outflow from W Hydrae.

With JHU postdoctoral fellow M. Spaans, Neufeld has been studying molecular hydrogen in diffuse interstellar clouds. A theoretical model for the fluorescent excitation of H_2 within such clouds suggests that rovibrational emissions in the *visible* wavelength region may provide the most sensitive probe of H_2 in the diffuse ISM that is currently available. Spaans and Neufeld have also been constructing three dimensional models of H_2 in diffuse clouds for comparison with far-IR continuum and H 21 cm observations. With JHU postdoctoral fellow S. Doty, Neufeld has continued work on a detailed model for the molecular line emissions from dense molecular cloud cores, with the goal of obtaining predictions against which observations by the Submillimeter Wave Astronomy Satellite (SWAS) and by *ISO* can be compared.

With D. Hollenbach (NASA/Ames), Neufeld has been modeling the free-free radio emissions expected from the accretion shocks that are expected to accompany the formation of stars. Such emissions are a potentially valuable probe of the mass of an accreting protostar, and are a possible explanation of the unexpectedly large low-frequency radio fluxes detected recently from the source NGC 1333 IRAS 4.

Neufeld continues to serve as a co-investigator on the Submillimeter Wave Astronomy Satellite, a NASA Small Explorer mission now scheduled for launch in early 1997. 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.

Yichuan Pei, with S. M. Fall (STScI), completed new models of cosmic chemical evolution and compared them with the observed abundances of neutral hydrogen, heavy elements, and dust in damped Lyα systems. To allow for a wide range of possibilities, they considered closed-box, inflow, and outflow models. The novel feature of these models is a self-consistent correction for the absorbers that are missing from existing samples as a result of the obscuration of background quasars, accomplished by assuming a constant dust-to-metals ratio in the absorbers. The models, without any fine tuning of the input parameters, reproduce all of the available data on damped Lyα systems and are consistent with the average properties of present-day galaxies. High rates of star formation at intermediate redshifts ($z \approx 1-2$) cause a rapid rise in the mean metallicity. In contrast, models without obscuration have less star formation at these redshifts and fail to match the mean metallicity in the damped Ly-α systems.

Pei, with S. M. Fall (STScI) and S. Charlot (IAF), presented a method to compute the cosmic emissivity and the cosmic background radiation. The approach is quite new because the ''emission history'' of the universe is predicted from its ''absorption history.'' The inputs of this method are based entirely on data from quasar absorption-line studies, namely, the comoving density of neutral hydrogen and the mean metallicity and dust-to-gas ratio in damped Ly-α systems. These observations, when combined with models of cosmic chemical evolution, are sufficient to determine the comoving rate of star formation as a function of redshift. From this, they compute the cosmic emissivity and background radiation using stellar population synthesis models, including a self-consistent treatment of the absorption and reradiation of starlight by dust. In all of these calculations, the near-UV emissivity declines rapidly between $z \approx 1$ and $z - 0$, in good agreement with estimates from the Canada-France Redshift Survey. The background intensity is consistent with a wide variety of observational limits and with a tentative detection at far-IR wavelengths.

David Sahnow continues as instrument scientist for the Far Ultraviolet Spectroscopic Explorer. In this role, he is responsible for modeling the expected on-orbit performance of the FUSE instrument. This includes detailed analysis of the properties of the optics, pointing, and structural stability for FUSE.

Marco Spaans studied the chemical and thermal balance of inhomogeneous interstellar clouds. The enhanced penetration of ultraviolet radiation was found to strongly influence their ionization structure. These results have been applied to photon-dominated regions like the Orion Bar, IC 63 and S140 in collaboration with E. van Dishoeck (Leiden).

During the last six months he has investigated the multiphase structure of the interstellar medium in protogalactic disks in collaboration with C. Norman. The feedback between the cooling time of primordial gas and the radiation field produced by stellar activity was found to postpone the emergence of a cold molecular phase to redshifts of order unity.

Together with D. Neufeld, he investigated the H_2 fluorescent emission spectrum produced in interstellar clouds illuminated by the average interstellar radiation field. Measurements of these H_2 lines in the infrared and visual wavelength regions were found to yield sensitive diagnostics of the ambient density when combined with co-spatial HI observations.

