I. INTRODUCTION

The highlight of the past year was the International Astronomical Union General Assembly held in Baltimore (August 1988). Official host was The Johns Hopkins University, so CAS was very heavily involved indeed, and the first Director of CAS, Professor Arthur Davidsen, acted as Co-Chairman of the Local Organizing Committee. The other Co-Chair was CAS member and Space Telescope Science Institute Director Riccardo Giacconi. In a special section of this report, Davidsen details the very successful IAU General Assembly. The CAS computer systems continue to multiply rapidly at a rate of about one new computer per month with no end in sight. There are now over twenty significant computers available to astronomers and astrophysics researchers. These include a mix of MicroVAX II, MicroVAX 3XXX, and Sun 3 computers running the VMS, Ultrix, or Sun Unix operating systems. All of these machines are connected through a campus-wide ethernet supported by the Johns Hopkins Homewood Academic Computing Center, giving us direct access to Bitnet, SURAnet, and the ARPA Net. A direct line to the Space Telescope Science Institute connects us to NASA's SPAN network as well. A large, but insufficient 8.6 Gbyte file system is already in place. Almost all of it accessible across machines via either the Sun Unix NFS or VAX/VMS LAVC. Nine 9-track magnetic tape drives are also available. Access to these computers is through network terminal servers that support nearly 80 terminals. Direct connection to any machine on the ARPA Net is possible from the terminal servers, and many DECnet networks can be reached through gateway computers. About 200 login accounts have been issued for these computers, although only 100 or so are used regularly. There are three IVAS image displays on VMS computers, and two of the Sun workstations are equipped with color displays that run locally written image display software as well as the IRAF utilities.

Visitors to the Space Telescope Science Institute who look across the street will see vivid evidence of progress on the new building for the Department of Physics and Astronomy of The Johns Hopkins University. As of October 1988, the steel skeleton of the teaching wing was completed and the concrete first-floor research wing was in place. Work is continuing on schedule with completion scheduled for spring 1990.

Finally, the Hopkins Ultraviolet Telescope (HUT) is still on NASA's Space Shuttle manifest for two flights, in March of 1990 and September 1991.

II. PERSONNEL

All of us at CAS thank Professor Arthur Davidsen for his service as first center Director. Rosemary Wyse has accepted appointment as Assistant Professor. Holland Ford and Tim Heckman have accepted appointment as Professors (both of these are shared appointments with the Space Telescope Science Institute). Allan Sandage continues to visit us as a Homewood Professor. Alex Szalay is currently in Budapest as part of his joint appointment. David van Buren has completed his second year as the Allan Davis Postdoctoral Fellow and continues in that capacity. Keith Peacock has completed his tour as Lawrence Hafstad Fellow at Homewood and has returned to the Applied Physics Laboratory where he is participating in the planning for the proposed HUSE (Hopkins Ultraviolet Background Explorer) mission. Stephen McCandless has joined the rocket program as an Associate Research Scientist having just completed his Ph.D. at the University of Colorado. Scott Friedman has joined W. Moo in the Lyman Project as an Associate Research Scientist. Other permanent staff members contributing to research in astronomy and astrophysics are: P. J. Dagdigian, A. F. Davidsen, J. Doering, P. D. Feldman, R. Giacconi (Director, ST ScI), B. R. Judd, R. C. Henry, C. W. Kim, H. W. Moo, (Director, CAS), C. A. Norman, and D. F. Strobel, Professors; J. H. Kriolik, Associate Professor; R. A. Brown, S. M. Pall, and F. Paresce, Research Professors; S. Lubow, Assistant Research Professor; C. D. Fastie, Adjunct Research Professor; K. S. Long and S. T. Durrance, Research Scientists; W. P. Blair, C. W. Bowers, R. A. Kimble, G. A. Kriss, M. D. Morrison and A. Uomoto, Associate Research Scientists; and H. A. Weaver, Assistant Astronomer (ST ScI).

III IAU GENERAL ASSEMBLY

The Twentieth General Assembly of the International Astronomical Union (IAU) was held in Baltimore from 2 through 11 August 1988, with The Johns Hopkins University serving as the host institution, in cooperation with the National Academy of Sciences. The Local Organizing Committee (LOC), which was responsible for all of the arrangements for the meeting, was co-chaired by Professors Arthur Davidsen and Riccardo Giacconi. By all reports the meeting was a huge success.

There were 2686 people registered for the 20th General Assembly. IAU members and Invited Participants numbered 1720, and were accompanied by 361 Registered Guests. The LOC staff and volunteers included 224 people who were dedicated to making everything run smoothly. Individuals from companies and organizations who were donors, exhibitors, and support contractors numbered 148. In addition, there were 187 "Special Guests," mostly from the Baltimore and Washington academic and political communities. Finally, the General Assembly received widespread news coverage from 46 members of the press who attended.

Visitors came from 57 countries to participate in the 20th General Assembly. Almost
exactly half of the astronomers attending were from the U.S., with the largest foreign delegations coming from France (111, including registered guests), the United Kingdom (100), Italy (89), Canada (84), the Federal Republic of Germany (74), India (46), the Netherlands (45), Australia (43), and the People's Republic of China (34).

The most heavily represented state at the 20th General Assembly was not surprisingly Maryland, astronomy's largest state, with 138 registered guests. Other large delegations came from the District of Columbia (126), California (118), Massachusetts (71), Arizona (58), Virginia (47), Colorado (28), Illinois (28), and New York (28).

The 20th General Assembly began with an Inaugural Ceremony presided over by LOC co-chairman Arthur Davidson. Featured speakers from outside the astronomical community included Presidential Science Advisor William Graham, NASA Associate Administrator Noel Hinners, Maryland Lieutenant Governor Melvin Steinberg, and Baltimore Mayor Kurt Schmoke. Musical interludes, including a piece composed especially for the IAU by Elam Ray Sprengel of the Peabody Conservatory, were performed by the Annapolis Brass Quintet.

