I. INTRODUCTION

We have concluded another year of intense work spanning the gamut from theoretical astrophysics to flying sounding rockets and preparing for future space missions. We and the University are firmly committed to the Sloan Digital Sky Survey (SDSS). In addition to contributing ideas for the design of the survey and the subsequent reduction of the data, object identification, classification, and cataloging, we are building the spectographs for SDSS 2.5-m telescope. We submitted three excellent proposals for Small Explorer Satellites. Although two of our proposals were finalists in the ultraviolet category, none of our proposals were selected. The LymanFUSE project is in Phase B, and working hard toward a Critical Design Review in 1996. Preparations are underway for the second Astro Mission which will fly on the Space Shuttle in late 1994. The new silicon carbide coatings used on HUT are expected to improve its performance by a factor of three. In addition to theory and building space hardware, we continue vigorous observing programs using telescopes in orbit and around the world.

This report covers the period October 1992 through September 1993.

II. PERSONNEL

New CAS members include S. Casertano and E. Kaiser, K. Ratnatunga, Y. Pei, Associate Research Scientists; Hubble Fellow G. Mark Voit; A. Connolly, J. Daniels, R. Della Ceca, D. Golimowski, L. Neuchaefer, M. Vogeley, M. Dahlem and G. Meurer, Post Doctoral Fellows; and A. Illarionov, Visiting Research Scientist. R. F. G. Wyse was promoted to full Professor and D. A. Neufeld to Associate Professor; W. P. Blair and G. A. Kriss were promoted to Associate Research Professors; S. T. Durrance was promoted to Principal Research Scientist and M. Finkenthal to Visiting Professor; A. Uomoto was promoted to Research Scientist; T. Broadhurst and D. Sahnow were promoted from Post Doctoral Fellow to Associate Research Scientists. J. Lowenthal has left to take a Hubble Fellowship at Lick Observatory. M. Corbin has left to work at Kitt Peak National Observatory. C. W. Bowers now works at GSFC as an Optical Scientist on the STIS project. T. Snecker-Hane successfully defended her thesis and is now at Dominion Astrophysical Observatory. D. Balsara continues as Post Doctoral Fellow. B. Wang continues as the Davis Post Doctoral Fellow. Other permanent staff are: P. J. Dagdigian, A. F. Davidsen, J. P. Doering, P. D. Feldman, H. C. Ford (Director, CAS), R. Giacconi (Director, ESO), R. Griffiths, T. M. Heckman, R. C. Henry, B. R. Judd, C. W. Kim, J. H. Krock, H. W. Moos (Chair, Physics & Astronomy) C. A. Norman, D. F. Stobel, and A. Szalay, Professors; R. A. Brown, S. M. Fall, Research Professors; S. Lubow, Assistant Research Professor; Wm. G. Fastie, Adjunct Research Professor; M. Allen, R. Burg, R. Buss, S. Friedman, D. Hall, C. Holmes, L. Huang, J. W. Kruk, S. McCandliss, J. Murthy, Z. Tsvetanov, and W. Zheng, Associate Research Scientists; K. S. Long, Associate Astronomer (STScI)/Adjunct Research Professor (JHU/CAS); P. Madau, M. A. McGrath, and H. A. Weaver, Assistant Astronomers (STScI); and F. Paresce, Senior Astronomer (ESA/STScI).

III. RESEARCH AND ACTIVITIES

William P. Blair is an Associate Research Professor in the Department of Physics and Astronomy and is Deputy Project Scientist for the Hopkins Ultraviolet Telescope (HUT) Project. He also continued his involvement with the JHU portion of the Faint Object Spectrograph (FOS) Team. These duties included detailed involvement in data reduction and analysis of results from the Astro-1 mission in December 1990, participation in an Astro-related Mission Planning Team (which is looking into improving the mission planning for Astro-2), and participation in the FOS GTO science program. In addition, he has continued independent research on galactic and extragalactic supernova remnants using both ground-based telescopes and space-based instruments.

Blair and HUT team members have continued to work on data for several supernova remnants obtained during the Astro-1 mission. Work has continued this year to analyze spatially resolved optical and IUE (UV) spectra of a bright radiative filament in the Cygnus Loop observed with HUT. Since the HUT spectrum at this position contained no spatial information, these data are providing a more detailed look at this peculiar filament. In addition, with K. S. Long (STScI/CAS), J. C. Raymond (SAO), and members of the HUT team, the HUT spectrum of a nonradiative filament in the Cygnus Loop has been published this year. With JHU graduate student O. Vancura (now at Harvard) and the rest of the HUT team, the HUT spectrum of the LMC remnant N49 has also been published. With R. B. C. Henry (Univ. Oklahoma), Blair and other HUT team members published an extensive analysis of the HUT spectrum of the Crab Nebula. This spectrum demonstrates for the first time relative UV line intensity variations are present in the Crab, and points to possible carbon abundance variations between the filaments. Blair also contributed to a number of other HUT results which will be described elsewhere in this report.

Blair and collaborators have pursued far-UV observations of several supernova remnants with the Voyager Ultraviolet Spectrometers. A detailed analysis of several Cygnus Loop positions, including optical and X-ray data, was carried out in conjunction with Vancura, Long, and J. B. Holberg (LPL/Univ. Arizona). Spectra at two positions in the Vela supernova remnant are also being analyzed, demonstrating the presence of O VI emission in

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this object for the first time. Finally, with R. A. Fesen (Dartmouth College), a third galactic SNR has been detected with Voyager, that being G65.3+5.7.

Work also continues on several projects to investigate supernova remnants in nearby galaxies. A paper on an analysis of optical spectra of M33 supernova remnants was published this year with R. C. Smith (NOAO/CTIO) and collaborators, following up an earlier CCD survey project of this galaxy. A similar spectroscopic follow-up program was carried out by Blair at CTIO for remnant candidates in the southern spiral galaxy M83. This is the most distant galaxy that has been surveyed for supernova remnants, and comparison of these results to ROSAT data (when available) will be particularly fruitful. A preliminary search of CCD imagery of the galaxy NGC 6946 discovered an extremely bright, but previously unidentified supernova remnant at the position of a Rosat point source in this galaxy. This object is one of the most luminous optical supernova remnants ever identified. A detailed study of N132D, a young, oxygen-rich supernova remnant in the LMC using IUE was completed with Raymond and Long. Spectra at two positions show line intensity variations consistent with He, C, O, and Si abundance variations in this object.