Darrell Strobel has focused his research on the interaction of plasma in the inner Jovian magnetosphere with Europa's atmosphere/ionosphere. In collaboration with F. Neubauer and graduate student J. Saur of the University of Cologne, a model of the Alfven interaction of Io torus plasma with Europa's thin molecular oxygen atmosphere, which was first detected by *HST* GHRS observations, is being developed to more accurately determine the O2 abundance on Europa. With Meudon colleague E. Lellouch, millimeter wave observations of Io this summer were made to confirm the discovery of SO in Io's thin atmosphere and search for S_2O, a likely product of surface recombination of SO.

During most of the time covered by this report **L. G. Taff** was, while retaining his Hopkins affiliation, a visiting senior scientist at NASA Headquarters in the (old) Astrophysics Division and the (new) Research Program Management Division. In addition to playing an active role in the supervision of the *IUE* and *EUVE* satellites, he oversaw NRA's, peer reviews, and grant proposals for the (old) Ultraviolet, Optical, and Relativity Branch and the AIS Branch. Considerable effort was devoted to streamlining NASA HQ's operating policies and modes as the staff at Headquarters was cut by $\sim$60%. Throughout this time his research efforts in systematic error analysis and minimization and *HST* observing work continued. In particular, the multi-paper series on star catalog construction and de-construction has been completed, the last major problem with Schmidt plates—their magnitude term—categorized, and new applications of his techniques to celestial mechanics problems commenced.

Alan Uomoto is putting the finishing touches on two fiber-optic spectrographs for the Sloan Digital Sky Survey. The Survey will use a dedicated 2.5 m telescope at Apache Point Observatory to map one quarter of the northern sky in five broadband optical bandpasses and will obtain redshifts of the brightest million galaxies and 100,000 quasars during its five year observing run.

With R. Antonucci (U. CA, Santa Barbara), H. Ford, G. Kriss, Z. Tsvetanov, and JHU graduate student C. Tremonti, he continues observations of nuclear regions of Seyfert galaxies in polarized light. Recent *HST*/FOC observations of Mkn 463, a Seyfert 2 with an optical jet, show a broad kpc-sized fan of polarized UV light that is almost certainly the polarizing mirror redirecting light from the hidden Seyfert 1 nucleus into our line of sight.

Kim Weaver is continuing a study of iron K-α fluorescence lines in Seyfert galaxies using data from the *ASCA* satellite with collaborators J. Nousek (PSU), T. Yaqoob, R. Mushotzky (NASA/GSFC), I. Hayashi, and K. Koyama (Japan). The Seyfert galaxy MCG-5-23-16 possesses a remarkable iron K-α line which consists of two distinct components and is unlike any other iron line profile seen with *ASCA*. The primary component of the line is narrow (less than 6,600 km s^{-1} FWHM) while the secondary component is very broad with a FWHM of 90,000 km s^{-1}. The broad line contains a significant number of photons at energies higher than 6.4 keV and suggests a double-horned profile expected for an accretion disk viewed at an inclination of 30 to 60 degrees.

With JHU collaborator J. Krolik and E. Pier of NASA/GSFC, Weaver has also obtained XTE data for MCG-5-23-16. Preliminary analysis shows a strong signature of Compton reflection. The XTE data will be used with the *ASCA* data to provide even tighter constraints on the iron line profile and to study the time variability of the flux from reprocessed X-rays in this galaxy.

R. Wyse completed a major study of the internal kinematics of the Sagittarius dwarf galaxy, in collaboration with R. Ibata (U. British Columbia), G. Gilmore (Cambridge), M. J. Irwin (Cambridge) and N. B. Suntzeff (CTIO). The radial velocity data, combined with preliminary proper motion measurement, allow constraints on the orbit of this galaxy about the center of the Milky Way. The orbital period is a factor of ten or so shorter than the ages of the stars in the Sagittarius dwarf galaxy, so that this dwarf galaxy has completed many orbits, and implying that it is rather impervious to the effects of Galactic tides. We develop a model for the survivability of this galaxy, concluding that it has a roughly constant density dark matter halo.

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