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The following report covers the period from October 1998 through September 1999.

1. INTRODUCTION

The highlights of 1999 were the launch of the Far-Ultraviolet Spectroscopic Explorer (FUSE) and first light from the Sloan Digital Sky Survey (SDSS). Astronomers from JHU continue to play a major role in the broad collaboration guiding the SDSS. Work continues on the ACS (Advanced Camera for Surveys, for the Hubble Space Telescope). In addition, we continue to pursue a broad range of theoretical and ground-based astronomical projects.

As part of our educational and public outreach effort, we installed the new Morris W. Offit Telescope, a 20-inch reflector built by DFM Engineering, in the Maryland Space Grant Consortium Observatory on the roof of the Bloomberg Center for Physics & Astronomy. This telescope replaces the original 1991 instrument that was moved to Apache Point Observatory in New Mexico to provide photometric calibrations for the Sloan Digital Sky Survey.

2. PERSONNEL

CAS visitors were D. Bowen, S. Casertano, P. Chayer, J. Crocker, A. Dey, L. Dressel, B. Espey, A. Fullerton, J. Najita, M. Postman, P. Rosati, W. Sparks. Departed from CAS are R. Burg (to Goddard Space Flight Center), A. Connolly (to the University of Pittsburgh), B. Greeley (to Orbital Sciences Corporation), P. Knezek (to STScI), J. Murthy (tenured position at the Indian Institute of Astrophysics). Permanent staff are: S. Beckwith (Director, Space Telescope Science Institute), P. J. Dagdigian, A. F. Davidsen, J. P. Doring, P. D. Feldman, (Chair, Physics and Astronomy), H. C. Ford, K. Glazebrook (currently on leave of absence), T. M. Heckman, R. C. Henry (Director, Maryland Space Grant Consortium), B. R. Judd, C. W. Kim, J. H. Krolik, H. W. Moos, D. Neufeld, C. A. Norman, D. F. Strobel, A. Szalay, E. T. Vishniac (Director, CAS) and R. F. G. Wyse, Professors; R. Giacconi, Research Professor, S. Lubow, Assistant Research Professor, W. P. Blair, Associate Research Professor, K. Weaver (GSFC), Adjunct Assistant Professor, G. Kriss, Adjunct Associate Professor, Wm. G. Fastie, Adjunct Research Professor; R. F. Mushotzky (GSFC), Adjunct Professor, M. Finkenthal, Visiting Professor; STScI Scientists R. J. Allen, R. Brown, H. C. Ferguson, M. Hauser, G. A. Kriss, M. Livio, K. S. Long, P. Madau, M. McGrath, M. Postman; P. Stockman; Research Scientists L. Bianchi, S. Friedman, J. Kruk, S. McCandliss, W. Oegerle, Z. Tsvetanov, A. Uomoto, H. A. Weaver and W. Zheng; Associate Research Scientists B-G. Andersson, M. Dickenson, D. Golimowski, C. Gronwall, T. Henry, C. Holmes, B. Jain, M. E. Kaiser, P. Kunszt, A. Martel, G. Meurer, E. Murphy, K. Roth, D. Sahnou, K. Sembach, D. Stutman, A. Thakar and H. Tran; and Postdoc-

toral Fellows E. Agol, M. Carollo, R. Chandar, B. Chen, M. Houdashelt, C. Howk, M. Iovea, N. Levenson, T. Matsubara, M. May, E. Neilsen, K. Rauch, S. Ridgeway, R. Sankrit, R. Shelton, M. Sirianni, D. Strickland, G. Szokoly, P. Tozzi, J. Wiseman and B. Wolven.

3. THE FAR ULTRAVIOLET SPECTROSCOPIC EXPLORER

The largest project within the Center for Astrophysical Sciences is the Far Ultraviolet Spectroscopic Explorer (FUSE), an astronomy mission within the NASA Origins program. The FUSE satellite was successfully launched on a Delta II rocket from Cape Canaveral on June 24, 1999, at 11:44 EDT. Locally, over 400 people watched the launch live on NASA TV in Bloomberg's Shafier auditorium in an event hosted by the Department of Physics and Astronomy and the Maryland Space Grant Consortium, and emceed by FUSE astronomer and CAS research professor W. Blair. A large contingent was also present at the Cape for launch and related activities.