As part of the FOS QTO program, Blair and A. F. Davidsen (JHU/CAS) have published a paper on two M33 supernova remnants. WF/PC images of the objects were used to help understand the peculiar line profiles observed in ground-based echelle data. Other Hubble work on the peculiar remnant in NGC 4449 and the LMC remnant N49 are in progress. Many of the above results were presented at IAU Coll. 145, "Supernovae and Supernova Remnants," held in Xian, China, in 1993 May.

Richard H. Buss Jr. has worked toward calibrating, analyzing, and publishing the stellar spectra acquired with the Hopkins Ultraviolet Telescope (HUT) on the Astro-1 space shuttle mission. With several HUT spectra, he showed that the Galactic FUV-extincting dust evolves by the generally known process of coagulation. Buss also found a correlation between the FUV-extincting and IR-emitting dust, suggesting that some of the FUV dust is volatile and extremely small, evaporating and condensing as molecules, perhaps PAHs, on the surfaces of larger grains. The Galactic dust extinction mission was conducted with M. Allen (JHU/CAS), S. McCandless (JHU/CAS), J. Kruk (JHU/CAS), and graduate students J.-C. Liu and T. Brown (JHU/CAS). By analyzing the HUT, WUPPE (Astro-1), and IUE spectra of massive, hot, young stellar objects, Buss also investigated - with graduate student T. Brown (JHU/CAS), C. Grady (ARC), K. Bjorkman (Univ. Wisconsin), and R. Schultz-Ladbeck (Univ. Pittsburgh) - the proto-planetary disk surrounding the central star. Molecular hydrogen seems absent from the disk, and the dust appears to be larger than in molecular clouds, indicating that the disk has evolved since forming from the Galactic medium.

Buss assisted S. McCandless in calibrating the spectrum of the Wolf-Rayet star EZ Cna and interpreting the influence of interstellar extinction on the intrinsic spectrum, which mainly agrees with atmospheric models but also shows some discrepancies due to metals. Buss collaborated with J. Kruk (JHU/CAS) and R. Kimble (NASA/GSFC) in calibrating the HUT spectrograph data and began with the aid of J. Holberg (Univ. Arizona) a guest investigator program using the Voyager spacecraft to intercompare HUT and Voyager fluxes toward pinning down the absolute flux-calibration in the Far-UV. R. Buss has also assisted W. Blair (JHU/CAS) with the mission planning of Astro-2.

Paul J. Dagdigian and his group are continuing laboratory studies of the dynamics of inelastic and reactive collisions of atoms and small molecular free radicals. Of particular interest in the past year has been the collisional electronic quenching of the NH radical in its metastable 1a1 state, collision-induced transitions between the A2Π and X2Σ+ electronic states of the CN radical, and interactions, both reactive and nonreactive, of the boron atom in its ground p2P and several electronically excited states with inert gases and the hydrogen molecule.

Arthur F. Davidsen continues to direct the Hopkins Ultraviolet Telescope Project, including analyzing data obtained on the ASTRO-1 Mission and preparing HUT for ASTRO-2, currently scheduled for launch in November 1994. He also continues as a co-Investigator on the FOS team using HST. During the past year he chaired the NASA/NRC Task Group on AXAF, and he serves on the NRC Committee on Astronomy and Astrophysics.

Paul D. Feldman 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 was selected to lead a study of a possible Discovery mission to study the Jovian system from Earth-orbit using FUV/EUV imaging and spectroscopy. The team includes F. Bagenal (Univ. Colorado), M. J. S. Belton (NOAO), A. L. Broadfoot (Univ. Arizona), J. T. Clarke (Univ. Michigan), A. Delamere (Ball Aerospace), A. L. Lane (JPL) and D. R. Skillman (NASA/GSFC).

Feldman also continued his IUE comet program (in collaboration with M. F. A'Hearn of the Univ. Maryland), with observations of comets Swift-Tuttle (1992t) and Schaumasse (1992x). This latter comet was also the target for an HST program utilizing the Faint Object Spectrograph (led by H. A. Weaver of the STScI, together with A'Hearn and C. Arpigny of the Institut d'Astrophysique de Liege). Nearly simultaneous IUE and HST ultraviolet spectra of this comet were obtained. An expanded team (led by Weaver) also obtained both FC images and FOS spectra of comet Shoemaker-Levy 9 (1993e) in July 1993 in anticipation of the comet's crash into Jupiter during the summer of 1994. Feldman also participated in a team (led by A. Vidal-Madjar of the Institut d'Astrophysique de Paris) that obtained high resolution GHRS spectra of beta Pictoris in order to study the nature of possible cometary bodies surrounding the star, and was a member of the team (led by H. W. Moos) that obtained EUVE spectra of the Jovian system in March 1993.

Feldman has continued his collaborative analyses of cometary ultraviolet spectra with S. A. Budzien (Naval Research Laboratory), M. R. Combi (Univ. Michigan), M. C. Festou (Toulouse) and G. P. Tozzi (Arcetri). He also collaborated with M. A. McGrath (JHU/STScI), G. E. Ballester (Univ. Michigan), R. Courtin (Meudon), D. T. Hall, D. F. Strobel and H. W. Moos (JHU) in analyses of HST observations of Jupiter, Io and the Io plasma torus, and Titan. He is currently a member of the HST Users Committee and of NASA's Small Bodies Science Working Group and serves as a Trustee of the Universities Space Research Association.

H. Ford, X. Hui, and K. Freeman used a Tek 2048 CCD at prime focus of the CTIO 4-m telescope to survey the halo of Cen A for planetary nebulae at projected
distances between 20 kpc and 40 kpc. In spite of poor weather, they found approximately 70 new nebulae at radii larger than 20 kpc. They plan to measure the radial velocities of these nebulae in order to investigate the distribution of mass in the halo at the largest possible distances.

Ford and his FOS collaborators at JHU and the STScI have used narrow band images taken with the Hubble Space Telescope's Planetary Camera to resolve the narrow line region in several Seyfert galaxies and LINERS. These observations show [OIII] ionization cones in NGC 1068, NGC 4151, Markarian 3, and M51, and reveal a bright jet in Markarian 463. HST FOS spectra of "clouds" in NGC 1068's ionization cones show clear evidence of a bi-directional outflow from the nucleus. Ford and his collaborators conclude that the axis of the ionizing cones and outflows in the nuclei of active galaxies are often tipped with respect to the axis of the parent galaxy. In extreme cases, such as M51, the axis of the "engine" lies in the plane of the galaxy. The apparent extent and appearance of the narrow line region thus will depend on the angle between the axes of the engine and the galaxy, as well as the luminosity of the nucleus and the viewing angle of the observer with respect to the obscuring tori which often appear to surround active nuclei.