For details of the scientific program, including commission meetings, joint discussions, and the invited discourses, the interested reader is referred to the Transactions of the IAU. Here we note only that social and cultural activities were a normal part of the program for the 20th General Assembly. These included a gala welcome reception at Baltimore's Inner Harbor, with guests ferried by boats between the National Aquarium and the Maryland Science Center; a special concert for the IAU of music by American composers, performed by the Baltimore Symphony Orchestra; a special performance of American folk music, dance, and jazz outdoors at the Pier 6 Concert Pavilion in the Inner Harbor; and a closing banquet under tents on The Johns Hopkins University campus, described by veteran IAU participant Frank Edmondson as a "tour de force."

Organizing the 20th General Assembly of the IAU was an enormous undertaking for the CAS staff. We are particularly grateful to the extraordinary efforts of CAS Business Manager Harold Screen and Special Assistant to the Director, Karen Weinstock.

IV. RESEARCH AND ACTIVITIES

William P. Blair continues his duties as science planning coordinator for the HUT and FOS projects. These duties have included involvement in Astro mission planning exercises, in FOS calibration and testing at Lockheed, and ground system testing for FOS data reduction. In addition, he has continued research on galactic and extragalactic supernova remnants using both ground-based images and IUE data. With K. S. Long (JHU/CAS), a combined CCD imaging and spectroscopy study has been carried out at Las Campanas Observatory on supernova remnants in the Sculptor group spirals NGC 300 and NGC 7793. Upwards of 20 remnant candidates in each galaxy were identified from interference filter images and follow-up spectroscopy has confirmed many of the identifications. With Long and C. W. Bowers (JHU/CAS), a comparative study of densities in supernova remnants (derived from the [S II] and [O II] doublets) was begun using echelle spectra obtained at Las Campanas. Work also continues on a large sample of remnants in M33. With Long, R. P. Kirshner (Harvard) and P. F. Winkler (Middlebury Coll.), an imaging CCD survey of M33 to find remnants has been quite successful, and spectroscopic follow-up is continuing. With Y.-H. Chu (U. Ill.) and R. C. Kennicutt (U. Minn.), echelle spectra have been obtained for many of the brighter M33 SNRs. A spectroscopic study of the core nebula in the galactic remnant CTB 80 was carried out with R. A. Fesen (U. Col.) and R. H. Becker (U. Cal. Davis). This study conclusively demonstrates the shock heated nature of this emission and shows that no material is present at velocities higher than 300 km/s. With Long and S. van der Marel (DAO), a new proper motion study of faint filaments in SN 1006 was performed that constrains the distance to this historical supernova. Analysis of an O-rich remnant in the Small Magellanic Cloud involving combined UV and optical data has been completed, with collaborators J. C. Raymond (SAO), J. Danziger (ESO) and F. Matteucci (ESO). The same collaboration has resulted in the publication of an IUE observation of N132D, another O-rich remnant in the Large Magellanic Cloud. With Long and A. Uomoto (JHU/CAS), IUE spectra of the Crab Nebula are being reanalyzed for evidence of spatial line intensity variations.

Charles W. Bowers has continued pre-flight planning and instrument development for the HUT project. In the past year his efforts have been concentrated on assembling an improved flight detector for use with the new HUT spectrograph to be installed for the Astro-1 flight. By implementing an improved photocathode deposition method, higher and more uniform quantum efficiency has been achieved. In addition, studies of gain loss and microchannel plate lifetime have been conducted to characterize both the HUT detectors and to understand the implications of these processes for extended space mission.

Bowers also produced the optical design for the recently proposed SUSI (Small Ultraviolet Spectroscopic Instrument) for a microchannel plate imaging spectrograph in a modified Rowland circle mount and SiC coated optics, SUSI covers the spectral range of 850-1700 Å with (10cm) effective area at 1200 Å, a value comparable to HUT. SUSI will also be capable of spatial imagery (15') over a 10 arc-minute slit and is only one meter in length. SUSI has been proposed as a satellite instrument in the NASA small Explorer program. Bowers has also initiated an observing program of Type I planetary nebulae conducted at Las Campanas. These planetary nebulae are characterized by relatively high H/He abundances and are believed to have been formed from massive progenitor stars. In contrast to the classical spherical shell morphology, Type I are typically bipolar and display strong emission from both high ionization species as well as low ionization and neutral material. Many are believed to have a torus of neutral matter and dust surrounding the central star. CCD images were taken through a variety of interference filters of several of these objects in addition to a number of "normal" planetary nebulae. Long slit echelle spectra of the same set of Type I nebulae were also obtained by William Blair and Knox Long in April. In
Combination, this data set should allow the determination of the general ionization and kinematic structure of the nebulae and, in particular, whether or not these planetary nebulae are ionization bounded by torus. The data will also be analyzed to search for the high speed winds observed in a few members of this class for the faint haloes and multiple shells which have recently been photographed near other planetary nebulae. Paul Dagdigan has continued laboratory studies of inelastic and reactive collisions of molecular free radicals. The two-laser optical-optical double resonance technique has been used to measure relative rate constants for inelastic collisions involving argon atoms between specified initial and final rotational levels in the electronically excited B" state of molecular nitrogen. For collisions within the D=0 manifold, a marked propensity toward even ΔJ changes was observed, which decreased with increasing initial J value. This behavior could be related to the form of the N,(B)-Ar interaction potentials and the change from Hund's coupling case (a) toward (b). Collisional excitation transfer between the 3p P and 1P states of the oxygen atom has been studied using two-photon laser excitation and fluorescence detection.