FUSE was developed by an international and multi-university team directed by JHU and is operated out of a control center in the Bloomberg Center on the Homewood campus. This is the most complex mission NASA has ever handed off to a university to develop and operate. FUSE has begun its mission to explore the Universe through high-resolution ($R = 24,000\text{-}30,000$) far ultraviolet (905-1190 Å) spectroscopy. FUSE has 10,000 times the sensitivity of the *Copernicus* satellite, which was flown in the mid-to-late 1970s.

The spectral window observed by FUSE permits the study of many astrophysically important atoms, ions, and molecules to investigate the nature and composition of the interstellar medium, the intergalactic medium, active galactic nuclei, quasars, massive hot stars, supernova remnants, planetary nebulae and the outer atmospheres of cool stars and planets. The highest priority goals of the FUSE science team include comprehensive studies of the abundance and distribution of deuterium in the disk and halo of the Milky Way and the distribution and kinematics of hot gas in the disk and halo of the Milky Way and other galaxies. In addition, more than half of the available observing time will be awarded by NASA to the general astronomical community over the nominal three-year mission.

JHU/CAS scientists participating in the FUSE mission are Principal Investigator H. W. Moos, T. Ake, B-G. Andersson, L. Bianchi, W. Blair, P. Chayer, A. Davidsen, P. Feldman, S. Friedman, A. Fullerton, M. Kaiser, J. Kruk, E. Murphy, W. Oegerle, D. Sahnou, K. Sembach, and H. Weaver. In addition, a contingent of about 20 engineering and technical staff at JHU participate in mission operations and support activities.

At this writing (late October), FUSE has begun science operations even as it continues in an extended checkout pe-

riod. NASA has selected 63 groups of guest investigators to participate along with the FUSE science team in the first year of science observations. Mission operations from the satellite control center have been working nominally, and the satellite is in good health. Over two dozen abstracts on early science results have been submitted for the Atlanta AAS meeting, and we look forward to an exciting first year of operations. Updated information on the progress of the mission can be obtained from the project's web site at <http://fuse.pha.jhu.edu>.

4. EARLY RESULTS FROM THE SLOAN DIGITAL SKY SURVEY

The five-band SDSS imaging test data yielded the highest redshift quasar known ($z=5.0$) as well as two methane dwarfs, one of which was discovered by JHU scientists Wei Zheng, Zlatan Tsvetanov and David Golimowski. These objects are so small that they never ignite the nuclear reactions that power ordinary stars and are cool brown dwarfs. Previously, only one such object had been known.

The two dual-channel fiber optic SDSS spectrographs obtained their first full-field observations using the SDSS 2.5 m telescope at the Apache Point Observatory in New Mexico. These instruments, designed and built at JHU, can observe 640 objects at once in a three degree diameter field covering the spectral range from 3900 to 9100 Angstroms. During the SDSS observing period we expect to obtain one million galaxy redshifts and 500,000 quasar spectra.

5. THE ADVANCED CAMERA FOR SURVEYS

The Advanced Camera for Surveys (ACS) will be installed in the Hubble Space Telescope during the third servicing mission, now scheduled for early to mid 2001. The ACS is being built by a collaboration between Ball Aerospace, the Johns Hopkins University, and the Goddard Space Flight Center. Members of the science team, led by the PI Holland Ford, are at JHU, the Space Telescope Science Institute, the University of Arizona, the University of California Santa Cruz, Leiden University, the European Southern Observatory, and the Goddard Space Flight Center. A list of science and engineering team members and information about the ACS can be found at <http://adcam.pha.jhu.edu>.

The ACS was shipped to Goddard in late 1998 for preliminary thermal vacuum testing. That testing revealed a secular motion of tens of pixels on all three cameras as the temperature of the enclosure changed. Extensive testing showed that the kinematical connections between the optical bench and the enclosure were not isolating the bench from external loads. The instrument was returned to Ball Aerospace in mid-1999 in order to isolate the problem. After complete disassembly, the problem appears to be a mechanical interference between the front bulkhead and bench. After the interference has been removed, the instrument will be reassembled, realigned, and retested.