Ford and his collaborators W. Jaffe, (Leiden Univ.), R. O'Connell, (Univ. Virginia) and JHU graduate student L. Ferrarese, and F. van den Bosch (Leiden Univ.) used broad band HST planetary camera images of the radio elliptical galaxy NGC 4261 (E3) to find a small (1.7" x 0.74") dusty disk with sharp edges and a point-like nucleus. The disk's minor axis is aligned with the axis of the large scale bi-directional radio jet which originates in the nucleus. The disk contains HI and CO, and the nucleus is a LINER with unusually strong and broad (FWZI = 4500 km s^{-1}) emission lines of [NII] and [SII]. Ford and his collaborators conclude that they are looking directly at the structure, i.e., the nuclear disk, which fuels the engine and determines the direction of the radio jet. Although kpc-size disks of gas and dust are observed in some elliptical galaxies (e.g., Cen A), the disk in NGC 4261 is nearly unique in size and obvious relationship to the active nucleus. Because spectra from the William Herschel Telescope (WHT) show subtle but unmistakable evidence for rotation of ionized gas in the disk, Ford's group plans to use COSTAR corrected HST images with the FOS 0.99" aperture (0.1-PAIR) to map the velocity field at radii less than 20 pc from an active nucleus. The observations of this small nuclear disk may provide an opportunity to make an unambiguous measurement of the mass of an active nucleus.

The H0 Key Project Team, which includes H. Ford and L. Ferrarese, used HST wide-band F555W WF images taken at 18 independent epochs to find 30 new Cepheids in the nearby galaxy M81. Prior to this work two Cepheids were known in M81. The periods for the new Cepheids lie in the range of 10 to 55 days. The apparent period-luminosity relations in V and I were used to measure the total mean extinction to the M81 Cepheids (E(B-V) = 0.03 mag) and a true distance of 3.63 ± 0.34 Mpc. These observations show that with optimal (power-law) sampling of the light curves, the HST provides a powerful tool for finding extragalactic Cepheids.

Ford and his colleagues J. Crocker and G. Hartig at the STScI spent a great deal of time at Ball Aerospace in Boulder Colorado during the final months of assembly, alignment, and verification of COSTAR, an instrument which will be installed in the HST during the first servicing mission. For each optical path in the FOC, FOS, and GHRS a small COSTAR spherical mirror images the HST pupil onto a second anamorphic asphere which has the inverse spherical aberration of the HST primary, thereby removing the spherical aberration before the light reaches the corresponding scientific instrument. The tests at Ball verified that the deployable optical bench and the arms which carry the aspheric mirrors deploy correctly. More important, three independent tests using direct imaging in the focal plane, direct imaging through an engineering model of the FOC, and interferometry, show that the COSTAR optics will restore the HST image quality to very close to its design value.

**Scott D. Friedman** is the Hopkins Project Scientist for the Lyman Far Ultraviolet Spectroscopic Explorer (FUSE) mission, which is currently in the Phase B design stage. FUSE will make observations in the critical 910-1250 Å, at a spectral resolving power of approximately 30,000. FUSE is currently scheduled to be launched in 2000.

Along with A. Uomoto and P. Feldman (JHU/CAS), Friedman is also designing and constructing two fiber optic spectrographs that Hopkins is building as part of the Sloan Digital Sky Survey. Each spectrograph will record the spectra of 330 separate objects over a wide field of view. The first spectrograph is scheduled for delivery to the dedicated 2.5 meter telescope at Apache Point Observatory in late 1994.

**David Golimowski** has joined the Extrasolar Planet Search project headed by Prof. W. Fastie (JHU/CAS) as a postdoctoral fellow. The project currently involves analysis of laboratory-simulated images of the Planetary Camera (PC) aboard the Hubble Space Telescope (HST) as part of a feasibility study for detecting Jovian planets and substellar companions around nearby stars. The work will culminate with observations of 18 nearby stars, including Barnard's Star, with HST after the December refurbishment mission. Golimowski received his Ph.D. from JHU last May after a successful defense of his thesis entitled "Coronagraphic Imaging of Protoplanetary-Disk Candidate Stars using Adaptive Optics". The thesis included high-resolution coronagraphic images of the inner region of the Beta Pictoris circumstellar disk which revealed changing disk structure within 100 AU of the star. Portions of Golimowski's thesis have been published in *Applied Optics, The Astronomical Journal*, and *The Astrophysical Journal Letters*.

**Richard Griffiths** joined the Department in summer 1992, bringing with him the HST Medium-Deep Survey Key Project, as well as membership of the HST WFC2 Investigation Definition Team, and his Mission Scientist position for the X-ray multi-Mirror Mission (XMM). The Medium-Deep Survey is a large, collaborative effort led by the JHU Team (R. Griffiths, PI, and K. Ratnatunga, co-I, supported by L. Neutsch, E. Wyckoff and S. Casertano). The survey was approved for up to 200 hours of observation for each of the first three Cycles of HST observations, and has thus far accumulated nearly 200 hours of actual HST observations, primarily with WFC2. The random fields have included exposures as deep as 40 orbits in a field near NGC 5548. A large ground-based follow-up program has been in operation over the past year, in order to complement
the HST color-information (V and I only) and to get redshifts for the brighter galaxies in the survey. The ground-based follow-up is conducted in collaboration with co-Is in the U.S. and abroad. The MDS database is maintained at JHU, where the recalibration of the data is also carried out. The group has optimized software for the detection and classification of faint objects in the HST images, and continues work on the measurements of the sizes of faint galaxies, using galaxy models and the maximum-likelihood technique. The most important findings so far are the small sizes of galaxies at moderate redshift (0.5) and the high fraction of galaxies which show evidence of interactions or irregular morphology. The project has been re-approved for continuation after the HST refurbishment mission scheduled for December.

The Wide Field and Planetary Camera 2 team was joined in August 93 by S. Casertano, whose primary work will be on the analysis of GTO data from WF/PC2, in support of Griffiths' role as member of the IDT for WF/PC2.

The X-ray Multi-Mirror Mission (XMM) is an ESA cornerstone mission scheduled for launch in 1999, supported on the Science Working Team by R. Griffiths as one of two U.S. Mission Scientists. Griffiths is supported in this role at JHU by R. Della Ceca, who joined us in March 93. As well as carrying out simulations of the XMM observations, Della Ceca works on the luminosity functions of extragalactic X-ray sources, using data from the Einstein Observatory and the Deep Surveys with ROSAT, for which Griffiths is P.I. The ROSAT Deep Surveys have been carried out in collaboration with co-Investigators in the U.K., and have been used to show that the X-ray Background at 1 kev is dominated by AGN, but with important contributions from star-forming and other galaxies.

