I. INTRODUCTION

In this place last year, we advertised our determination that the Johns Hopkins University should join a ground-based telescope project. We are extremely pleased to be able to report, now, that at its 1992 June 8 meeting, the Astrophysical Research Consortium (ARC) Board voted enthusiastically to invite the Johns Hopkins University to join ARC. The invitation has been accepted, and Hopkins is now a participant in the Sloan Digital Sky Survey of the Northern Polar Cap. Alex Szalay is leading the effort at Hopkins, where portions of the fiber spectrographs will be built and some of the software will be written. The project goal is to image about 25% of the sky in four colors to almost 24th mag. Follow-up spectroscopy of one million galaxies found in the survey will be used to study the large-scale structure of the Universe. Meanwhile, Arthur Davidsen and his colleagues continue a vigorous mining and publication of the mountain of high quality data which came from the successful flight of the Hopkins Ultraviolet Telescope (HUT) as part of the Astro-1 mission in December 1990, and planning for the next flight proceeds apace. The next HUT flight will involve a guest investigator program. Also, Lyman Far Ultraviolet Spectroscopic Explorer (FUSE), and a host of other theoretical, observational, and experimental activities are progressing, as detailed below.

This report covers the period October 1991 through September 1992.

II. PERSONNEL

New CAS members include R. Griffiths, Research Professor; M. Allen, R. Buss, D. Hall, Z. Tsvetanov, and W. Zheng, Associate Research Scientists; M. Corbin, Post Doctoral Fellow; B. Wang, Davis Post Doctoral Fellow. D. Buzasi has taken a visiting scientist position at NASA Headquarters. S. Caganoff has left to take a position at the University of Melbourne. M. Clampin has left to join the Space Telescope Science Institute (STScI) as an instrument scientist. P. Madau and M. A. McGrath have recently moved to Assistant Astronomer positions at STScI though they continue various associations as members of CAS. J. Pringle has returned to the Institute of Astronomy (IoA) in Cambridge, England. D. Balsara, J. Lowenthal, and D. Sahnow continue as Post Doctoral Fellows. During the past year K. S. Long was promoted to Adjunct Research Professor. Other permanent staff are: P. J. Dagdigian, A. F. Davidsen, J. P. Doering, P. D. Feldman, H. C. Ford, R. Giacconi (Director, STScI), T. M. Heckman, R. C. Henry, B. R. Judd, C. W. Kim, J. H. Krolik, H. W. Moos (Director, CAS), C. A. Norman, D. F. Strobel, and A. Szalay, Professors; R. F. G. Wyse, Associate Professor; D. A. Neufeld, Assistant Professor; R. A. Brown, S. M. Fall, Research Professors; S. Lubow, Assistant Research Professor; Wm. G. Fastie, Adjunct Research Professor; W. P. Blair, S. T. Durrance, G. A. Kriss, Research Scientists; M. Finkenthal, Visiting Research Scientist; C. W. Bowers, R. Burg, A. W. Campbell, S. Friedman, C. Holmes, L. Huang, J. W. Kruk, S. McCandless, J. Murthy, and A. Uomoto, Associate Research Scientists; K. S. Long, Associate Astronomer (STScI)/Adjunct Research Professor (JHU/CAS); H. A. Weaver, Assistant Astronomer (STScI); and F. Paresce, Instrument Scientist (STScI).

III. RESEARCH AND ACTIVITIES

Marsha Allen joined R. C. Henry's ultraviolet space astronomy group in mid-December 1991. The group is supporting the data analysis efforts for the UV and visible detectors (imagers and spectrometers) on-board a Department of Defense satellite which is being built at the Applied Physics Laboratory. Launch is currently scheduled for the fall of 1993. In addition to this work, Allen has been continuing with analysis of Voyager spectra in collaboration with T. Snow at the University of Colorado. This work will enable astronomers to disentangle the effects of interstellar extinction and absorption by molecular hydrogen in the ultraviolet spectra of reddened O and B stars. Also, Allen has been working on the analysis of the abundance of CH+ in the interstellar medium aiming toward identifying how the molecule is formed.

William P. Blair is a Research Scientist in the Department of Physics and Astronomy and is now a 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 have 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 process for Astro-2), and participation in FOS calibration and the FOS GTO science program. In addition, he has continued research on galactic and extragalactic supernova remnants using both ground-based telescopes and space-based instruments.

Blair and the HUT team have continued to work on data for several supernova remnants obtained during the Astro-1 mission. Blair was the lead on a paper last year describing HUT data on a bright radiative filament in the Cygnus Loop. Since the HUT spectrum at this position contained no spatial information, work has continued this year to obtain optical and IUE spectra within the HUT aperture to better interpret the HUT spectrum. 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 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 below under the first author’s name.

With Vancura, Long, and Raymond, an extensive analysis of the LMC supernova remnant N49 was published. This investigation combined IUE spectra, optical imagery, optical low resolution and echelle spectra, and archival X-ray data to understand this enigmatic remnant. Reddening variations on very small spatial scales were found, which complicates the comparison of UV and optical spectroscopy. Nonetheless, they conclude that the remnant is expanding into a dense region, with varying densities (and hence a wide range of shock velocities) responsible for the observed properties.

A deep interference filter/CCD survey of the southern spiral galaxy M83 has been made with the CTIO 4 meter telescope. Analysis of these data has resulted in a list of some 40 supernova remnant candidates in this galaxy. 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. From this same data set, Long, P. F. Winkler (Middlebury College), and Blair discovered that the optical remnant of SN 1957D in M83 had faded by a factor of three in only a few years.

As part of the FOS GTO program, early acquisition Wide Field Camera images have been analyzed for four remnants: N49, the O-rich remnant in NGC 4449, and two M33 supernova remnants. An empirical analysis of these images indicates that the count rates were systematically lower than expected even after taking the Hubble PSF problem into account. Some cases can be explained if the narrow interference filters in the WF/PC have shifted to the blue with age, although further data are required to verify this result. The images are sufficient to set up FOS spectroscopy, which is scheduled for Cycle 2.

Charles W. Bowers has assumed the position of Instrument Scientist for the Lyman Far Ultraviolet Spectroscopic Explorer satellite. During the current Phase B period, detailed instrument design is being completed in preparation for the start of fabrication. System level issues are being investigated including, for example, instrument calibration, both during integration and in-flight, as well as detailed estimates of instrument performance. In particular, modeling of the combined performance of the novel spectrograph and detector designs has been performed to assure that the requirements for FUSE science can be met. Along with other members of HUT team, Bowers has also continued to analyze data from two HUT observations: the line of sight toward the quasar 3C273 and the planetary nebula NGC 1535.