The Wide Field Camera (WFC) is approximately half way through assembly. The two 2K x 4K CCDs chosen for this build have high QE, low read noise, good cosmetics, and good charge transfer efficiency. The tests at Goddard showed that we would not meet our specifications for scattered light

within the WFC and within the High Resolution Camera (HRC). To bring the cameras within their specifications, a black multi-layer coating with 1% to 2% reflectivity in the optical, and low emissivity in the thermal infrared, has been put on the inside of both cameras.

The ACS will be shipped to Goddard in mid 2000 for final vacuum testing and calibration. We expect the ACS to meet *al.l* of its demanding performance specifications.

6. RESEARCH AND ACTIVITIES

Eric Agol studies active galaxies (especially quasars), accretion disks and gravitational lensing. In the last year, Agol has worked with **Julian Krolik** on a possible mechanism for how bright accretion disks shine, involving radiation damping of magnetically driven turbulence which is important when radiation pressure equals or exceeds gas or magnetic pressure. One way to directly image an accretion disk in a quasar is using microlensing, which amplifies different parts of the quasar as a function of time. Agol and Krolik have simulated a caustic crossing a quasar and shown that the lightcurve can be deconvolved, revealing the spectrum as a function of radius and constraining the inclination of the disk, mass of the black hole, and possibly the black hole spin. The efficiency of accretion disks may be dramatically altered by magnetic stresses at the inner edge of the disk, an idea mentioned in the literature in the 70's but only recently explored quantitatively by Julian Krolik and Charles Gammie. Agol and Krolik have computed the observational consequences for black hole accretion disks which have a strong torque (presumably due to magnetic forces) at the inner edge. The disk becomes much brighter in the inner regions where relativistic effects are important, causing much of the radiation to return to the accretion disk and causing the torque on the black hole to be modified. The returning radiation can alter line profiles, lead to phased variability and possibly lead to rises in polarization at higher frequencies. Agol has also carried out radiation hydrodynamic simulations of the structure of accretion disks (with Krolik, in preparation); simulated images of optically thin accretion flows (with Heino Falcke and Fulvio Melia, submitted to ApJ); computed the global spectra of standard accretion disks with parameters appropriate for active galaxies (with Ivan Hubeny, Omer Blaes, and Julian Krolik, submitted to ApJ); and observed the Einstein Cross quasar in the mid-infrared (with Barbara Jones and Omer Blaes, in preparation).

Steven Beckwith, Michael Meyer, Antonella Natta and Massimo Robberto used ISO to search for thermal emission from circumstellar disks around stars between the ages of 106 and 108 years, the period during which planet-building is thought to occur. By the end of ISO operations, the observations were complete. The data have been analyzed with several different versions of the PIA reduction software. Early versions of this software produced results that were inconsistent with extant data on some of the objects (mainly from IRAS); in some cases, they were internally inconsistent. Calibration of the ISOPHOT data against ground-based observations (see next topic) suggests that ISO can deliver

good quality results. A paper is currently in preparation describing the results.

Beckwith, Meyer, Natta and Robberto also obtained observations of 16 stars in Chameleon to give spectral energy distributions from 3 to 200_m , including continuous spectra (PHOT-S) from 3 to 13_m for the first time. The scientific goal is to distinguish among the various geometrical models for circumstellar disks around these stars - for example, flared vs. flat disks. The spectra demonstrate that 10_m silicate emission features from optically thin dust are commonly seen in these disks, so it is almost certain that the disks are heated externally, probably by the central objects. It has been difficult to calibrate the data accurately enough to realize the scientific goals. There are inconsistencies with IRAS data on some of these stars as well as some internal inconsistencies in the ISO calibration. To check the calibration, the team got ground-based data at 10_m on 6 of the stars and discovered that the ISO results match well, whereas the IRAS data are often inconsistent with the ground-based observations. Some stars are variable. The PIA data reduction program has undergone substantial changes to cure the internal inconsistencies in the data, so all data were re-reduced this year with the "final" version of PIA to ready the data for publication. A paper was submitted in August 1999.