Doyle Hall joined CAS October 1992 after receiving his Ph.D. from the University of Arizona. He is a Planetary Scientist whose interests span many subjects pertinent to Ultraviolet Astronomy. His Ph.D. thesis involved the investigation of the structure of the heliosphere and the Local Interstellar Medium using data from the Voyager spacecraft Ultraviolet Spectrographs. He has actively worked in the investigation of the upper atmospheres of Jupiter, Saturn, Titan, Uranus and Neptune using data from the Voyager, Pioneer, and IUE spacecraft. Currently he is collaborating with D. Strobel (JHU/CAS) in a reduction and analysis of the airglow and extended UV emissions of Neptune and Triton. He and J. Murthy are analyzing cosmic background UV emissions. He also is working with a large team (including CAS members W. Moos, P. Feldman, and D. Strobel) analyzing the first observations of Jupiter and the Io torus using the EUVE satellite.

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. Lehner (LLNL/GPP) have analysed long-slit optical spectra and deep H-Alpha images of a sample of 50 of the nearest and brightest starbursting disk galaxies oriented such that their large-scale stellar disks are seen nearly edge-on. This orientation is the most favorable one for studying the superwind as it flows out along the minor axis of the galaxy. They find clear evidence that outflows are occurring in most if not all of the galaxies in their sample. Faint H-Alpha loops and bubbles extend far out into the galactic halo in many cases. The gas located projected along the optical minor axis (halo gas plus disk gas seen in projection) is much more kinematically disturbed than the gas along the major axis (pure disk gas). While the gas along the major axis has emission-line ratios implying it is photoionized by OB stars, the gas along the minor axis has emission-line ratios consistent with shock-heating by the superwind. The measured gas pressures in the galactic halos are far larger than in normal galaxies, and agree with the predicted ram pressure of the superwind. The inferred outflow velocities and the size of region affected by the outflow both increase with the starburst luminosity.

In a related project, Heckman (with JHU graduate student A. Marlowe, JHU faculty member R. Wyse, and CTIO staff member R. Schommer) have discovered evidence for a qualitatively similar starburst-driven outflow phenomenon in a sample of 20 blue compact and amorphous galaxies (low mass galaxies undergoing bursts of star formation). About half the galaxies studied have kpc-scale bubble-like structures seen in deep Fabry-Perot H-Alpha images. Long-slit echelle spectra show that these structures are expanding at about 100 km/sec (comparable to the escape velocity from these galaxies). This may provide key observational support for models of the evolution of dwarf galaxies which posit that starburst-driven mass loss is the fundamental mechanism that governs the evolution of such galaxies.

Heckman and collaborators L. Armus (Caltech), M. Dahlem (STScIJHU), G. Fabbiano (Harvard-Smithsonian), D. Gilmore (STScI), M. Lehner (LLNL/GPP), C.M. Urry (STScI), and K. Weaver (Univ. Maryland and GSFC) have begun the analysis of Rosat HRI and PSPC 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 spatially-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 tentatively 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 fit as either thermal emission with kT >> few keV or a hard powerlaw. Numerical hydrodynamical simulations of superwinds conducted with collaborators D. Balsara (JHU), C. Leitherer (STScI), and A. Suchkov (STScI) reproduce many of the properties of the X-ray data and suggest that the X-rays arise primarily from ambient halo gas that is shock-heated by the more tenuous and hotter superwind.

Heckman has also participated in several other theoretical studies of starburst galaxies. He and collaborators R. Allen and A. Suchkov (STScI) have explored the physical conditions expected in molecular gas subjected to the unusually high cosmic ray flux within a starburst such as M82. They find that the observed properties of the molecular gas in M82 can be understood using simple arguments of thermal equilibrium and pressure balance. Some of these arguments appear to be relevant to molecular gas in the disks of spiral galaxies. Heckman and collaborators C. Leitherer and C. Robert (STScI) have constructed synthetic ultraviolet spectra of starbursts for a
wide range in initial mass functions and star-formation histories. These models were compared to IUE spectra of starbursts with roughly solar composition. The data are well fit by models in which stars have been forming for at least 10 Myr, with an IMF that extends at least as high as 60 solar masses (contrary to some other published claims of a deficiency of very massive stars in starbursts). Heckman and collaborators C. Leitherer and J. Sokolowski (STScI) have constructed photoionization models appropriate for the interpretation of gas subjected to a very dilute radiation field produced by an ensemble of massive stars. They have included the effects of both depletion of refractory elements onto dust grains and of radiative transfer on the shape of the ionizing continuum. They find that the resulting spectra agree well with the integrated optical emission-line spectra of infrared-luminous galaxies (many of which have been considered to have 'AGN-type' spectra) and of gas in the halos of edge-on spiral and starburst galaxies.

Heckman has continued to investigate the environments of high-redshift quasars. He and collaborators J. Elias (CTIO), J. Hutchings (DAO), M. Lehner (IGPP/LLNL), and J. Lowenthal (JHU/STScI), have obtained Ly-Alpha, optical continuum (B or V), and near-IR continuum (K) images of two samples of radio-quiet quasars (one at z = 1 and one at z = 2 to 3). In contrast to our earlier results on radio-loud quasars at these redshifts, the radio-quiet quasars are all spatially-unresolved. The host galaxies of these radio-quiet quasars are therefore fainter by at least two magnitudes than are either the host galaxies of radio-quiet quasars or powerful radio galaxies at similar redshifts. The lack of spatially-extended Ly-Alpha emission is especially surprising, and may mean that the quasar has somehow either blown away the gaseous halo of its host galaxy or heated it to very high temperatures (thereby greatly reducing the recombination rate). Lowenthal and Heckman are also using deep Ly-Alpha and multicolor images of fields around high redshift radio-loud and radio-quiet quasars to search for galaxies at the same redshift as the quasar.

Heckman and collaborators S. Baum and C. O'Dea (STScI) have analysed IRAS data for several samples of radio-loud active galactic nuclei. They find that 3CR Broad Line Radio Galaxies are much stronger emitters of mid-infrared continuum than are 3CR Narrow Line Radio Galaxies with similar radio powers and redshifts. In contrast, the far-infrared continuum is similar in strength in the two classes. These results are consistent with recent models for infrared emission from an 'obscuring torus' that emits anisotropically along the radio axis in the mid-infrared, and which obscures our view of the Broad Line Region in the Narrow Line Radio Galaxies. They also find that Fanaroff-Riley Class I radio galaxies are weaker infrared emitters than Fanaroff-Riley Class II radio galaxies of the same radio power. This agrees with other indications that the 'central engines' in the two classes are qualitatively different.