In related theoretical work, the reflection symmetry of the spatial part of the electronic wave function for ^1Π diatomic electronic states has been examined for the individual λ-doublet levels in both the low-J case (a) and high-J case (b) limits. This symmetry is often reflected in a preferential population of λ-doublet levels in a variety of photodissociation and photodissociative ionization experiments yielding molecules in Π electronic states. In response to an increasing need for a new notation for λ-doublet levels in rotating linear molecules, Dagdigan worked with a group in the chemical physics community to propose the notation λ(A')/λ(A") to designate the λ-doublet levels for which at high J the electronic wave function is symmetric/antisymmetric with respect to reflection of the spatial coordinates in the plane of rotation. The utility of this notation is that it is often of most relevance in the mechanistic interpretation of reactive or photodissociative processes involving open-shell molecules. A theoretical interpretation of spin- and λ-doublet selectivity in the infrared multiphoton photodissociation of NN(X' A') to yield NH in the X'2Π and A' state has also been carried out.

A crossed molecular beam apparatus has been set up in Dagdigan's laboratory for the study of chemical reactions of small free radicals. The vibration-rotation distribution of the NO product from the H + NO reaction is being determined from NO laser fluorescence excitation spectra. Molecular free radicals are also being prepared in this apparatus by excimer laser photolysis of a suitable precursor in the expansion zone of a supersonic nozzle. With this technique, rotationally inelastic collisions of NH(X'2Π) and NH(X'2Π) with inert gases have been investigated.

Arthur Davidsen completed his three year term as the first director of CAS on September 1, 1988. A large portion of his time during the past year was spent on preparations for the IAU Twentieth General Assembly, described elsewhere in this report. Davidsen also continued to lead the Hopkins Ultraviolet Telescope project as Principal Investigator, and lead the JHU involvement in the Magellan Project. He also continued his role as a Co-Investigator on the Faint Object Spectrograph team for HST, and has established the East Coast Data Node for the FOS Team. During the hiatus in space shuttle flights, Davidsen has begun a program of spectro photometric observations of elliptical galaxies with Kimble and Sandage at Las Campanas. This work, which is now about 75% complete, is aimed at investigating the properties of the 4000 A break in the spectra of E galaxies, its correlation with luminosity and other galaxy parameters, and its significance for galactic evolution.

John P. Doering and his students have completed the laboratory measurement of electron excitation cross sections for all important transitions in OI. Transitions measured include all allowed strong resonance transitions as well as forbidden transitions to the singlet and quintet manifolds.

New work carried out recently has centered on the extension of the inelastic electron scattering method to cross section and oscillator strength measurements in other species. Using microwave discharge techniques, it has been possible to measure relative oscillator strengths for the strong resonance transitions in N1 and S1. In addition, the first measurements of relative intensities in CS have been carried out. Using the laser evaporation technique, relative oscillator strengths of the resonance lines of CI produced from solid graphite have also been measured. The results on CI and S1 are of particular interest to cometary problems. The S1 relative oscillator strengths provide a basis for further work on cometary spectra and the Io and Io torus emission spectrum problems.

Michael Fall has extended his arguments concerning the spin up of protogalaxies during collapse to estimate the distribution of redshifts at which galactic disks formed. Since the specific angular momentum of a galactic disk today is likely to be equal to or less than the specific angular momentum in the protogalaxy, a lower limit to the initial size can be calculated as a function of the initial rotation velocity or spin parameter. This in turn sets a lower limit to the free-fall time, hence the collapse time, and therefore an upper limit to the redshift of formation. Recent N-body simulations of hierarchical clustering indicate that the initial spin parameter has a broad distribution with very little dependence on the initial conditions. The present specific angular momenta of galactic disks can be derived from their surface brightness profiles and rotation curves. Fall's calculations indicate that the median redshift of disk galaxy formation is less than 2.5 for q=0.5 and less than 5 for q=0.05. Some of the implications of these results are being explored by Charlot and Fall.

Fall and Pei have searched for dust in damped Lyα systems along the lines of sight to quasars at high redshifts. This is worthwhile because the damped Lyα systems contain nearly all the neutral hydrogen in the universe and may be protogalaxies or galactic disks in an early, gas-rich phase of evolution. Fall and Pei first
compare the spectral indices of quasars that have damped Lya systems along the line of sight with those that do not (the control sample) to determine or set limits on the dust-to-gas ratio in the damped Lya systems. They then use the known redshifts and column densities of the damped Lya systems to determine or set limits on the mean optical depth as a function of redshift along random lines of sight. This includes a correction for the effect, emphasized by Ostriker and Heisler, that highly obscured quasars are less likely to be included in optically selected samples than quasars with little dust in the foreground.

In the first study, Fall and Pei used data from the survey by Wolfe et al. No dust was detected. The 95% confidence limit on the dust-to-gas ratio in the damped Lya systems is about half the observed value in the interstellar medium of the solar neighborhood and the 95% confidence limit on the mean optical depth (in the B band) to a redshift z = 3 is 0.9. Fall and Pei conclude that the apparent cutoff in the counts of quasars at z > 3 is probably not caused by dust in the damped Lya systems. In a second study, Fall and Pei, in collaboration with McMahon of Cambridge, used data from the recent survey by Sargent, Steidel and Boksenberg. In this case, a small amount of dust was detected in the damped Lya systems. The most probable values of the dust-to-gas ratio and mean optical depth are 2 to 4 times smaller than the upper limits derived from the Wolfe et al. data. Thus, for most purposes, the reddening and obscuration of objects at high redshifts can be neglected.