The bright quasar 3C273 lying at high galactic latitude provides an excellent source for absorption studies of the galactic halo. Strong absorption was observed in two HUT observations near the OVI doublet near 1035 Å. Using GHRS observations toward 3C273 and longward of 1200 Å, interstellar absorption from O I and C II near 1035 Å was modeled. Additional models of interstellar molecular hydrogen as well as a number of weak atomic lines were produced to form a coherent picture of absorption in the far-UV. Airglow contamination was subtracted using a HUT observation of the nearby object 3C279. The resultant spectrum reveals a significant detection of the high temperature tracer, O VI, toward 3C273. The amount of OVI detected is much greater than predicted by photoionization models of the halo but is in agreement with models of galactic fountains in which disk gas is heated by supernova explosions, expands into the halo, radiatively cools and falls back to the galactic disk.

The HUT ultraviolet spectrum of the planetary nebula NGC 1535 showed the strong signature of molecular hydrogen absorption. Comparison of the HUT data with model spectra shows good agreement with a modest column of molecular hydrogen at a temperature of about 300 K. Copernicus observations of a nearby line-of-sight star show much less interstellar molecular hydrogen in this direction leading to the conclusion that the detected molecules are probably associated with the nebular shell itself. The low temperature indicates that shock excitation is not occurring, contrary to most planetary nebulae.
with detected molecular hydrogen. Instead the molecular hydrogen appears to be associated with a photodissociation region near NGC 1535. The mass of molecular hydrogen still present near NGC 1535 is just 0.03 $M_\odot$ or less; Exosat measurements indicate an upper limit of about 1 $M_\odot$ of atomic hydrogen present. Combined with measurements of ionized nebular mass and determinations of the mass of the central star, we have derived an upper limit to the progenitor mass of NGC 1535 of 1.8 $M_\odot$, a value in good agreement with current stellar evolution predictions for this object.

Richard H. Buss Jr. joined CAS in mid-year as an Associate Research Scientist for the Hopkins Ultraviolet Telescope to study stellar, interstellar, and related calibration topics. He and JHU graduate student J.-C. Liu have helped to correct HUT spectra containing flux inaccuracies caused by unstable telescope pointing, and with W. Zheng (JHU/CAS), provided a cross-calibration for the Ultraviolet Imaging Telescope. Buss and Liu accomplished the flux-correction by statistically analyzing the HUT count rates, adding their programs to the HUT spectral data-processing pipeline for release to the astronomical community. Other work with hot star spectra has provided an observed instrumental fixed-pattern spectrum which agrees with the laboratory spectrum, permitting an additional reliable flux-correction to the HUT spectra.

In addition, many CAS members, partially including Buss, Feldman, and Bowers, used HUT and IRAS data (with M. Werner (NASA/JPL)) to examine gas and grain emission from the reflection nebula IC 63. The investigators were the first to measure, below Lyman-$\alpha$, the molecular-hydrogen fluorescence in a dissociation region. The observations will help clarify the relationship of the UV fluorescence to visual and IR non-equilibrium dust emission, and a comparison with photoexcitation models is in progress. The IR data showed that the geometry of the region can help explain the nebular emission at all wavelengths, but they also revealed a cavity in the dust and an extremely-cool star-formation object nearby.

Publishing work completed with others at NASA Ames, Buss submitted a paper on circumstellar grains in transition nebulae. The nascent grains exhibit a variety of characteristics that seem to be related to the evolutionary state of the mass-losing star. Either the grains themselves co-evolve with the stars, or depend on the composition of the stellar atmosphere, or both. Finally, Buss has finished a draft of a paper on the three-dimensional filling of interstellar hydrogen, sampled at extremely fine spatial scale of about 0.2 pc. He found that the cold neutral gas fills about 4% of the interstellar medium, which, when combined with a subsample of warm H I from J. Murthy (JHU/CAS), H. J. Walker (Rutherford Appleton Labs), and R. C. Henry (JHU/CAS) (1992), shows that the hot ionized medium and warm neutral hydrogen occupy the vast bulk of the ISM.

Michael Corbin joined CAS in November 1991. During this period he has been working in collaboration with R. C. Henry on mission planning and instrument calibration for a Department of Defense satellite project, due to be launched in November of next year. The main participation in the project is the planning of an ultraviolet all-sky survey for the purpose of understanding the nature of the diffuse cosmic ultraviolet background radiation. During this period Corbin has also pursued the following independent research: in comparing the emission-line properties of 55 low-redshift QSOs with their 2 keV X-ray luminosities, he has discovered several previously unseen correlations, which together suggest that much of the broad-line emission in these objects is produced by collisional excitation in the interiors of optically-thick clouds. In collaboration with K. T. Korista (STScI) and W. D. Vacca (UC Berkeley) Corbin has also completed an imaging study of the "prototypical" Wolf-Rayet galaxy He 2-10. The B and V band CCD images go significantly deeper than the previous photographic images of this object, and reveal it to be a single galaxy, and not an interacting pair as previously concluded. In terms of size and overall morphology, the galaxy resembles a dwarf elliptical, supporting models in which blue compact dwarf galaxies evolve into dwarf ellipticals following the cessation of their starburst episodes.

Paul J. Dagdigian and his group are continuing laboratory studies of the dynamics of inelastic and reactive collisions of small molecular free radicals. Of particular interest in the past year has been the study of several chemical reactions of the NH radical and the mechanism of predissociation of its excited $^3$II electronic state.

Arthur F. Davidsen and his colleagues and students continue to analyze the large quantity of unique new data obtained with the Hopkins Ultraviolet Telescope aboard the Astro-1 space shuttle mission, as well as to prepare for a second mission in 1994. Results from HUT have been numerous and wide-ranging, spanning topics from solar system astronomy to galaxies, quasars and cosmology. Highlights include: a significant advance in understanding the origin of the UV light from elliptical galaxies and spiral bulges; the detection of absorption by O VI in the galactic halo, supporting the galactic fountain model for the interstellar medium; evidence for the existence of shock-wave heated gas in the nucleus of the Seyfert galaxy NGC 1068; and determination of the ionization state of the very local interstellar medium in the solar neighborhood. Davidsen and his colleagues are also pursuing a number of related observational programs with the Hubble Space Telescope and with ground-based telescopes at the national observatories.
Davidsen has also served as chairman of the HST Users Committee for the past 2.5 years, and as a member of the Task Force on NASA-University Relations of the NASA Advisory Council during the past year.