Richard C. Henry conducts research on the interstellar medium, cosmology, and ultraviolet background radiation. A major undertaking of the past year was the preparation of a proposal entitled "HUBE: The Hopkins Ultraviolet Background Explorer," which was submitted in January 1993 in response to the second NASA call for Small Explorer (SMEX) proposals. Co-Investigators were P. A. Charles, M. Clampin, A. F. Davidsen, P. D. Feldman, H. C. Ford, P. Jakobsen, Mi. A. Jura, R. A. Kimble, J. Murthy, D. A. Neufeld, R. W. O'Connell, L. J. Paxton, Keith Peacock, and Allan Sandage. As of writing, the SMEX selection has not been announced. Meanwhile, intensive work continues in preparation for the launch of a Department of Defense satellite with important astronomy capabilities. Some description of the instrumentation appears in a paper by Henry et al. in SPIE Conference "Ultraviolet Technology IV." Launch has slipped to 1994. Work on ultraviolet background radiation continues apace: a paper will appear shortly in the Astrophysical Journal reporting detection of strong line emission (C III 977 A and O VI 1032 and 1036 A) in the superbubble in Eridanus; Henry was the invited speaker on observations of the diffuse ultraviolet background radiation at the 1993 May Space Telescope Science Institute Symposium "Extragalactic Background Radiation," a meeting in honor of Riccardo Giacconi; and an Astrophysical Journal Letter is in press bringing up to date Henry's 1991 Annual Review of Astronomy and Astrophysics article "Ultraviolet Background Radiation," and presenting a reanalysis of the UVX space shuttle data on the diffuse ultraviolet background. The reanalysis shows that the UVX data are compatible with other recent determinations of the albedo and scattering asymmetry parameters in the ultraviolet. We have also carried out Voyager and Hopkins Ultraviolet Telescope (HUT) studies of the scattering properties of dust; in particular, the dust in the nebula NGC 7023. Work also continues on analysis of additional Voyager data, particularly observations of the Coalsack. IRAS work also continues, with the appearance of our paper on the low filling factor of dust in the galaxy. Henry continues as Director of the Maryland Space Grant Consortium (formerly known as the Johns Hopkins Space Grant Consortium). Consortium members include Hopkins, the Applied Physics Laboratory of the Johns Hopkins University, Morgan State University, and the Space Telescope Science Institute.

Julian Krolik has maintained his continuing interest in the nature of obscuration and reflection in active galactic nuclei. Building on the infrared transfer models for obscuring tori computed by E. Pier (JHU) for his Ph.D. thesis, Pier and Krolik have both suggested a plausible mechanism for supporting these obscuring tori (infrared radiation pressure) and made an extensive comparison of the model predictions with existing observations. They found that by and large the model calculations are consistent with the data already in hand, and provide reasonable explanations for a number of effects previously not understood. The flip side of the coin is the reflecting gas, whose most likely origin is freshly photoionized material burnt off the inner edge of the obscuring torus by the AGN ionizing continuum. With D. Balsara (JHU), Krolik has begun a program of simulating these winds using large-scale hydrodynamics codes. In the first installment they studied the limit of zero orbital angular momentum and simplified radiative heating and cooling. In that limit, they found that there was a critical value of luminosity relative to Eddington (around 0.08) above which it becomes possible to drive a substantial wind. They also found that the observed reflected flux should be a very strong function of viewing angle, being weakest when our line of sight lies in the equatorial plane.

Krolik's second major program is the study of the high energy properties of AGN. With C. Done (Leicester University) and G. Madejski (NASA/GSFC), he showed that
the X-ray lightcurves of AGN indicate no phase coherence. With A. Zdziarski (Copernicus Astronomical Center, Warsaw), he showed that the smooth power-law spectra exhibited by blazars in the energy range from 50 MeV to above 1 GeV (and sometimes 1 TeV) can be readily explained by a balance between Klein-Nishina depression of the electron cooling rate and Klein-Nishina depression of the electron inverse Compton scattering rate. Zdziarski, Krolik, and P. Zycki (also from the Copernicus Center) also showed that, despite earlier indications to the contrary, the hard X-ray spectra of AGN do in fact have the right shape to match the X-ray background. They were also able to show that the Rosat/Einstein survey of AGN in the 1 keV band has already found enough AGN to explain the background intensity.

**Jeffrey W. Krulk** is the Deputy Project Scientist for Instrumentation for the Hopkins Ultraviolet Telescope (HUT) Project. He has primarily been involved in upgrading HUT and making preparations for the Astro-2 mission, now scheduled for November 1994. The major upgrades to HUT are a new spectrograph with a silicon carbide coating on the diffraction grating, and replacement of the primary mirror with its backup, which has had its iridium surface overcoated with silicon carbide. The silicon carbide coatings were produced by R. Keski-Kuha and her group at Goddard Space Flight Center. Considerable development work was required to produce high quality coatings over such a large surface, and to obtain high reflectivities at visible wavelengths as well as in the far UV in order to preserve the sensitivity of the guide star tracking system. HUT’s effective area will increase by a factor of two to three, in comparison with Astro-1, due to silicon carbide’s much higher reflectivity in the far ultraviolet than the osmium and iridium used previously.

**Knox S. Long** is a Research Professor in the Department of Physics and Astronomy and a co-investigator on the Hopkins Ultraviolet Telescope. Dr. Long pursues research topics in supernova remnants, the properties of the interstellar medium in nearby galaxies, and the ultraviolet characteristics of cataclysmic variables.

Long, in collaboration with R. A. Wade (Penn State), W. P. Blair and A. F. Davidsson (JHU), and I. Hubeny (NASA/GSFC), carried out a detailed analysis of a 830-1860 Å HUT spectrum of the novalike variable IX Vel. This spectrum if the first ever obtained of this, the brightest cataclysmic variable, with sufficient spectral resolution (3.5 Å) to resolve the absorption lines in the sub-Lyman alpha region, which include S VI λ 933, 945, C III λ 797, Lyman B, O VI λ 1032, 1038, P V λ 1118, 1128 and C III λ 1176. No emission was detected below the Lyman limit. The overall spectrum of IX Vel in the FUV can be approximated using models of optically thick accretion disks in which the integrated spectrum has been constructed by summing model stellar atmospheres. If the distance to IX Vel is approx. 95 pc, the best fits to the spectrum are obtained if the inner accretion disk radius is about 2.5 times the WD radius. However, none of the models reproduces the strong 1s-2p absorption lines which are almost surely due to a wind above the disk.