Steven Beckwith, Thomas Herbst, Michael Meyer and Massimo Robberto used the MAX thermal infrared camera to detect disks around young stars at unprecedented sensitivity at 10_m . During 1997 and 1998, the team observed and detected essentially all of the disks in the Trapezium core that were discovered with HST - both the ionized and dark disks. Owing to the strong background emission from the nebula, background subtraction is difficult. By varying the spacing used for background subtraction, it is possible to eliminate most of the extended emission to get photometry on the unresolved disks. The results were presented at a meeting in Japan in June, 1999, and a paper should be submitted for publication late this year.

Steven Beckwith, David Thompson and Filippo Manucci continued their search for young, emission line galaxies at high redshift using narrow-band interference filters to look for emission-line objects (MAGIC and Omega Prime cameras on the Calar Alto 3.5m telescope and the CGS4 spectrometer on UKIRT and NIRSPEC on Keck for spectroscopic followup). More than a dozen new emission line galaxies have emerged from this work, most of which are irregular, spiral galaxies at redshifts 1 or greater. A paper describing the results of this second survey was submitted last year and they are now using the Hubble Space Telescope to observe the additional candidates. It appears that damped Ly absorption systems pinpoint regions of vigorous star formation and will lead to a revision of the search strategies for young galaxies at high redshift.

David Thompson, Steven Beckwith and several collaborators have found many extremely red galaxies (EROs for Extremely Red Objects) in the fields of the Calar Alto Deep Imaging Survey (CADIS). These objects have R-K colors exceeding 6 magnitudes. All of these objects are seen in the K band but not the R band; most are a few seconds of arc in extent, indicating galaxies at redshifts greater than about 0.2.

Objects of this type have been seen in early surveys, but only a few were known. The one CADIS field completely reduced revealed 20 EROs. A paper describing EROs was accepted for publication in June 1999. A second finding is that there are more quasars at high redshift discovered using the multi-filter CADIS technique than have previously been discovered with more traditional methods. Two papers describing these results have been submitted and a more extensive paper will be submitted making use of better statistics on the quasars as the survey observations are finished next year.

Thomas Herbst, David Thompson and Steven Beckwith searched for dark matter in galaxies that might be in the form of underluminous stars such as brown dwarfs. Evidence for luminous matter was reported by Sackett *et al.* (1994, Nature), who looked at the edge-on Sc galaxy NGC 5907 for faint R-band light, and subsequently by Rudy *et al.* (1997, Nature), who observed near infrared emission at K. They reported the detection of excesses in the halo well above and below the disk plane. The group led by Herbst observed several edge-on spirals, including NGC 5907, with the MAGIC and Omega Prime cameras, reaching limits of 26th and 25th mag/sq. arcsec in J and K bands, respectively, and do not see the emission claimed by Rudy *et al.* The group believes the initially reported results are in error. The intensity profiles above and below the disk plane are inconsistent with a luminous component of the dark matter needed to produce the observed rotation curves. This work is currently being prepared for publication in 2000.

Luciana Bianchi is co-Investigator of the NASA SMEX mission GALEX (The Galaxy Evolution Explorer), and is leading the GALEX science data archive development (Bianchi *et al.* 1999a, b, c, d; Martin *et al.* 1999). GALEX entered phase C/D, and is planned to be launched in 2001 to perform imaging and spectroscopic imaging and spectroscopic surveys of the sky in the Ultraviolet in a 28 month mission. Bianchi also continued her study of hot massive stars in Local Group galaxies based on HST and ground based data with analysis of young massive star populations in NGC6822 (Bianchi & Scuderi 1999; Hutchings, Bianchi & Cavanagh 1998; Hutchings, Cavanagh & Bianchi 1999). Bianchi continues to serve in the Organization Committee of IAU of Comm. 42.

William P. Blair is the Chief of Mission Planning for the Far Ultraviolet Spectroscopic Explorer (FUSE) Project at JHU, in charge of continuing development and operation of the mission planning segment of the ground operations system. While these duties have taken the bulk of his time, Blair has continued his independent research projects on supernova remnants, cataclysmic variables and related topics using data from the Hopkins Ultraviolet Telescope (HUT), the Hubble Space Telescope (HST) and ground-based optical observatories.