**J. P. Doering** has completed new measurements of the excitation of the atomic oxygen $^1D$ state by low-energy electron impact. The presence of a peak in the cross-section near 6 eV has been verified. In a related study, the reference cross-section used for the $O \,^1D$ work, the $O_2 \,^1Δ_g$ excitation cross-section has been remeasured. Additional work on atomic nitrogen has led to measurements of the cross sections for the two resonance transitions. With Luke Goembel, work continues on the coincidence measurements for the determination of ionization-excitation branching ratios in electron impact processes. The apparatus has been rebuilt to allow angular scans of the ejected electrons over a much wider range than previously available. Preliminary results show that the relative branching ratios change as a function of secondary electron energy, primary electron energy, and ejection angle. Secondary electrons are ejected at different angles to the primary electron direction depending on which final ion state is produced. This effect may be important in the understanding of energy deposition by auroral primaries.

**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. Feldman also continued his IUE comet program (with JHU graduate student S. A. Budzien, who received his Ph.D. in February 1992 and is now at the Naval Research Laboratory, and in collaboration with M. F. A'Hearn of the University of Maryland), with observations of Ceres and of comets Zanotta-Brewington (1991g) and Shoemaker-Levy (1991a). This latter comet was also the target for two HST programs 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 Liège) and the Goddard High Resolution Spectrograph (with Weaver and A'Hearn). Nearly simultaneous IUE and HST ultraviolet spectra of this comet were obtained. Feldman also collaborated with M. A. McGrath (STScI/CAS) and H. W. Moos (JHU/CAS) in HST observations of Jupiter, Io and the Io plasma torus, and Titan.

Feldman was a member of the team that built and operated the Hopkins Ultraviolet Telescope as part of the Astro-1 Space Shuttle mission in December 1990, and continued his data analysis with investigations of the spectra of the Jovian atmosphere and of the terrestrial nightglow. He also carried out, with support from NASA’s Astrophysics Data Program, a comparative analysis of the ultraviolet spectra of comet Halley taken by the ASTRON satellite of the former Soviet Union, and used the unique ASTRON data to derive the relative ammonia abundance in the comet. Feldman continued as a member of the Imaging System Science Team for NASA’s Comet Rendezvous/Asteroid Flyby mission until the termination of the mission in February 1992. He completed a three-year term on NASA’s Sounding Rocket Working Group and currently serves as a Trustee of the Universities Space Research Association.

X. Hui (Caltech), **Holland Ford**, and K. Freeman (MSSSO) are continuing their study of the halos of galaxies. The have submitted two papers with R. Ciardullo (Penn State) and G. Jacoby (KPNO) which report the identifications of ~ 800 planetary nebulae in NGC 5128 and ~ 400 planetary nebulae in M104. They used the observations to derive the distances to both galaxies, and derived a value of $87 \pm 3$ km s$^{-1}$ for the Hubble constant by using their distances to M104, the Leo Group, and the Virgo cluster. They have measured the radial velocities of ~ 400 planetary nebulae in NGC 5128, and ~ 200 planetary nebulae in M104.

Ford’s HST observations with his FOS collaborators at JHU and the STScI, and with his GO collaborators W. Jaffe (Leiden Univ.), R. O’Connell (Univ. Virginia), JHU graduate student L. Ferrarese, and F. van den Bosch (Leiden Univ.) are leading to clear conclusions about how a particular class of active galaxies, LINERs, fit the AGN paradigm. For the first time small-scale (30 to 150 pc) dusty nuclear disks have been directly imaged. These disks may be the tori which were postulated to surround and hide (depending on aspect angle) the black holes in the centers of galaxies. Ford and his collaborators at JHU and the STScI are using their observations to revise the AGN paradigm.

Ford and Jacoby used the KPNO 2.1-m to take spectra of the faint outer halos of galactic planetary nebulae. In collaboration with Emanuel Vassiliadus (STScI), they will measure the helium abundance in the shells to look for evidence of helium diffusion during the main sequence lifetime of the parent star. Significant helium diffusion would shorten the lifetimes of low mass stars, and help reconcile the ages of globular clusters with the age of the Universe inferred from high values of the Hubble constant.

W. Sparks (STScI), Ford, and A. Kinney (STScI) used KPNO 4-m telescope emission-line and continuum images to show that the Hα + NⅠ lines in M87 display a braided or ribbon-like morphology and are dusty. The dust spatially coincides with the ionized gas to the limits of the data. The presence of dust requires that either (1) the filaments result from accretion of gas and dust external to the M87 system, (2) dust produced by stars has been injected into the filaments or (3) both gas and dust have condensed from the hot
coronal gas.

Spectroscopy of the filaments shows monotonically varying velocities within individual features. The innermost filaments are blue-shifted with respect to systemic velocity. The presence of associated absorption and alignment with the radio/optical jet suggests that this gas lies on the nearside of the galaxy, in which case much of the material is flowing out from the nucleus rather than falling in. Conversely, line emitting gas associated with the more distant radio lobe, as deduced from Faraday rotation observations, appears to be infalling and not outflowing as might be expected if the lobe is moving out from the nucleus.

Ford received NASA’s Medal for Exceptional Scientific Achievement for his work on AGNs with the Bubble Space Telescope.

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 900–1250 Å bandpass at a spectral resolving power of approximately 30,000, as well as extreme-ultraviolet observations from 100–400 Å at somewhat lower resolving power. He continues investigations of the radiation effects on the CCD detectors that will be used in the fine error sensor star trackers on FUSE. FUSE is currently scheduled for launch into a highly elliptical, 24-hour high-Earth orbit near the end of 2000.

Along with A. Uomoto and P. Feldman (JHU/CAS), Friedman is also beginning design work on the 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 Survey will measure the redshifts of one million galaxies and 100,000 QSOs in about 25% of the sky in the direction of the north Galactic cap. It will also map this region of the sky in four colors to a point source limiting magnitude of approximately g = 23.5.