Long, in collaboration with E. M. Sion & M. Huang (Villanova), and P. Szkody (Univ. Washington) have recently completed the analysis of two FOS spectra of the dwarf nova U Geminorum. The two spectra which were obtained about 13 and 70 days after the end of a normal outburst of U Gem were intended to confirm earlier observations with the Hopkins Ultraviolet Telescope that suggested that all or part of the WD in U Gem cools between outbursts. Model fits to the spectrum do confirm that the WD in U Gem cools from about 39,000 K 13 days after outburst to 32,000 K 70 days after outburst. A GHRS spectrum obtained 8 days after the same outburst shows that the WD in U Gem is rotating at less than 300 km/s.

Long has also continued his studies of SNRs in the nearby spiral galaxy M33 with collaborators W. P. Blair (JHU), R. P. Kirshner & S. Gordon (Harvard Univ.), N. Duric (Univ. New Mexico), & R. C. Smith (CTIO). They have now expanded the number of spectroscopically confirmed SNRs to 72. ROSAT observations of M33 reveal 31 sources within 15 arcmin of the nucleus. Of these 10 are positionally coincident with the spectroscopic sample (while only 2 are expected by chance). In a companion optical study of M83, Blair, Long and Smith have used the 4m at CTIO to spectroscopically confirm identifications of approximately 20 SNRs in that galaxy; the optical luminosity of the remnant of SN1957D in that galaxy appears to have remained constant in the last year after fading by a factor of six over the previous five years.

**Stephen Lubow** was on sabbatical at the IoA Cambridge and at Queen Mary College in London for the year. Lubow has continued investigating the nature of an eccentric disk instability that may provide an explanation for superhump phenomena in dwarf nova systems. The instability occurs as a result of a tidal resonant interaction at the 3:1 resonance. It was found that disks are mildly tilted unstable at this resonance. The most clearly defined observable parameter in the theory is the eccentric disk precession rate. Factors influencing the eccentricity growth and precession rates were investigated. Nonresonant tidal interactions due to the m=2 component of the potential truncates the disk and acts to diminish or possibly kill the instability.

P. Artymowicz (UCSC) and S. Lubow have completed an investigation of the tidal truncation radii of disks within and around binary star systems. Binaries with nonextreme mass ratio and nonzero eccentricity were considered. This work has application to recent observations of young binaries.

Lubow and Pringle (Cambridge) analytically investigated properties of three dimensional waves in accretion disks. Both p-modes and g-modes were found. Modes were found in which the midplane of the disk undergoes vertical oscillations. The range of propagation of the various modes was determined.

Lubow and Pringle investigated the gravitational stability of a compressed slab of gas as a model for the effects of colliding interstellar clouds. An analytic formulation of the stability analysis was found to agree with earlier work by Elmegreen and Elmegreen (1979). The results indicate that dynamical instabilities that result from cloud collisions do not substantially enhance star formation. Lubow, Pringle, and Kerswell (Newcastle) investigated a parametric disk instability proposed by Goodman (1993) for tidally distorted accretion disk. They show that m=1 standing g-modes that are corotating with the binary are dynamically unstable and demonstrate how these tightly wrapped waves can gain angular momentum from the smoothly varying tidal field. They show that an interaction between the leading and trailing components of the standing wave, in second order of the wave amplitude, is responsible
for the net torque.

**Stephan R. McCandliss** is the Project Scientist for the sounding rocket group headed by P. Feldman. His main concerns are the day-to-day aspects of science planning, instrumentation development, and calibration for the two current sounding rocket missions: the far ultraviolet (FUV) calibration of the hot white dwarf G191-B2B from 912 to 1300 Å, and the simultaneous imaging of atomic and molecular hydrogen UV emissions from the Jovian aurorae with 1 resolution. This work is conducted with JHU graduate students M. Martinez (G191-B2B) and P. Morrissey (Jovian aurorae).

The calibration mission makes use of ion-beam sputtered SiC on normal incidence optics to achieve sensitivity to the Lyman limit. This is a less costly alternative to the expensive grazing incidence optics normally called for in this wavelength regime. McCandliss gave a paper at SPIE conference 2011, on Multilayer and Grazing Incidence X-RAY/EUV Optics II, describing the effective area of the telescope in the FUV. The Jovian mission will use a UV sensitive CCD and a curved LiF prism (the properties of which have recently been rediscovered by P. Morrissey) in the converging beam of an f/24 Cassegrain telescope to achieve high throughput and image quality. In preparation for the CCD mission a study has been conducted, in collaboration with the now defunct NASA Comet Rendezvous/Asteroid Flyby mission, to measure the UV sensitivity of lumigen coated CCDs from 1200 to 5000 Å. A paper describing these results is in press in Applied Optics.

McCandliss is Co-I with J. Janesick (PI) and J. Trauger (Co-I), both at JPL, on a 3 year proposal entitled "UV/Visible CCD Development" that was accepted for funding by the NASA Space UV/Visual Detector Development Program. Work will begin in the fall of 1993, with JHU responsible for measuring the UV quantum efficiencies of various experimental CCDs. This program will give the sounding rocket group access to up-to-date developments in UV sensitive CCDs.

In addition to his work on instrumentation, McCandliss has recently collaborated with members of the Hopkins Ultraviolet Telescope (HUT) team (R. Buss, W. Blair, C. Bowers, A. Davidsen, P. Feldman, and J. Kruk) on a comparison of the HUT EZ CMa (HD 50896; a WN % a 5 Wolf-Rayet star) spectrum to the continuum of a model atmosphere with an spherically expanding pure He wind. This paper has been accepted by the Astrophysical Journal. He has also aided R. Buss in his determination of the extinction toward several B-stars observed by HUT, the paper on which has been submitted to the Astrophysical Journal. In the area of ground-based observations and in collaboration with B. Bohannan, C. Robert, and A. Moffat he has recently reexamined his thesis work that utilized a timeseries of 152 echelle spectra observed over 12 nights of the Wolf-Rayet star HD 191765 (WR-134). He has found evidence for a 2.24 day period that appears most strongly in the line skew, which is a measure of the line profile asymmetry. He has given a paper on this subject at a recent workshop on Instabilities and Variability in the Winds of Hot Stars (Isle-aux-Coudres Quebec).

**Warren Moos** is the Chair of the Department of Physics and Astronomy. He is also the Principal Investigator for the Lyman Far Ultraviolet Spectroscopic Explorer astronomy satellite. Also participating in this activity at the Center are: A. F. Davidsen, P. D. Feldman and S. Friedman as Co-Investigators, C. Holmes as Software Scientist and D. Sahnow as Instrument Scientist. Moos is also participating as a Co-Investigator in the development of the Space Telescope Imaging Spectrograph. Also participating in the STIS activity are M. E. Kaiser (Calibration Scientist) and L. K. Huang. Moos continues to study the outer planets using data from HUT, HST and IUE.