Elson (Institute for Advanced Study) and Fall have re-examined the empirical relation presented in their 1985 paper between the ages and the integrated broad-band colors of star clusters in the Large Magellanic Cloud (LMC). The new relation, which included 57 clusters, is based entirely on ages derived from main sequence turnoffs. It is very similar to the previous relation except possibly for some of the oldest clusters. As a consequence, the age distribution derived from the new color-age relation is also similar to the one found earlier by Elson and Fall. The SFR range of the LMC clump is about 1 x 10^{-3} yr^{-1}, which is much larger than that for open clusters in the Milky Way. This indicates that disruptive mechanisms, such as encounters with molecular clouds, are less effective in the LMC.

Elson, Fall, and Freeman (Mount Stromlo and Siding Spring Observatories) have determined the stellar luminosity functions of six rich star clusters in the LMC with ages 3-5 x 10^7 yr. The corresponding initial mass functions (IMFs) are considerably flatter than the Salpeter IMF over the accessible range 1.5 - 6.0 M☉. The luminosity functions of the fields surrounding the clusters are steeper than those of the clusters and there are large variations from one field to another. This indicates that either the field IMF or star formation rate varies on small scales. The flat IMFs of the young LMC clusters are consistent with the upper limits on their mass-to-light ratios derived recently by Lupton et al. (see below). Another consequence of flat IMFs is that stellar winds, supernovae, and other stellar ejecta, played important roles in the early evolution of the clusters.

Lupton (University of Hawaii), Fall, Freeman, and Elson have measured the radial velocities of 10-30 stars in each of three rich young star clusters in the LMC. The observational errors (a few kms^{-1}) are comparable to the observed velocity dispersions and the samples are inevitably contaminated by a few field stars. Under these circumstances, only upper limits can be set on the true velocity dispersions within the clusters. Lupton et al. find σ < 3 - 4 kms^{-1} at the 95% confidence level. Combining these results with the observed surface brightness profiles, they derive upper limits on the total masses of 4 x 10^6, 2 x 10^6, and 4 x 10^8 M☉, respectively, for NgC1866, NgC2164, and NgC2214. The corresponding limits on the mass-to-light ratios are 0.4, 0.6, and 1.1 in solar units. From the small velocity dispersion in NgC1866, Lupton et al. infer that the cluster is not yet tidally limited by the LMC and that at least 35% of its total mass lies in an unbound halo. The other two clusters may also have unbound halos, but the limits on the velocity dispersions are not tight enough to draw definite conclusions.

Paul D. Feldman directs the NASA supported sounding rocket program, which as its main focus the development of new instrumentation for far- and extreme-ultraviolet astronomy. A recently developed two-dimensional image intensified photometric array detector was to have been flown as part of an instrument payload to observe the Io plasma torus in December 1987, but was postponed a year when NASA redirected its sounding rocket resources to two Australian campaigns to observe SM1987A. This work was initiated with Thomas N. Woods (now at LASP, University of Colorado) and graduate students David Snow and Mel Martinez. Graduate student Ken Dymond has continued the analysis of the long-slit ultraviolet spectra of Halley obtained in February and March 1986, with particular attention given to the spectroscopy of weak features. Feldman also continued his IUE comet program (with graduate student Elizabeth Roettger and in collaboration with M. P. A'Hearn of the University of Maryland and M. C. Festou of the Observatoire de Besançon) with observations of comets Bradfield (1987a), P/Borrelly, Ichimura (1987d), and P/Tempe-2. Feldman has continued as a member of the Imaging System Science Team for NASA's proposed Comet Rendezvous Asteroid Flyby mission and as a member of the imaging Instrument Definition Science Team for the Cassini mission. He has also continued to serve on the Committee on Planetary and Lunar Exploration of the Space Science Board and was elected a Trustee of the Universities Space Research Association.

Holland Ford, in collaboration with R. Ciardullo (KPO), G. Jacoby (KPO), and X. Hui (Boston University) have shown that the planetary nebulae [O III] λ5007 luminosity function (PNLF) is an accurate standard candle. The luminosity function is universal and has a sharp bright-end cutoff near M_{5007} = -4.48 which provides an excellent distance estimator. The cutoff is a direct result of the small range in masses (0.6 ± 0.02 M☉) of PN central stars (to the high side of the distribution) in combination with the extremely rapid evolutionary timescales for the more massive stars. Using the technique of
maximum likelihood, the luminosity functions for PN in M81 (SB), NGC 5128 (E0), the NGC 3379 (E0) group, including NGC 3384 (SB0) and NGC 3377 (E), have been used to derive distances to these and other galaxies as distant as Virgo. Distances to galaxies in a single group (NGC 3379) having a range of Hubble types, and different fields within a single galaxy (NGC 5128) agree to better than 5%, consistent with the formal errors derived using statistical tests.

H. Ford, X. Hui, and R. Ciardullo, in collaboration with K. Freeman (MSSSO), M. Dopita (MSSSO), and S. Meatheringham (MSSSO), have observed the radial velocities of 116 PN in Cen A. They used these velocities to measure the stellar velocity dispersion and stellar rotation velocity out to 20' (4r < 20 kpc), approximately 4 times more distant than previous measurements in an elliptical galaxy. They find a slowly declining velocity dispersion and a rotation curve which is flat between 10 and 20 kpc. They use the Boltzmann equation to derive the mass distribution throughout the galaxy. The M/L increases smoothly from the center of the galaxy out to ~17.7', thus providing direct dynamical evidence for the presence of a dark (or dim) halo with a scale length greater than that of the stars. Comparison of V_0 = 0 and c with models shows that Cen A is one of a small number of luminous ellipticals which appear to be rotationally supported oblate spheroids. Comparison of the slowly rotating cluster halo with the rotating stellar halo suggest that the clusters form a kinematically distinct, older population.