During the past year R. Giacconi has continued his research in the following areas: studying the nature of the X-ray Background (XRB), studying the properties of clusters of galaxies, and designing and studying new missions in X-ray astronomy. Much of this research centered on utilizing data from the ROSAT observatory. The ROSAT Deep Survey, which consists of the highest sensitivity observations taken to date in X-ray astronomy, has resolved approximately 55% of the XRB. In addition, initial results from cluster surveys with ROSAT have been obtained. Giacconi is also a member of the AXAF Science Working Group and participates in the design and development of the Wide-Field X-ray Telescope.

Timothy Heckman and collaborators have continued their studies of the galactic “superwind” phenomenon: the galaxy-scale outflows associated with starburst galaxies that are presumably driven by the collective effect of the energy and momentum input from massive stars and supernovae. He and M. Lehnert (JHU and LLNL/IGPP) have analyzed long-slit optical spectra and deep H-α 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. Paires H-α loops and bubbles extend far out into the galactic halo in many cases. The gas located 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, R. Wyse (JHU/CAS), and R. Schommer (CTIO)) has 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-α images. Long-slit echelle spectra show that these structures are expanding at about 100 km s⁻¹ (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 G. Fabbiano (CFA), L. Armus (Caltech), and K. Weaver (Univ. Maryland and GSFC) have begun the analysis of ROSAT HRI and PSPC data for a small sample of 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 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 (as expected for a superwind).
Heckman has continued to investigate the environments of high-redshift quasars. He and collaborators J. Lowenthal (JHU) and M. Lehner have obtained Lyα, optical continuum (B or V), and near-IR continuum (K) images of a sample of radio-quiet quasars at $z = 2$ to 3. In contrast to their 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 Lyα 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 the deep Lyα images of the radio-loud and radio-quiet quasars to search for galaxies at the same redshift as the quasar (e.g., low luminosity AGNs or starbursts in the same group or cluster as the quasar).

Richard C. Henry conducts research on the interstellar medium, cosmology, and ultraviolet background radiation. A major effort focuses on use of a Department of Defense satellite with important astronomy capabilities; launch is scheduled for late 1993. Planning continues for a possible small explorer satellite dedicated to the spectroscopic and spatial imaging characterization of the cosmic diffuse ultraviolet background. A paper with J. Murthy (JHU/CAS) and J. B. Holberg (Univ. Arizona) has appeared in the *Astrophysical Journal* in which Voyager observations of the diffuse ultraviolet background are used to set limits on the albedo and scattering characteristics of interstellar dust grains in the ultraviolet. A large number of additional Voyager observations are under analysis, including an observation of the Coalsack nebula that shows a large flux of scattered ultraviolet starlight. Henry and collaborators' work on use of IRAS data to understand the distribution of dust in space has led to interesting results concerning the filling factor of the dust; the paper is "in press" at the *Astrophysical Journal*. Henry was appointed a member of the Principal Professional Staff of the Applied Physics Laboratory in 1991 (an honorary position). Henry continues as Director of the Johns Hopkins Space Grant Consortium, the members of which include Hopkins, the Applied Physics Laboratory, Morgan State University, and the Space Telescope Science Institute. In early 1991, Henry delivered an eight-week course of lectures on "Physics and the Universe," at the Smithsonian Institution in Washington, DC.

Gerard A. Kriss was appointed Project Scientist for the second flight of the Hopkins Ultraviolet Telescope, currently scheduled for the fall of 1994. His duties include overall management of the instrument refurbishment and improvements for the second flight as well as supervising the delivery of the Astro-1 flight data to the NSSDC archives. The extended far-UV wavelength coverage provided by HUT down to the Lyman limit has already provided new views of the nearby Seyfert galaxies NGC 4151 and NGC 1068. In NGC 4151, the HUT spectrum reveals outflowing absorbing gas with densities typical of the broad-line region. In NGC 1068, strong emission from C III λ977 and N III λ991 suggests the presence of shock-heated gas.

Kriss is also actively involved with the FOS instrument team's imaging and spectroscopic observations of nearby active galaxies. Most observations to date have been early acquisition images for subsequent spectroscopy with the FOS, but several spatially resolved spectra of discrete clouds in the narrow-line region of NGC 1068 have been obtained as well. Broad lines with widths comparable to the polarized broad Hβ are seen for Lyα, N v λ1240 and C IV λ1549, all with ratios typical of Seyfert 1 galaxies and QSO's. Comparison of these spectra to those obtained with HUT, which also show broad Lyα and C IV, show that the region scattering the broad lines and continuum in NGC 1068 must be extended on a scale of ~ 1''. A UV continuum "image" constructed from the FOS peak-up acquisition sequences confirms this, and reveals that 20% of the UV continuum flux comes from an unresolved peak near the nucleus, 40% from a region extended over ~ 0.3" which lies wholly within the ionization cone defined by the [O III] emission, and 40% from an area larger than 1''.

Early acquisition PC images in the light of [O III] of the Seyfert 1 galaxy NGC 4151 reveal a striking biconical structure which challenges the simplest unified models of Seyfert 1 and Seyfert 2 galaxies. In these models a dense, optically thick, molecular torus surrounds the central engine and serves both as a shield which prevents one from viewing the centers of Seyfert 2's and as the source of the collimation for the ionizing radiation. The difference between Seyfert 1's and Seyfert 2's is then due entirely to the opening angle of the torus and its orientation. Simple geometric arguments for NGC 4151 place our line of sight outside the cone of ionizing radiation. Since we have a nearly unobstructed view of the UV continuum and broad-line region, an optically thick molecular torus cannot be the source of the collimation. The lower column density material visible in the HUT spectrum is largely transparent at UV and optical wavelengths, but opaque beyond the Lyman limit. It can collimate the ionizing radiation field without obscuring our view of the central engine.

As a member of the international AGN watch, Kriss is also investigating the structure of the broad line regions in AGN. The successful campaign of
IUE observations of NGC 5548 (Clavel et al. 1991, ApJ, 366, 64) has led to another recently completed IUE campaign on the Seyfert 1 galaxy NGC 3783, and a successful proposal to follow up the results on NGC 5548 with a 40 day monitoring program using the Hubble Space Telescope in the spring of 1993.