Work with HST has concentrated in two areas. With postdoc R. Sankrit (JHU), K. S. Long (STScI), and J. C. Raymond (SAO), HST/WFPC2 data on a nonradiative shock in the northeastern Cygnus Loop have been analyzed. The faint filament at the very edge of the X-ray emission represents the primary blast wave as it first encounters the interstellar medium. At HST resolution, the faint ribbon of light can be

seen in exquisite detail as the sheet of gas gently rolls along our line of sight. When edge-on, the filament reduces to less than one WFC pixel across, confirming predictions for the sharpness of the shock transition. By comparing the filament position with respect to stars in the field against ground-based data taken 45 years earlier, a more accurate proper motion has been derived. In conjunction with shock velocity information for the filament (constrained by other data), a revised distance estimate of 440 pc has been derived to the Cygnus Loop. This is some 40% closer than the canonical 770 pc distance used by most researchers in the field, and has important ramifications for studies of this prototypical galactic supernova remnant.

The other HST project this year, which is in press in the *Astronomical Journal*, involves an HST/WFPC2 study of an ultraluminous supernova remnant in the spiral galaxy NGC 6946. This work, in conjunction with R. A. Fesen (Dartmouth) and E. M. Schlegel (SAO), uses HST to resolve the bright nebular emission into an interlocking set of loops and rings of emission with associated stars in and near the nebula. The interpretation, based largely on the observed morphology, involves possible multiple SN explosions in close temporal proximity, with the possibility that the object represents a nascent superbubble. In any event, shock heating and dense circumnebular environment are definitely involved in creating the huge luminosity of the nebula.

On another front, Blair oversaw the completion of thesis work by JHU student Bradford Greeley (in conjunction with K. Long, STScI). A published work arising from Greeley's thesis (including J. C. Raymond) involved detailed analysis and modelling of the HUT FUV spectra of the polar AM Herculis. Time-resolved FUV spectroscopy over a large fraction of binary orbital phase has allowed an unprecedented look at the variability of emission lines and continuum shape. These variations have been carefully modeled considering geometrical effects and X-ray heating of the face of the companion star. We concluded that the inclination of the binary must be $> 45^\circ$ (as opposed to the accepted value near 35°). Also, in addition to changes with orbital phase, the observed flux is seen to vary by up to 50% over timescales of 10s of seconds. The modeling implicates a hot spot near the foot of the accretion column (and rapid reprocessing of this emission on the face of the companion star) as the sources of these emission flares.

Important duties on the FUSE project have included development and testing work of the mission planning system, and support of launch, in-orbit checkout, and science verification of the satellite. In addition, Blair maintains the public Web site for the project (see <http://fuse.pha.jhu.edu>) and participates in various education and outreach activities, including duties as Press Liaison officer.

Rupali Chandar defended her thesis (Title: "Star Clusters in M33 and NGC 6822," Advisors: Dr. Luciana Bianchi, Prof. Holland Ford, Committee: Dr. Brad Whitmore (STScI), Dr. Carol Christian (STScI), Dr. Daniela Calzetti (STScI)) on July 30, 1999. 132 star clusters in M33 from multiband HST WFPC2 images were discovered; 103 were previously unknown. M33 clusters formed continuously from $\sim 10^6 - 10^{10}$ years, and have masses $\sim 4 \times 10^2 M_\odot$

$- 3 \times 10^5 M_\odot$. Surface brightness profiles show that these clusters are more compact on average than Galactic and Magellanic Cloud clusters. The first candidate core collapse cluster in M33 was discovered. (Chandar, Bianchi, & Ford 1999a,b). Radial velocity measurements for 113 clusters from follow up ground based (WIYN) spectra revealed that velocity dispersion increases with age. Young M33 clusters rotate with the HI disk. The old cluster population instead exhibits a bimodal velocity dispersion distribution, correlated with cluster position in M33. This is suggestive of distinct disk/halo subpopulations of globular clusters as found in the Milky Way. Additionally, halo candidates have a large age spread ($\sim 10 - 15$ Gyrs) indicating that either 1) the M33 halo formed over timescales $\sim 2 - 3$ times longer than the Milky Way spheroid, or 2) some halo clusters may have been accreted.