H. Ford and R. Ciardullo made an analysis of novae as distance indicators, beginning with a critical look at distances derived from expansion parallaxes. They began by showing that nova shells are characteristically prolate with equatorial bands and polar caps. Failure to account for the geometry can lead to large errors in expansion parallaxes for individual novae. When simple prescriptions are used for deriving expansion parallaxes from an ensemble of randomly oriented prolate spheroids, the average distance will be too small by factors of 10% to 15%. The absolute magnitudes of the novae will be underestimated and the resulting distance scale will be too small by the same factors. If observations of partially resolved nova shells select for large inclinations, the systematic error in the resulting distance scale could easily be 20% to 30%.

Extinction by dust in the bulge of M31 may broaden and shift the intrinsic distribution of maximum nova magnitudes versus decay rates. Ford and Ciardullo investigated this possibility by projecting Arp's and Rosino's novae onto a composite B - A6200 color map of M31's bulge. Thirty-two of the 86 novae projected onto a smooth background with no underlying structure due to the presence of a dust cloud along the line of sight. The distribution of maximum magnitudes versus fade rates for these "unreddened" novae is indistinguishable from the distribution for the entire set of novae. They conclude that novae suffer very little extinction from the filamentary and patchy distribution of dust seen in the bulge of M31.

Time averaged B and Hα nova luminosity functions are potentially powerful new ways to use novae as standard candles. Ford and Ciardullo analyzed their modern CCD observations and the photographic light curves of M31 novae found during the last 60 years to show that these functions are power laws. Consequently, unless the eruption times for novae are known, the data cannot be used to obtain distances.

Riccardo Giacconi, Director of Space Telescope Science Institute, is pursuing research on cosmology and large scale structure in the universe through a number of programs related to the study of the formation and dynamic evolution of clusters. The approach is to use the observations in X-rays of the high temperature plasmas in clusters as a tool to study the evolution of characteristic cluster parameters.

In collaboration with Richard Burg (Space Telescope Science Institute), Christine Jones am-William Forman (Center of Astrophysics) he is studying the X-ray luminosity function of Abell Clusters of different richness classes and using it to predict the logN-logS relationship at faint X-ray fluxes. In collaboration with Richard Burg and Brian McLean (Space Telescope Science Institute), Tommaso Maccacaro and Isabella Giola (Center for Astrophysics) he is studying the characteristics of clusters observed in the MSS flux limited "Einstein" surveys.

In collaboration with the Max Planck Group (Max-Planck-Institut fur Extraterrestriche Physik) he is planning a program of optical source identification and cluster research utilizing the all sky ROSAT X-ray survey (launch 1990).

In collaboration with Maarten Schmidt, Gianni Zamorani, Joachim Trumper, Gunther Hassinger and Richard Burg he is gathering optical material for a program of deep pointed surveys with ROSAT.

He is continuing his contributions to the AXAF mission as Interdisciplinary Scientist (launch 1996).

Richard C. Henry conducts research on the interstellar medium, cosmology, and ultraviolet background radiation. Data analysis continues on the UVX experiment, which flew on the Space Shuttle in January 1986 (the last flight before Challenger). A paper by Murthy, Henry, Feldman, and Tennyson will appear in the January 15, 1989 issue of the Astrophysical Journal, and results from an unsuccessful search of the data for evidence of line emission from the galactic halo. A second paper, describing the low levels of cosmic background that was found on all targets, is almost ready for publication. Henry reported these results to Commission 21 of the IAU at the recent Baltimore General Assembly. With Paresce and Kimble and other, Henry is preparing a proposal to NASA to build and launch HUBE, the "Hopkins Ultraviolet Background Explorer", a Scout-launched satellite to map the entire sky 1380-1800 Å with arcminute spatial resolution and to spectroscopically analyze large numbers of selected regions over the sky 1250-1800 Å with 5 Å spectral resolution. Henry's work on UV study of the local interstellar medium continues, with a paper on the line of sight to β Gem "in press" at Ap.J. and additional observations in hand, undergoing analysis with J. Murthy and J. Wofford. This work is cooperative with H. W. Moores, J. Linsky, A. Vidal-Nadjar, C. Gry. Also in the past year, Henry (with present and former graduate students, plus R. Wilson of UCL) has...
published an Atlas of the Ultraviolet Sky (Johns Hopkins University Press, Baltimore) which is formatted to be most useful in conjunction with IRAS images; Henry, with J. Murthy, R. Kimble, J. Wofford, M. Werner, and H. Walker, is conducting an IRAS investigation of the relationship between ultraviolet sources (stars) and cosmic IR cirrus.

Randy Kimble has continued his work as Deputy Project Scientist for the Hopkins Ultraviolet Telescope Project; his principal activity this year has been participation in the development of an improved prime focus spectrograph which will be installed on the telescope at Kennedy Space Center this fall.

Davidsen, Kimble, and Homewood Professor Allan Sandage have continued their spectrophotometric observations of elliptical galaxies in nearby clusters, using the Las Campanas Observatory's 2.5 m Du Pont telescope. Kimble has presented their results regarding the relationship between the strength of the 4000 Å break and other fundamental galaxy parameters to the AAS at the Austin meeting and also to the "Evolutionary Phenomena in Galaxies" workshop in Tenerife.

Kimble, Richard Henry, and student Jim Wofford, along with recent Hopkins graduate Jayant Murthy of GSFC and Mike Werner and Helen Walker of NASA Ames, have continued their investigation of the distribution of interstellar dust, using IRAS observations of infrared cirrus. Walker has presented their initial results regarding the patchy distribution of the cirrus-producing dust at the recent IAU Symposium No. 135 "Interstellar Dust."