Krisz is continuing an active program of optical and X-ray studies of clusters of galaxies. In collaboration with H. Ferguson (IOA), E. Malumuth (STScI/CSC) and JHU graduate student W. V. D. Dixon, he has obtained ROSAT PSPC observations of the galaxy clusters A496 and A2052. The data for A496 show a clear decrease in temperature toward the center of the cluster over the central 4'. The outer regions of the cluster have a column density of cold gas consistent with purely galactic absorption. In the region dominated by the cooling flow, however, the column density rises significantly higher than the galactic column. The spatially resolved temperature and surface brightness profile will be used to derive a mass profile for A496. With this constraint on the gravitational potential, the maximum entropy technique of Richstone and Tremaine can be used to solve for the internal distributions of radial and tangential velocity dispersions allowed by the projected velocity dispersion profile of the cluster (Malumuth et al. 1992, AJ, 104, 495). Additional ROSAT observations of the poor clusters MKW 4, AWM 4, and MKW 3s have also been obtained in collaboration with C. Canizares (MIT).

In the past year Julian Krolik has concentrated on a topic to which he has devoted considerable effort over the past half-dozen years: the theoretical investigation of the obscuration/reflection region which has recently been found in many active galactic nuclei. On the obscuration side, he has supervised the Ph.D. thesis of JHU graduate student E. Pier, in which Pier computed the angle-dependent infrared spectrum to be expected from an obscuring torus re-radiating the energy it absorbs from the active nucleus it surrounds. The spectrum turns out to be significantly anisotropic at almost all wavelengths, suggesting that there is almost no band in which AGN radiation is isotropic. In addition, they found that the 10 μm silicate feature, ordinarily expected to be deeply in absorption when the dust extinction is as great as in these objects, can in many cases be partially filled in, or even driven into emission, depending on the viewing angle and the details of geometry and opacity. These calculations also show that the long-standing puzzle of how such obscuring tori manage to be geometrically thick while still cool may be solved by the large infrared radiation pressure they contain.

The other side of the coin is the study of the warm, ionized reflecting gas. In collaboration with D. Balsara (JHU/CAS), Krolik has carried out detailed numerical hydrodynamics simulations which confirm the earlier suggestion of Krolik and Begelman that the reflection is probably due to an X-ray heated wind driven off the inner surface of the obscuring torus. The simulations allow detailed knowledge of the minimum L/L_B required to allow substantial mass loss (as opposed to mass capture), and the details of many viewing angle-dependent diagnostics: the polarization, the reflected fraction, the velocity shift of reflected lines, the thermal broadening by electron scattering of reflected lines, and the ionization state of Fe K lines radiated by the "mirror."

Knox S. Long is an Adjunct Research Professor in the Department of Physics and Astronomy and an Associate Astronomer at STScI. He is also a co-investigator on the Hopkins Ultraviolet Telescope. Long is pursuing 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 CAS members Blair, Bowers, Davidsen, Krisz, and E. M. Sion (Villanova), and I. Hubeny (GSFC), has recently completed the analysis of the HUT spectrum of the dwarf nova U Geminorum. This spectrum, which was obtained about 10 days after the end of a normal outburst, is dominated by the white dwarf; it shows not only the broad Lyman line profiles typical of a white dwarf but also numerous strong metal absorption lines which reflect the fact that abundances in the atmosphere are nearly solar. Using a grid of model atmospheres, Long and his collaborators concluded that two components are required to fit the spectrum—a lower 30,000 K component which comprises most of the white dwarf surface and a higher 38,000 K component which they associate with a boundary layer region left over from the previous outburst.

Long, in collaboration with Blair, Bowers, Davidsen, Vancura, and J. C. Raymond (SAO) have also completed a detailed study of the nonradiative filament observed with HUT in the Cygnus Loop. They found that this shock could be modeled in terms of a 180 km s⁻¹ shock. Optical measurements made of this same shock suggest a shock speed of 175 km s⁻¹ if electron and ion temperatures equilibrate instantaneously behind the shock front or 130 km s⁻¹ if they equilibrate on Coulomb timescales. Taken together, the UV and the optical observations suggest (surprisingly) rapid equilibration in the post-shock flow.

Long and Blair continue their studies of nearby normal galaxies, especially as related to supernova remnants. An analysis of interference filter imagery of several Sculptor group spirals, carried out with senior K. McQuade, has provided the first SNR identifications in NGC45 and NGC247. ROSAT observations of NGC300 and M33 reveal 15 and 40 sources respectively, but few of these appear to be associated with SNRs.
James Lowenthal continued a Fabry-Perot Lyman-α imaging study of damped Lyman-α QSO absorption line clouds with R. Green (NOAO), C. Hogan (Univ. Washington), and B. Woodgate (GSFC). Lyman-α emission is expected from regions of strong star formation and low dust, and the group’s previous effort revealed a strong Lyman-α-emitting galaxy at $z \approx 2$, either a primeval galaxy or a low-luminosity AGN. Some candidate Lyman-α companion galaxies at redshift $z \approx 3$ were discovered in the new search but need spectroscopic confirmation. If confirmed, they will support the claim that significant clustering has been detected at high redshift.

With J. Bechtold (Univ. Arizona), R. Elston (CTIO), and M. Rieke (Univ. Arizona), Lowenthal conducted a deep near-IR search for redshifted optical line and continuum emission from damped Lyman-α clouds. Both near-IR imaging and spectroscopy at the MMT, the Steward 90-inch, and the KPNO 4-meter were employed, and some possible emission was detected, indicating powerful star formation associated with the absorption line clouds at lookback times about 3/4 of a Hubble time, but again, confirmation is needed; confusion with foreground sources is an ongoing problem.

Lowenthal is collaborating on a related project with B. Yanny (IAS), D. York (Univ. Chicago), R. Green, B. Woodgate, and A. Cault (ST-ECF), using Fabry-Perot imaging to search for extended [O II] 3727Å emission from Mg II QSO absorption line systems at $0.5 < z < 1$. It is at these redshifts that there seem to be significant signs of galaxy evolution; evidence for enhanced star formation rates in galaxies associated with the absorbers would support this view.

With S. Baum and J. Gallimore (STScI) and G. MacAlpine (Univ. Michigan), Lowenthal is conducting a program of Fabry-Perot narrow-band imaging of face-on disk galaxies to search for high-velocity ionized gas, especially that associated with putative galactic fountains or chimneys. While the paradigm of the galactic fountain has not been firmly established, such observations can help confirm the existence of such mechanisms, which could be important for galactic structure and energy transfer processes.