**David Neufeld**'s research activities lie primarily in the theoretical study of the interstellar medium and of fundamental physical processes that operate there. A particular area of interest has been regions of active star formation and the interstellar shock waves associated with them. Atomic and molecular emissions prove to be a powerful probe of the physical conditions within such regions.

With JHU graduate student M. Kaufman, Neufeld has been studying the importance of molecular cooling in the thermal balance of warm dense interstellar gas. The results of this investigation underscore the importance of far-infrared emission from water in controlling the cooling rate of warm regions of the interstellar medium. Neufeld and Kaufman have also been constructing models for the water maser emission expected from magnetohydrodynamic interstellar shock waves. Preliminary results suggest that such models are successful in accounting for the observed properties of water masers in star-forming interstellar regions.

With D. J. Hollenbach (NASA-Ames), Neufeld has completed a theoretical study of the accretion shocks which are created during the process of star formation. It is within such shock waves that all infalling supersonic material must have been decelerated as it fell onto the proto-solar nebula during the formation of our Sun and other stars. The results suggest that such shocks may be responsible for the luminous CO vibrational emission actually observed from some accreting protostars. The extent to which interstellar dust grains are destroyed as they pass through accretion shocks was also considered.

With JHU graduate student W. Chen, Neufeld has investigated how ultraviolet spectroscopic observations of the Lyman alpha line of atomic hydrogen can be used to study the interstellar gas in distant galaxies. Chen and Neufeld have recently offered an explanation as to why many such galaxies show Lyman alpha absorption lines rather than emission lines.

Neufeld continues to work as a co-investigator on the Submillimeter Wave Astronomy Satelite (SWAS) project — a Small Explorer mission selected by NASA for a launch in 1995 — which will fly an orbiting radiometer capable of detecting line emission from cold interstellar water, molecular oxygen, atomic carbon, and warm carbon monoxide. With JHU graduate students M. Kaufman and S. Conger, he has also been considering how far-infrared line spectra can be used to probe the chemical composition of warm regions of the interstellar medium; observations of such spectra will be carried out in collaboration with M. Harwit and G. Melnick, using the European Space Agency's Infrared Space Observatory (ISO).

**Colin Norman** and H. Hasan continued the study of barred galaxies with central mass concentrations. The three dimensional study with D. Pfenniger (Geneva) was published. The relevance of this to aspects of Bulge Building in Normal galaxies was discussed by Norman at the IAU meeting on Bulges in Ghent. An attempt to seriously...
study secular evolution using improved methods for N-body codes is now underway. This work was stimulated by the ITP workshop on Dense Stellar Systems.

With A. Ferrara (STScI and Florence), Norman is studying the turbulent structure of the interstellar medium and the role of real turbulence in supporting the extended structure of the disk. Preliminary results were presented at the STScI meeting on the Disk-halo Interaction.

Norman is continuing to study the dynamics and structure of starburst galaxies. With N. Scoville (Caltech) he is studying the relation of central starburst systems to Broad Absorption Line Quasars.

With Y. Uchida (Tokyo), Norman is studying the propagation of jets through a protogalactic environment using supercomputer simulations.

With Heyvaerts (Paris) he is continuing analytic studies of the general structure of axisymmetric magnetized flows from accretion disks, protostars and other more exotic environments.

Observational studies of the environments of galaxies are also underway using the Hubble Space Telescope and the X-ray satellite ROSAT.

Francesco Paresce, in collaboration with M. Clampin (STScI) and M. Robberto (Toro Observatory) modified the STScI coronagraph for operation at the MPI Calar Alto, Spain 2.2m telescope where a 7 night run yielded excellent images of the circumstellar regions around P Cygni, NGC 7027, T Tauri and other bright pre and post main sequence stars with disks and shells. They also built a new stellar coronagraph for the ESO NTT at La Silla, Chile where another successful observing run allowed an unprecedented look deep into the interior of the Beta Pictoris disk and the surroundings of galactic and LMC luminous blue variables. Paresce, in collaboration with W. Hack (STScI), has analyzed the most recent HST observations of R Aqr and HM Sge in the UV. Both objects show clear evidence for formation of highly collimated bipolar outflows probably due to the interaction of the red giant and hot subdwarf companion winds. In the case of R Aqr, collimation of the jet takes place within a projected distance of 15 AU from the Mira with an apparent opening angle of 25 degrees. This implies that the jet originates inside the orbit of the binary whose semi-major axis has been estimated to be of order 18-20 AU. This represents by far the closest distance from its source that any jet has yet been traced thereby placing severe constraints on possible emission mechanisms. Paresce has also imaged Nova Cyg 1992, the brightest classical nova to appear in nearly 20 years, with the HST. The images show a well developed circular ring of emission around the white dwarf. The present position of the shell limb at a radius of 0.13" at day 467 after outburst implies that the limb at the time of observation had reached a radius of 400 AU from the star. This means that Nova Cyg 1992 is located at a distance of 3.2 kpc. This observation represents the closest look obtained so far at an expanding nova shell so early in its evolution before it has lost most of the initial conditions impressed on it at outburst. Finally, Paresce, in collaboration with G. De Marchi (STScI and U. Florence), continued his analysis of HST UV high resolution images of the cores of high central density globular clusters. The unexpected discovery of very blue objects lying to the left of the main sequence in M15's core can be explained only as the effect of significant dynamical evolution of the stellar population in this possibly collapsed cluster.

Yichuan C. Pei joined CAS in October 1992 as an Associate Research Scientist for the FOS team to carry a series of studies on the structure and dynamics of the nucleus of nearby galaxies. The first of the series is on the nucleus of M31. Analysis of the recent HST PC V band image indicates that within the dynamically distinct triaxial nucleus there is a rotating binary consist of a black hole (showing a power law density cusp) and a captured object (showing a King density profile). Whether the captured object is a reman of cannibalized dwarf galaxy nucleus is still under detailed investigation. Together with the kinematic data derived from the FOS spectra and obtained by others, we have developed a self-consistent kinematic model of the nucleus of M31 that may provide natural solutions to puzzling asymmetries of both photometric and kinematical offsets in the nucleus of M31. The work is now in preparation for publication.

Pei has developed a new method to calculate the magnification bias on the statistical properties of quasars caused by cosmologically distributed gravitational lenses. In particular, an explicit expression for the true luminosity function can be derived in terms of the observed luminosity function, based on a differential operator method. Given the luminosity function, the information on the number counts of quasars as a function of either magnitude or redshift can be easily inferred. The main conclusion is that the lensing magnification effect on the luminosity function of quasars is small if gravitational lenses are extended objects, such as galaxies, and can be large (by a factor of 10 at high luminosity end) if gravitational lenses are sufficiently compact objects, such as black holes in example. The work is in the final preparation stage to be submitted for publication.