G. A. Kriss is continuing studies of the dynamics of clusters of galaxies. In collaboration with E. Malumuth (ST ScI/GSC) and graduate students H. Ferguson and W. V. D. Dixon, he has obtained over 100 redshifts in the clusters A65, A496, A2052, D0774, and DC1842-63, all clusters with strong cooling flows. The selected clusters have bright X-ray emission with well-mapped surface brightness distributions available in the Einstein Observatory data bank and high energy spectra available from the HRAO A-2 experiment. Cooling flow models are being fit to the combined HRAO-1 and HRAO-2 X-ray data to obtain the density and temperature distribution of the hot gas and hence the cluster mass profile. In clusters with 100 to 200 known galaxy velocities, the orbit distribution of the galaxies can be ascertained using the linear programming technique of Tremaine and Richstone which the observed projected velocity dispersion profile of the cluster and the inferred mass distribution serve as constraints. The clusters A2052 and DC1842-63 have orbit distributions consistent with an isotropic distribution of galaxy velocities. Analysis is still in progress on the remainder.

In collaboration with M. Malkan (U.C.L.A.) and T. McNulty, Kriss is analyzing quasi-simultaneous X-ray and ultraviolet observations of the active galaxies Mrk 705, Ton 951, and Ton 1542. The EXOSAT X-ray spectra of these AGN span a wide range from the canonical 0.7 power law energy index for Mrk 705 to an extremely steep spectrum with an energy index of 1.51 ± 0.05 for Ton 1542. Accretion disk models fit to the optical and UV data require black hole masses of several x10^5 M☉ for each of these AGN. Working with E. Feigelson (Penn State U.), Kriss has identified 7 new potential X-ray selected pre-main-sequence stars in the Chamaeleon I dark cloud. Einstein Observatory IPC observations of three overlapping fields in the Chamaeleon cloud revealed 22 X-ray sources. Two thirds of these are identifiable with previously known PMS stars in the region, but the remainder have no cataloged counterpart. Spectra obtained with the CTIO 4m telescope show the newly discovered X-ray sources to be pre-main-sequence stars with only weak or absent Hα emission, similar to the "pre-main" T Tauri stars defined by F. Walter. The PMS stars in the Chamaeleon cloud show a strong correlation of X-ray luminosity with optical magnitude, but there is no significant relation between spectral type, IR or optical colors, or emission line fluxes with X-ray luminosity.

In the past year, Julian Krolik has split his time between active galactic nuclei and cosmology. Two subjects in the former area have attracted his attention: his on-going program studying the "intermediate zone" in active galactic nuclei, and the problem of measuring the size of the broad emission line region by observations of time variability. One project related to the "intermediate zone" was brought to completion in 1988: with Stephen Lepp (Harvard-Smithsonian Center for Astrophysics), he has shown that the molecular clouds comprising the obscuring torus have fractional ionization several orders of magnitude greater than found in normal molecular clouds, and temperatures ≳ 1000K, in contrast to the usual 10-100K. Because these clouds have such large column densities, even the rare isotopes of CO are optically thick in the the J = 1-0 rotational transition. Observations of these rare isotope lines should provide easy observational diagnostic of the tori which is not confused by molecular emission farther out in the galaxy.

In order to reliably measure the size of the broad emission line region by observations of time variability, he has collaborated with Richard Edelson (CASA, U. of Colorado) to develop a statistically unbiased method of analyzing unevenly sampled time series. With this method they have shown that emission line and continuum variability data which had been used to support claims that the broad emission line region in Seyfert galaxies is ten times smaller than previously thought in fact are entirely consistent with the standard size derived from photoionization models. The very large effort now being expended to monitor NGC 5548 with UUE was organized in direct response to Krolik's work on this subject. Because the problem of unevenly sampled time series is endemic to all of astronomy, they plan to apply this method to problems in a great many other subfields of astronomy in coming years.

Finally, Krolik made two contributions to cosmology in 1988. He has recalculated the rate at which the matter in the Universe recombined, having discovered several important physical mechanisms omitted in earlier work. The magnitude of the changes from earlier calculations depend on the combination of cosmological parameters Ω/Ωc/a; for currently popular numbers, the old calculations were fortuitously fairly good, but if the real baryon...
density is smaller than currently thought, recombination proceeded at a rather slower pace because of these new effects. This calculation has the potential for significant impact on our efforts to understand galaxy formation, for the expected amplitude of small-scale fluctuations in the microwave background depends significantly on the pace of recombination.

Secondly, with John Raymond (SAO), he has invented a new method by which XAAF measurements will be able to determine both H₂ and Q₁ through observations of quasars aligned behind clusters of galaxies. This method promises to be more accurate than any other way of measuring distances to galaxy clusters because it automatically provides for a number of independent internal cross-checks.

Knox Long is a Co-Investigator and the Project Scientist for the Hopkins Ultraviolet Telescope, now scheduled for launch on the Shuttle in 1990. Long continues to be active in the development of a design for an 8-m telescope at Las Campanas. He is a member of the science working group for that project and, in conjunction with it, is an Adjunct Associate of the Mt. Wilson and Las Campanas Observatories. While the Shuttle was inactive, he pursued his research interests in supernova remnants for the ground.

Long, in collaboration with W. P. Blair (JHU), R. P. Kirshner (Harvard) and P. F. Winkler (Middlebury), has completed an interference survey of the inner spiral arms of M33 using the FF/CCD on the Kitt Peak 4-m to significantly increase the sample of ≈20 SNRs known in that galaxy. Twenty new candidates have been identified on the basis of strong [SII] emission relative to Ha and no evidence of continuum emission. The imaging observations are being followed up spectroscopically at the MMT. Encouraged by this success, Long and Blair imaged the more distant Sculptor group spirals NGC300 and NGC7793 using Longi TiO and the CII/Hβ on the 2.5-m DuPont telescope at Las Campanas; spectroscopic observations using the new CCD-band Modular Spectrograph have been carried out. Although the analysis is still underway, there appear to be 15-25 confirmed remnants in each galaxy. Additionally, Long and Blair imaged M83, a galaxy with a rich history. A much smaller position of SN1957d, they discovered a point source bright in [OIII]λλ4959, 5007 which was weak in Ha, [SII] and the continuum. Long, Blair, and W. Krzeminski (Carnegie Institution) subsequently confirmed that the oxygen nebula was the remnant of supernova with the Modular Spectrograph; the velocity width of the [OIII] lines is ≈300 km s⁻¹.