Lowenthal, E. Fomalont (NRAO), B. Partridge (Haveford), and R. Windhorst (Arizona State) completed their analysis of deep VLA maps of two fields at 8 Ghz, studying both the discrete source counts and the possible fluctuations of the cosmic microwave background radiation. The deeper map was complete at about the 15 $\mu$-Jy level and was thus the most sensitive yet; 20 sources above that level were detected. The source counts are similar to those at lower frequencies. After careful modeling of the fluctuations expected from extremely faint discrete sources, it was determined that no significant anisotropy of the CMBR had been detected; at around one arcminute, the 95% confidence limit on $(\Delta T)/T$ is $2 \times 10^{-5}$.

In the past year, Piero Madau has devoted part of his research effort to studying models for the re-ionization of the intergalactic medium (IGM). He has used the quasar luminosity function and its evolution, as recently derived from multicolor optical survey, to estimate the integrated UV background as a function of redshift, and concluded that, within the uncertainties, the observed QSOs can provide the required number of ionizing photons at early epochs in several of the models studied.

Stephan R. McCandless’ work with Paul Feldman’s rocket group continues to provide opportunities to participate in cutting-edge technological developments which are of interest to future NASA far-ultraviolet space missions. In collaboration with Ritva Keski-Kuha and John Osantowski of the Goddard mirror coating laboratory, the faint object telescope’s (FOT) primary and secondary mirrors and the gratings of the evacuated spectrometer were successfully coated with ion-sputtered SiC. The normal incidence reflectivity of SiC ranges between 30 and 40% from the Lyman edge to Lyman-α. This is nearly a factor of two better than the Ir and Os coatings that were used on HUT. The SiC coating facility, which was developed to coat our 40 cm diameter primary mirror, can probably accommodate mirrors as large as 1 m. The SiC coating project also showed that an Al coated glass substrate could be successfully overcoated with SiC and that the visual reflectivity was about a factor of 2 better than SiC over glass alone. Data were also generated showing that the reflectivity decay of ion-sputtered SiC coatings could be slowed by storage of the coatings in vacuum. The FOT with the evacuated spectrometer will be flown by JHU graduate student Mel Martinez to obtain an FUV calibration of the dwarf stars G191-B2B and BD +28 4211 for his Ph.D. thesis and provide calibration support for HUT and other future NASA FUV missions.

In the next flight McCandless and collaborators plan to simultaneously image the Jovian aurora in Lyman-α and in a H$_2$ band around 1600 Å with 1" resolution, showing the relative intensity and proximity of the atomic H emission to the molecular H emission. They will use an afocal telescope with an imaging prism spectrometer, designed by JHU graduate student P. Morrissey, with a thinned CRAF/CASSINI 1024 x 1024 CCD. The CCD will be UV flooded in air, then evacuated and cooled to "pin" the backside charge necessary to provide the UV sensitivity. Currently, the project is in the design and procurement phase of this project with an estimated time to launch of 18 months.

In addition to the rocket work McCandless is drafting a paper with the HUT group on their
observation of the WN5 Wolf-Rayet star EZ CMa. The spectral output of this star has been modeled extensively and compared to IUE, visual and infrared observation, but this is the first look at the FUV flux and lines. The wind-broadened emission lines of high ionization atomic species (He II, N III-IV, O VI, S IV & V, P V), between the Lyman edge and Lyman-α are affected by interstellar atomic and molecular H absorption causing some lines to be attenuated, split or completely absent from the spectrum. After accounting for the H absorptions and dereddening the HUT spectrum with an average galactic extinction of Seaton (1979), an \( E_{B-V} = 0.06 \) and a distance of 2.05 kpc, the observations are compared to a pure He continuum model whose parameters were determined from a previous analysis of UV, visual and infrared lines. They find that while the visual and IUE portions of the spectrum are fairly well matched, the FUV flux of the model is low by about a factor of 1.5. There are three possibilities for this discrepancy: that blending of the wind-broadened emission lines has created a "pseudo-continuum" which the model does not take into account; that the model parameters need to be "fine tuned"; that the dereddening procedure is wrong, either in the value of \( E_{B-V} \) used or the reddening curve is not an average galactic law.

Melissa McGrath, former Associate Research Scientist in the Department of Physics and Astronomy, has recently moved to an Assistant Astronomer position at Space Telescope Science Institute, working in the Science Planning Branch. She remains a member of CAS. She continues her research on outer planet atmospheres, and has recently finished a major study of Lyman-α emission from Saturn (McGrath & Clarke 1992). In collaboration with CAS members D. Strobel, G. Ballester, P. Feldman and W. Moos, a comprehensive program of HST observations of Io was completed in March and May, which included FOS spectra in the far and near-ultraviolet, spatial scans of the atmospheric emissions of sulfur and oxygen with the FOS and HRS, and FOS spectra and WFC images of the Io plasma torus. Two other programs of HST observations, on dayglow emissions from Jupiter and UV emissions from Titan, have also been completed in the past several months. She also began a ground-based program of high-resolution spectroscopy of the Io torus in collaboration with D. Huntten and K. Wells (Univ. Arizona) and R. Brown (STScI/CAS) using the Lunar and Planetary Laboratory echelle spectrograph at the University of Arizona Catalina Observatory 61" telescope.

Warren Moos continues as the Director of the Center for Astrophysical Sciences. 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 Bowers as Instrument Scientist, C. Holmes as Software Scientist and D. Sahnow as Instrument Scientist. Warren Moos is also participating as a Co-Investigator in the definition of the Space Telescope Imaging Spectrograph with specific responsibility for overseeing calibration. Moos continues to study the outer planets using data from HUT, HST and IUE.

Jayant Murthy is heavily involved in a program to understand the diffuse radiation field in the far ultraviolet (with R. C. Henry and J. B. Holberg (Univ. of Arizona)). Some preliminary results include observations of line emission from the Eridanus superbubble and scattering of starlight from the Coalsack Nebula. He is also continuing an effort to characterize dust clouds near hot stars using data from the IRAS satellite (with R. C. Henry and H. J. Walker (Rutherford Appleton Labs) and JHU graduate student A. Dring). The first results from this work are to be published shortly.

David Neufeld remains primarily engaged in theoretical studies of the interstellar medium and of the 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.