Chandar, Bianchi and Ford have extended the photometric and spectroscopic cluster study to the dwarf irregular galaxy NGC 6822. Multiband HST WFPC2 photometry revealed three new clusters. Age and mass estimates for a handful of clusters indicate that NGC 6822 has (leisurely) formed massive ($10^4 M_\odot - 10^6 M_\odot$) compact star clusters over its lifetime, similar to the population in M33. The metallicity of two clusters (from integrated CTIO spectra) is lower both the LMC and SMC values, in conflict with previous work which suggested that NGC6822's metallicity is intermediate between the LMC's and SMC's.

Paul D. Feldman currently serves as Chair of the Department of Physics and Astronomy. He directs the NASA supported sounding rocket program, which has as its main focus the development of new instrumentation for far- and extreme-ultraviolet astronomy. He has continued his collaboration with H. A. Weaver (JHU) in a program of HST/STIS observations of comets Hartley 2 and Lee. He collaborated with H. W. Moos and D. F. Strobel (JHU) in HST/STIS observing programs of Io and Ganymede, and with A. Vidal-Madjar (IAP) and colleagues in HST studies of CO and atomic carbon in the gaseous disk surrounding β Pictoris. He is a member of the science teams for the Far Ultraviolet Spectroscopic Explorer (FUSE), the Advanced Camera for HST, the Alice ultraviolet spectrometer experiment for Rosetta and the Comet Nucleus Tour mission.

Scott D. Friedman is the Hopkins project scientist for the Far Ultraviolet Spectroscopic Explorer (FUSE) mission, which was launched June 24, 1999. FUSE will make observations in the critical 910–1195Å region at a spectral resolving power of approximately 25,000. FUSE will address problems such as the abundance of primordial light elements, including the deuterium/hydrogen ratio and the distribution of intergalactic helium, the composition and dynamics of galaxies, and the origin and evolution of stars and stellar systems. Friedman's interests include studies of the interstellar medium, Big Bang nucleosynthesis and astronomical instrumentation.

David Golimowski is an associate research scientist who splits his time between searching for and studying substellar objects and evaluating CCDs for the Advanced Camera for Surveys (ACS) program. His searches for substellar objects, as companions to nearby stars or as isolated members of the

solar neighborhood, are both ground- and space-based. With collaborators Ben Oppenheimer (UC Berkeley) and Shri Kulkarni (Caltech), Golimowski has recently completed an extensive survey of nearby and approximately 1 Gyr-old stars using JHU's Adaptive Optics Coronagraph and Palomar Observatory's 60-inch telescope. This survey led to the identification of several very low mass companions to stars, including the first unambiguous brown dwarf, Gliese 229B, in 1995.

Golimowski and Daniel Schroeder (Beloit College) have completed a direct imaging survey of 23 of the nearest stars using HST's WFPC2. Although no new faint companions were found in this sample of stars, Golimowski and Schroeder established very sensitive limits on the presence of stellar and substellar companions to stars within 5 parsecs of the Sun. Their observations of several multiple star systems exposed several inaccuracies in their current astrometric orbits. Their observations of the Procyon system appear to reconcile the longstanding discrepancy between Procyon's luminosity and its dynamically computed mass.

With collaborator Todd Henry (JHU), Golimowski is analyzing images of 118 stars within 10 pc obtained with HST's NICMOS Camera 2. No substellar companions have yet been found, but the analysis remains preliminary. One new stellar companion (Gliese 54B) was discovered, however. This discovery was announced at the NStars Conference held at NASA/Ames in June 1999.

Golimowski and Henry have joined forces with JHU quasar hunters Zlatan Tsvetanov and Wei Zheng to seek substellar objects (brown dwarfs) in imaging data from the Sloan Digital Sky Survey (SDSS). Coincidentally, both cool brown dwarfs and high-redshift quasars appear pointlike and extremely red in SDSS images. To distinguish these objects, spectroscopy and/or broadband infrared photometry are needed. The search for high-redshift quasars in SDSS data by Princeton and JHU astronomers led to the first two discoveries of isolated, Gliese 229B-like, methane brown dwarfs in April and May of 1999. These discoveries were announced to the press at the Centennial Meeting of the American Astronomical Society in June 1999.