Long and Blair are studying optical emission from selected galactic supernova remnants in the Southern Hemisphere using data obtained from the 1-m Swope and 2.5 DuPont telescopes. Data obtained of SN1006 was used by Long and Blair and S. van den Bergh (Dominion Astrophysical Observatory) to provide a more accurate measurement of SN1006−0.30 ± 0.04 arcsec per year -- than was available previously. The optical images of Kepler's SNR, along with spectra obtained by R. H. Becker (U. of California, Davis) and R. A. Fesen (U. of CO) demonstrates the existence of Balmer-dominated non-radiative filaments in the SNR which is the only young remnant of a type I SN, in which this type of emission had not been observed previously.

Long, Blair and Charles W. Bowers (JHU) have recently used the new cross-dispersed echelle spectrograph to simultaneously observe the density sensitive doublets of [OIII]λλ3727, 3729 and [SII]λλ6717, 6731 at several positions in six galactic supernova remnants (and a similar number of planetary nebulae). The data are being analyzed to determine the degree to which both line ratios indicate the same density in the recombining plasma which dominates emission from radiative shocks.

Steve Lubow has investigated a model for starbursts in which the burst is due to an increase in the wave amplitude of a star-gas density wave near a galactic center. For plausible galaxy models, the wave effects of the gas are stronger than those of the stars and become increasingly stronger towards the galactic center. This wave focusing effect is possible because the gas has a shorter characteristic wavelength than the stars. The spiral wavelength can then become shorter towards the center. This effect combined with simple geometrical wave convergence make wave focusing possible.

A dynamical model was constructed for gas flow over an accretion disk in a close binary star system. The gas stream in close binary stars can likely flow over the disk edge because the stream vertical thickness is greater than that of the disk. Stream matter passing over the disk was shown to strike down onto the disk at about binary phase 0.6, where the stream is at closest approach to the compact object. A simple model suggests that regions of strongest interaction between the stream and the disk occur at the disk edge and at the point of stream impact at phase 0.6. Observational support for this model comes from doppler tomography of dwarf nova Z Cha and RX085 observations of X-ray burster EXO 0748-676.

Graduate student Pawel Arteymovich and Steve Lubow are investigating nonlinear spiral waves using softened particle hydrodynamics (SPH). Tests of this scheme with known nonlinear solutions for gas response to spiral wave forcing reveal satisfactory agreement.

Steve Balbus (U Va.) and Steve Lubow have begun a study of possible stochasticity of spiral waves as a means to explain irregular spiral structure.

Warren Moos is using the IUE satellite to study the outer planets with G. Ballester, P. D. Feldman, T. Livengood, M. McGrath and D. Strobel. Studies continue on the neutral atmosphere of Io, the stability of the warm Io torus, the Jovian aurora and dayglow, and also emissions from Saturn and Uranus. Moos is the Principal Investigator for the NASA Phase A study of The LYMAN Far Ultraviolet Explorer astronomy satellite mission. Recent laboratory work is concerned with the development of pulse-counting intensified two-dimensional solid-state arrays for space astronomy.

Colin Norman in collaboration with Nick Kylafis continues work on their H₂O maser models which are now widely quoted and used. An experiment has been done by the Bonn group who have detected Zeeman splitting in H₂O and found fields weaker than they predicted but still large, as they thought. Kylafis and Norman have tried very hard to solve the SiO stellar maser
problem. This is a simple molecule but paradoxically it seems harder to make it a maser at the high luminosity end. One of Norman's more visible projects is starbursts. Papers with Nick Scoville will both appear in the September issue of the Ap. J. it was presented as an invited paper at the IAU meeting on Active Galaxies at Santa Cruz. Their ideas started from a consideration of the nature of the broad emission line regions of active galactic nuclei and quasars. Although the current model is very dubious. Their interpretation is that red giants illuminate from the outside by a central source which would have all the correct properties. This naturally lead to consideration of a dense central star cluster formed in a burst and furthermore its relation to the growth of a massive central black hole. The discovery of almost self-gravitating masses of gas, $10^9 M_\odot$ within 500 pc in ultra-luminous systems and the discovery of powerful point source quasars embedded in these sources seem to be quite consistent with their model.

Darrell F. Strobel continued his study of the upper atmosphere of Uranus with the aid of the Voyager Ultraviolet Spectrometer data. In collaboration with Yeager and L. Doose of the University of Arizona and Jack McKeon, at York University, the UV spectrum of Uranus in the 1250-1700 Å region was analyzed as primarily solar reflected light from an H2 Rayleigh and Raman scattering atmosphere with small but measurable absorption by hydrocarbons. The hydrocarbon abundances determined in our analysis depended on the total column of Uranus and were far below the abundances at comparable levels in the atmosphere of Jupiter or Saturn. Combining the results of the UVS occultation experiment with our analysis we inferred strong latitudinal gradients in the hydrocarbon abundances with substantial depletions of the subsonar, polar stratosphere, which cannot be understood in terms of a meridional circulation with upwelling at low latitudes and downwelling at polar latitudes.

In collaboration with Michael Summers of the Naval Research Laboratory, a one dimensional photochemical model with vertical transport and explicit treatment of condensation was used to study the abundance of chemically and physically processes that control the hydrocarbon abundances in the Uranian stratosphere. Condensation of diacetylene in the 0.2-4 mbar region is the major loss of carbon atoms from gas phase and the major source of the stratospheric haze observed by the Voyager Imaging Experiment.