During the past year, Neufeld has continued to study the phenomenon of interstellar masers. He has recently pointed out fundamental problems with parts of the standard theory of three-dimensional astrophysical masers. Efforts to address these shortcomings in the standard theory are underway in collaboration with M. Elitzur (Univ. Kentucky). With JHU graduate student M. Kaufman, Neufeld has constructed models for the water maser emission expected from non-dissociative magnetohydrodynamic shocks. Such models are apparently successful in accounting for the observed ratio of the 22 GHz and 321 GHz maser line strengths in star-forming interstellar regions.

With D. J. Hollenbach (NASA-Ames), he has undertaken a theoretical study of the accretion shocks through which material must have passed in entering the proto-solar (and other proto-stellar) nebulae. Preliminary results suggest that such shocks may be responsible for luminous and narrow-line CO vibrational overtone emission observed in the protostar SVS 13. He has also continued to study the transfer of Lyman-α and other resonantly scattered radiation. With JHU graduate student W. Chen, he is constructing models for the Lyα emission and absorption lines observed in star-forming galaxies.

Neufeld continues to work as a co-investigator on the Submillimeter Wave Astronomy Satellite (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, and atomic carbon. With JHU graduate students M. Kaufman and S. Conger, Neufeld has also been computing the far-infrared water and OH line spectra expected from both dissociative and non-dissociative shocks; 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).

Francesco Paresce continued his research programs as the PI of several GTO proposals for HST. This work consisted mainly in the application of high resolution imaging in the UV domain. The scope of the research encompassed three broad areas: auroral emissions of the giant planets in the far UV, hot stellar populations in galactic globular clusters and jets in symbiotic novae. In the planetary area, both the surface of Io and the polar cap of Jupiter were imaged for the first time in the near and far UV. The Lyman-α and H₂ aurorae were found to be very narrow and very bright features aligned with L = 15 magnetospheric field lines. The Io surface in the near UV was found to be almost exactly the mirror image of the visible surface as expected from a dominant S and SO₂ frost surface. In the globular cluster area, blue stragglers were discovered in M15 for the first time and their properties elucidated in NGC 6397. A magnetic CV was discovered in the core of 47 Tuc which was also shown to exhibit a cusp not observed before from the ground. In the stellar jet area, the symbiotic system R Aqr was observed in the far UV with both the imaging and objective prism facilities on HST. The results indicate that the core of a stellar jet has been resolved into its components with a resolution exceeding that of the VLA. All these results were reported at the Baia Chia, Sardinia Symposium on HST results. Paresce also continued his development of large area, high resolution, photon-counting image devices for ground-based telescopes and satellite applications and a second generation coronograph to be mounted in February 1993 at the focus of the ESO NTT at La Silla, Chile.

David Sahnow is currently the Detector Scientist for Lyman FUSE. He is currently planning (along with C. Bowers (JHU/CAS)) for the arrival of two candidate FUSE detectors (a MAMA and a Delay Line). They will be tested at JHU during 1993 as part of a competition to determine which detector technology is most appropriate for FUSE. In support of this effort, Sahnow has developed a model of microchannel plate detector response in order to anticipate the performance of the detectors, both in the laboratory and in flight. He also continues (with Paul Feldman) analysis of data from two sounding rockets obtained when he was a graduate student. A paper describing the results of observations of Comet Austin (1990 V) has been accepted for publication, and work continues on the analysis of the Io Plasma Torus data. In addition, a paper describing the diode array detector used for these observations is in preparation.

Darrell Strobel in collaboration with M. Summers (NRL) has continued to devote most of his research effort the past year to further understanding of the thin nitrogen atmosphere of Triton. This research has led to a consistent first-order description of Triton's upper atmosphere as discussed in their forthcoming chapter entitled "Triton's Upper Atmosphere and Ionosphere" to appear in Neptune and Triton, a book published University of Arizona Press as part of its Space Science Series.

In a paper submitted to Icarus Strobel and Summers present a comprehensive photochemical model of Triton's atmosphere and ionosphere including coupled carbon-hydrogen-nitrogen chemistry and suggest a new scenario, based on ion-molecule reactions with CO if its mixing ratio exceeds 10⁻⁶, for formation of the ionosphere observed by Voyager 2. Magnetospheric electron precipitation is required to obtain the observed peak electron densities measured by the Voyager 2 radio occultation experiment. The required magnetospheric power input is consistent with the magnitudes derived from EUV airglow, N₂ escape rate ratio, and thermal balance.

The Voyager 1 ultraviolet spectrometer (UVS) solar occultation and airglow data obtained during the Titan flyby were re-analyzed for composition and thermal structure of the upper atmosphere and relative importance of airglow excitation processes. From the shape of the observed bright limb profile for N₂ emission (924–998 Å) it was concluded that the magnetospheric power dissipation is, at most, 10% of the solar EUV power input to Titan's extended atmosphere and consistent with estimates of magnetospheric power delivered to the ionopause by curvature drift of thermal and suprathermal electrons. This value of magnetospheric power input is a factor of 25 lower than the original estimate of Strobel & Shemansky (1982). The nonthermal N atom escape rate was estimated to be ≤ 10²⁵ s⁻¹. An upper limit on the tropopause Ar mixing ratio of 0.14 was derived from a comparison of the calculated relative intensities of the Ar resonance lines at 1048 and 1067 Å with the N⁺ (1085 Å) multiplet to the observationally inferred upper limit of 0.5.

Alex Szalay has been continuously working on the very deep 'pencilbeam'-like redshift survey of galaxies with D. Koo (Lick Observatory), R. Ellis (Durham), T. Broadhurst (ROE), N. Ellmann (UCSC) and J. Munn (Univ. Chicago). In the direction of the Galactic Poles the survey now covers more than a 6 by 6 degree area, with over 1300 galaxies. The strong large-scale clustering signal at around 128 Mpc is present at an even stronger level in the data than in the original pencilbeam, indicating large transverse coherence in the galaxy.
distribution.

With JHU graduate student I. Szapudi, Szalay has laid down the framework for treating the higher order statistics of the galaxy distribution in a particularly elegant manner. JHU graduate student M. SubbaRao, and Szalay in collaboration with R. Schaefer (Bartol), S. Gulkis and P. von Groenefeld (JPL), have calculated the Compton distortions in the microwave background due to very large-scale structure. They found that one can hope to detect large filamentary patterns, about 10 degrees by 10 arcmins with a dip of $10^{-4}$, due to edge-on pancakes, without violating any other constraints. Given a broader Gaussian beam much of this would be smoothed out. Szalay and collaborators also suggest a technique to amplify the non-Gaussian contributions in the temperature correlation function. JHU graduate student S. Landy and Szalay derived an optimal estimator for the angular two-point function of faint galaxies, and also showed that the errors in the usual angular correlation function may be much larger than the common wisdom. With D. Koo, R. Kron, and J. Munn, another paper on pencilbeam redshift surveys in different directions is soon to be published. With E. Regos (UCSC) the velocity correlation function of clusters of galaxies is calculated for various Gaussian spectra.