David Sahnow continues as detector scientist/postdoctoral fellow for Lyman FUSE, now in the Phase B design stage. He has spent time this year modelling the delay line detector planned for use on FUSE. Using data supplied by O. Siegmund and collaborators at UC Berkeley, he has been able to realistically simulate the detector response to input radiation. In upcoming months, he will be involved in the testing of and analysis of data from the FUSE Phase B demonstration delay line detector, recently completed at UC Berkeley. Currently, he is involved in modelling of the telescope, spectrograph and structure of Lyman FUSE, in an attempt to anticipate the response of the instrument once in orbit. In addition, he has recently submitted (with P. Feldman and S. McCandless) a paper describing the diode array detector used in the rocket observations of Comet Austin (1990 V) and the Io Plasma Torus, made while he was a graduate student.

Prof. Darrell F. Strobel is spending his sabbatical year at the Departement de Recherche Spatiale, Observatoire de Paris-Meudon, with Dr. Daniel Gautier, his host. They are Interdisciplinary Scientists on the joint ESA-NASA Cassini Mission and are working on a broad range of fundamental problems in atmospheric chemistry, dynamics, and radiation pertinent to the atmospheres of the giant planets and their satellites. Specific problems that are currently being addressed are: 1) photochemistry of Titan's stratosphere, 2) photochemistry of Neptune's stratosphere, 3) the nitrogen source on Neptune, 4) the chemical composition and thermal structure of Io's atmosphere, and 5) internal gravity wave propagation, saturation, and stresses.
on upper atmospheres as revealed by stellar occultation measurements. In addition they are involved in advanced planning and coordination of the Cassini Orbiter and Huygens Probe experiments. Strobel and his colleague M. Summers (NRL) have completed their studies of the Triton's upper atmosphere and ionosphere, which they have been pursuing over the past 4 years and are summarized in the forthcoming book Neptune and Triton in the University of Arizona Press' Space Science series.

Alan Uomoto continues work on two fiber optic spectrographs for use on the Sloan Digital Sky Survey 2.5 m telescope at Apache Point Observatory. The two spectrographs, each capable of observing 330 objects simultaneously, will be used to model redshifts of about one million galaxies around the north galactic pole.

He continues work with the Faint Object Spectrograph instrument team in studies of nuclear regions of active galactic nuclei using HST. He also works in collaboration with K. Davidson (Univ. Minnesota) and others on HST observations of the Crab Nebula, and with G. MacAlpine, S. Lawrence (Univ. Michigan), and B. Woodgate (GSFC) on ground-based imaging of the Crab. With A. Landolt (LSU) he continues work on generating faint photometric standard stars.

Boqi Wang, in collaboration with J. Silk (UC Berkeley), investigated the observational consequences that arise for the heavy element abundances in normal spiral galaxies from variations in the initial mass function (IMF). They calculated the oxygen yield for a given IMF, using the most recent calculations of supernova nucleosynthesis. It was found that the overall abundance is well explained by the IMF determined in the solar neighborhood. It was shown that the oxygen abundance is very sensitive to the underlying IMF; some of the modified IMFs proposed for our Galaxy and starburst galaxies result in an oxygen abundance an order of magnitude larger than solar. Thus the fact that the available data for normal spiral galaxies including our Galaxy show the overall oxygen abundance to be about solar suggests a rather constant IMF outside the solar neighborhood. Wang and Silk took into account the effects of inflow and ejection of material in normal disk galaxies, and found that the impact on the metallicity is in general small compared to any modification of the IMF. They concluded that truncation of the IMF in starburst regions results in an oxygen abundance in conflict with the available observations.

Recent observations indicated that the QSO heavy element absorption line (HEAL) systems are associated with extremely large galactic halos. Wang investigated the origin of the absorbing gas, and demonstrated that an extremely large star formation rate is required if the HEAL gas originates from galactic discs. The large star formation rate is incompatible with the observed moderate evolution and the normal colors of the galaxies associated with the MgII absorption lines (MgALs). He proposed that the absorption lines originate from progressive gas accretion from satellites galaxies (or large gas clumps) as a result of dynamical friction and tidal interaction. He pointed out that there are two possible channels through which the gas is ejected from satellites and accretes onto the primary: the direct tidal stripping by the primary's massive halo, and the satellite wind resulting from the heating by supernovae. Wang estimated the velocity, the column densities, the time variation of the equivalent width, and the ionization structures, and showed they are consistent with observed characteristics of MgAL systems. His proposal may account for not only the HEALs of low ionization states such as MgII but also of high ionization species such as CIV observed at larger galactocentric distances.

Rosemary Wyse, together with J. Silk (UC Berkeley) wrote a lengthy review on Galaxy Formation and the Hubble Sequence for Physics Reports, being published in September 1993. They intend this to be a comprehensive review of current trends in research for graduate students and beyond. JHU graduate student A. Ferguson continues her thesis research into the outer regions of disk galaxies; preliminary results suggest that star formation continues extremely far out in the disk of some galaxies, beyond the radius expected in currently accepted theory. Among the problems in T. Smecker-Hane's thesis is the first self-consistent viscosity-driven model for the evolution of the disk of our Galaxy, with the slow return of chemical elements from Type I supernovae taken properly into account.

Wei Zheng works closely with the HUT team members in the preparation for the Astro-2 mission, including the mission planning and guest observer program. By analyzing the HUT, IUE and HST data, it is found that there may be a correlation between the soft X-ray strength and the O VI 1034 emission intensity. The discovery yields support to the photoionization theory that the soft X-ray photons produce the high-ionization lines. Cooperating with G. Kriss, G. Lee and A. Davidsen, he is studying the archival HST spectra to search for intrinsic Lyman-alpha discontinuity, which may be the signature for an accretion disk in QSOs.

In a joint work with J. Kwan (Univ. Mass), F. Z. Cheng (Univ. Sci. Tech., China) and L. Z. Fang, high-resolution spectra of some Fe II-strong quasars are taken. The preliminary results suggest the existence of Fe I emission, believed to be formed in a region, possible the outer layers of an accretion disk, which is shielded from the radiation from the central energy source. Zheng and M. Malkan (UCLA) have studied the continuum shape of many Seyfert galaxies and quasars. They found that the continuum shape between optical and UV steepens at higher luminosity. A stronger UV continuum level may thus explain the Baldwin effect.

I would like to acknowledge Dr. Richard Henry's and Ms. Susanne Marier's invaluable work in compiling this report.

Holland C. Ford
Director

IV. PUBLICATIONS