Graduate student Mike Stevens and Darrell Strobel analyzed the thermal structure of the upper atmospheres of the giant planets to deduce the location and magnitude of the heat sources.

Each of the outer planets encountered by the Voyager spacecrafts has a neutral temperature at the top of its atmosphere substantially hotter than expected. Although the derived magnitudes of the integrated heating rate on these planets are comparable, Uranus is unique in that its heating occurs deeper in the thermosphere, approximately three orders of magnitude higher pressure than on Jupiter and Saturn.

Alan Uomoto is continuing his study of supernovae in Population I environments using the facilities of the Kitt Peak National Observatory. In collaboration with G. MacAlpine (U. Michigan), studies of the chemical abundances of the Crab Nebula using long slit spectroscopy and interference imaging have been made. He is also collaborating with A. Landolt (LSU) in the manufacture of faint UVBVI standard star sequences suitable for CCD calibrations, a project that promises to be useful to both ground based observers as well as the Hubble Space Telescope, which will use the stars for calibration of the WF/PC and FOC.

Harold A. Weaver is continuing his research on comets but there has been a significant expansion in the scope of his work. Recently, he has been focusing on the connection between comets and the pre-solar nebula and between comets and the interstellar medium. He is particularly interested in using observations of volatile abundances in comets to constrain their formation environments. An invited talk on this topic was given at the recent IAU meeting in Baltimore. He was also one of the principal organizers of an international workshop at the Space Telescope Science Institute this past spring entitled "The Formation and Evolution of Planetary Systems". As discussed at this meeting, comets are important probes of the physical and chemical state of the solar nebula during the protoplanetary period when the planets formed. He is now editing (along with F. Faires and L. Danly) a book scheduled for publication in early 1989 that will contain the reviews and discussions from the Institute's workshop.

Weaver and his collaborators (M. Mumma at GSFC, H. Larson at the University of Arizona, and S. Drapatz at MPI-Garching) have been busy analyzing their data on Comet Wilson (1986)1 taken in April, 1987 from the Kuiper Airborne Observatory (KAO). These observations produced a direct detection of methane in the comet (although S/N=3 on the measured feature) and the derived abundance is difficult to reconcile with either equilibrium or non-equilibrium models of solar nebula chemistry. The excitation of the water lines in Comet Wilson was virtually identical to what was previously observed in Comet Halley, except that the presence or absence of some "hot" band lines still defies explanation. Unlike Halley, Comet Wilson showed virtually no intrinsic temperature. Chemical and physical properties of the cometary spectra have been used to infer properties of the neutral gas outflow from the nucleus. It appears that the terminal velocity of the molecules in the coma of Wilson is significantly larger than what has been "traditionally" assumed. These and other results are reported in a recently accepted paper.

Ongoing work on the Wilson data includes analysis of a new coma emission feature near 2.7 microns whose source has not yet been identified. Plausible candidates are fluorescence from water molecules and thermal emission from hot hydrated mineral grains. Hopefully, the combination of high and low spectral resolution KAO data will answer this question shortly.

Weaver has been spending a significant fraction of his time trying to improve the planetary science capabilities of the Hubble Space Telescope (HST). Solar system targets present unique and complex problems for HST that were not solved prior to the launch and are more difficult to resolve. He will present new science results at the fall 1986. However, due to the concerted efforts of many people over the past
two years, the capabilities of the observatory have been significantly improved and the HST should now be an excellent tool for planetary scientists.

Rosemary Wyse continues to investigate the structure and evolution of galaxies, including our own Milky Way. Our Galaxy offers a unique opportunity for addressing fundamental problems in the areas of galaxy formation and evolution; Wyse, with G. Gilmore (Cambridge U.K.) has undertaken a long-term observational project to map the distribution function of Galactic spheroid stars. Their approach is to utilize new detector technology to obtain spectrally and photometric data for large samples of faint stars in situ down several optimally chosen lines-of-sight in the Milky Way. These data will allow them to develop detailed models of the present day distribution of chemical elements, three dimensional structure, and kinematics of the stellar component of our Galaxy, thus mapping the Galactic potential well. This information will greatly enhance our ability to discover the relative importance of such processes as dissipation, violent relaxation and interaction with other galaxies in the early evolution of a typical disk galaxy. The data acquisition phase of this project is almost complete and analysis techniques are being developed.

Wyse, with Silk (University of California, Berkeley) has focussed on the star formation rate in disk galaxies, extending the simple Schmidt-like law that Wyse had earlier found to provide a good fit to the local spiral hydrogen content of galaxies. Their model is by no means unique, but does have the advantage of simplicity, and passes all observational tests posed thus far (quite a few!). They are currently extending their models to include the earliest phases of galaxy formation.

Wyse, with Jaszczykiewicz (Warsaw) and Vittoria (Rome), has investigated the amount of large-scale power that is acceptable for the primordial power spectrum, given the results of all-sky surveys such as that provided by the IRAS satellite. They find that, contrary to some statements in the literature, cosmological models with substantial large-scale power are viable—and indeed, may be preferred.

I would like to thank Professor Richard Henry for co-ordinating the preparation of this report.

H. Warren Moos
Director

V. REFERENCES


Sections for Atomic Oxygen, 4, The (3p-3s'3p^3), (3p-2s2p' 3p^5), (3p-4d' 3p^5) Autoionizing Transitions (876Å, 792Å, and 776Å) and Five Members of the (3p-nd 3D^o) Rydberg Series (1027Å), J. Geophys. Res., 93, 289.


Weaver, H. A., Mumma, M. J., Larson, H. P., and