Zlatan Tsvetanov is actively involved with the FOS team’s GTO program for imaging and spectrophotometric study of nearby Active Galactic Nuclei with the HST. The first part of the program—WF/PC narrow-band images—is completed with images of about a dozen objects taken. The unprecedented optical spatial resolution of the HST images revealed some unexpected results. The emission-line morphology of both Mrk 3 and M51 fits the popular unified model of AGN quite well; however, the biconical structure observed in NGC 4151 challenges the simplest version of the scheme. Many of the critical questions will be addressed through the observations in the second part of the GTO program—FOS small-aperture spectroscopy of the resolved circumnuclear structure. Papers on NGC 4151 and on Mrk 3 are in the final preparation stage to be submitted to Ap. J.

In collaboration with J. P. Harrington and K. Borkowski (Univ. Maryland), Tsvetanov is conducting a program for complex imaging and spectroscopic study of hydrogen-poor Planetary Nebulae using both the HST and ground-based telescopes. As part of the ground-based preparations O III images were taken for two of the objects with the ESO NTT. The PN in globular cluster M22 revealed a strongly asymmetric half-moon-shaped morphology, which is interpreted as a result of the ram pressure of the ambient ISM through which the cluster is moving. This is the first direct evidence for removal of gas from globular clusters. A paper is accepted for publication in Ap. J. Letters.

Tsvetanov is continuing work on a project for narrow-band imaging of a distance-limited sample of southern Seyfert galaxies [in collaboration with R. Fosbury (ST-ECF), C. Tadhunter (Univ. Sheffield)]. The main aim is to relate the systematics of the Extended Emission-Line Region to other parameters such as Seyfert type, properties of the host galaxy, etc. Data for about 60% of the objects are already collected. When finished, this will be the most complete sample of ground-based emission-line images of nearby Seyferts and will be an important source for planning HST and other detailed observations. Near-IR long-slit spectroscopic observations of some of the best radiation cone examples from the sample were obtained at the NTT [with R. Fosbury and A. Morwood (ESO)] in order to study the physical conditions in the emitting gas and to look for signatures of the obscuring formation.

In collaboration with A. Wilson (STScI) and J. Pérez-Fournon (IAC), Tsvetanov is continuing study of the kinematics and ionization structure of the Extended Emission-Line Regions in nearby Seyferts based on long slit spectra collected in previous years. A paper on the analysis of the velocity field in NGC 3516 is published in Ap. J. and analysis of the low-resolution spectra, which will be used to study the ionization structure, is in advanced stage.

In collaboration with S. Lipari (STScI) and F. Macchetto (STScI), Tsvetanov has studied the relationships between the nuclear activity and massive starformation in the nearby active galaxy NGC 6860 (IRAS 20044-6114). Emission-line imaging and optical and near-IR spectroscopy of this luminous IR source have revealed the composite nature of the ionizing source – a variable Seyfert 1 nucleus embedded in a dusty star formation environment. The analysis of the velocity field shows signatures of gas inflow that can be fueling the active nucleus. A paper is accepted for publication in Ap. J.

Alan Uomoto is working on the construction of two fiber optic spectrographs for use with the Sloan Digital Sky Survey 2.5 m telescope. Each spectrograph will feed 330 fibers to two (blue and red channel) 2048 × 2048 CCD detectors and will be used for studies of the redshift distribution of galaxies, the spectral properties of quasars, and the intergalactic medium.

He also continues to work with the Faint Object Spectrograph instrument team in studies of the nuclear regions of active galactic nuclei using HST.

In collaboration with G. MacAlpine and S. Lawrence (both at Univ. Michigan) and B. Woodgate (GSFC), he is working on understanding the three-dimensional structure of the Crab Nebula. Available data using the Goddard Fabry-Perot imager is sufficient to map the composition and density of the nebula in three dimension, as well as generate a dynamical map of the emitting gas.

He also continues to work on the manufacture
of faint, broad band photometric standards with A. Landolt (Louisiana State) using the facilities at Las Campanas Observatory.

R. Wyse, together with Y. Hoffman (Hebrew Univ., Jerusalem) and J. Silk (UC Berkeley) developed a theory to explain the existence of giant, low-surface brightness disk galaxies, such as Malin I, which have unevolved disks but normal, old, metal-rich bulges. Their proposal hinges on the fact that these galaxies populate only underdense regions of the Universe, which, in the context of the Gaussian peaks formalism, results in initial conditions that are dense in the inner regions, but very diffuse in the outer regions. She analyzed possible scenarios for the bulge of our Galaxy, in collaboration with G. Gilmore (IoA), emphasizing the crucial role that element ratios play in discriminating among the evolutionary histories. The formation history of classical subdwarf halo of our Galaxy was analyzed by JHU graduate student T. Smucker-Hane and Wyse, who investigated various means of dating halo objects, in an attempt to reconcile the spread of a few Gyr in globular cluster ages with chemical enrichment arguments that favor a significantly faster evolution. They concluded that an inhomogeneous, “bloppy” model of halo formation was favored, but only if the chemical evolution of each blob was constrained to be complete prior to the onset of Type Ia supernovae.

Wei Zheng has participated in the HUT data calibration, reduction and analyses. In collaboration with Daviden, Kriss and other CAS members, he has studied the HUT spectra of several active nuclei. In Mrk 335, a decline of continuum flux in the sub-Lyα region fits the description of Lyman edge absorption, presumably intrinsic to an accretion disk. Progress is made to model the disk and to find more evidence for such absorption.

He is also studying the effect of EUV continuum on the emission lines, especially the high-ionization lines. The HUT data reveal very strong O VI 1035 emission in several active galactic nuclei, a sign for excessive soft X-ray emission. Information derived can be used to constrain models of an accretion disk, which is believed to produce the UV bump.

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Warren Moos
Director

IV. PUBLICATIONS


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Quiones, E. and Dagdijgan, P.J. (1992). “Study of the Pressure Dependence of the N₂ B²Πg−