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

Timothy M. Heckman conducts research on starburst and active galaxies and serves as the Chair of the Board of Governors of the Astrophysical Research Consortium, which manages the 3.5-meter telescope and the Sloan Digital Sky Survey at the Apache Point Observatory. He is also a member of the science team for the Galaxy Evolution Explorer (GALEX) mission (PI, C.D. Martin, Caltech).

Heckman, with D. Strickland (JHU), K. Weaver (GSFC/JHU), C.L. Martin (Caltech) and M. Lehnert (MPIE, Garching) has continued a long-term program to elucidate the

physics of starburst-driven galactic winds ("superwinds") and thereby ascertain their role in the evolution of galaxies and the inter-galactic medium. Recent work has focussed on the analysis of ROSAT and ASCA X-ray data for well-defined samples of the nearest and brightest starbursts and spectroscopy of the interstellar absorption-lines using both ground-based telescopes and HST. The two approaches are complementary: the X-ray data probe the hot gas that contains the majority of the energy in the superwind, while the absorption-lines yield unique diagnostics of the dynamics and energetics of cooler material entrained into the hot outflow. Both types of data show that superwinds are ubiquitous in local starbursts and that starbursts are ejecting metal-enriched material at a rate similar to the star-formation rate and at a velocity sufficient in principle to leave low-mass (but not high-mass) galaxies. The absorption-line data strongly suggest that dust is also being carried out in the flow. These results quantitatively support models in which powerful galactic winds driven by the starbursts associated with the formation of bulges and elliptical galaxies have chemically-enriched and heated the intra-cluster and intergalactic media.

Heckman, with G. Meurer (JHU), C. Leitherer (STScI), D. Calzetti (STScI) and C. Tremonti (JHU) is conducting several complementary programs designed to document the UV properties of local starbursts. The overall goals are to understand the roles played by dust, metallicity, "host" galaxy mass, etc. in determining the UV properties of local starbursts and to use these results to make inferences about actively-star-forming galaxies at high-redshift. Results to date suggest that typical UV-selected galaxies at high-z suffer 2 to 3 magnitudes of extinction, have metallicities from 0.1 solar to solar, and may represent less extreme (lower metallicity, lower mass, lower luminosity) versions of the high-z sources selected by sub-mm surveys. The lessons learned for local starbursts will ultimately be exploited to interpret the data obtained with GALEX.

Heckman, with R. Gonzalez-Delgado (Instituto de Astrofisica de Andalucia) and C. Leitherer (STScI) is engaged in a systematic spectroscopic survey of the brightest Type 2 Seyfert nuclei. Near-UV spectra directly demonstrate that an unusually hot (young) stellar population is present in roughly half of these nuclei and *may* be present at a low level in the others. In the best-studied cases, these young stars are located in a compact (radius of 10^2 pc) dusty starburst that provides a significant fraction of the bolometric luminosity of the galaxy.

Heckman, with S. Ridgway (JHU), M. Lehnert (MPIE), and D. Calzetti (STScI) has obtained and analysed HST NICMOS near-IR images of 5 high-redshift ($z \sim 2$) radio-quiet quasars. An underlying "host" galaxy is detected in 4 of the 5 cases. These galaxies are surprisingly small and faint compared to radio galaxies at similar redshifts and to the hosts of similarly-powerful quasars at lower redshifts. Perhaps these galaxies are not fully assembled at the redshifts probed.

Richard C. Henry conducts research on the interstellar medium, cosmology, and ultraviolet background radiation. Henry is principal investigator for HUBE, the Hopkins UI-

traviolet Background Explorer, which in the first MIDEX round was selected by NASA as an ‘‘Alternate’’ Mission. A disappointment of 1999 was NASA’s failure to select HUBE (re-named ‘‘Hot Universe Background Explorer’’) in the second MIDEX round. Preparation has already begun on re-proposal of HUBE as a SMEX, this time as a mission that is more tightly focused on the spectroscopic analysis of the diffuse ultraviolet and soft X-ray background radiation (in cooperation with Ball Aerospace and David Burrows of the Pennsylvania State University.)

With Murthy, Henry continues work on the *Voyager* body of observations of the cosmic ultraviolet background radiation. They continue to find many locations where the cosmic background is $< 100 \text{ photons cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1} \text{ \AA}^{-1}$. A paper on the analysis of seventeen years of *Voyager* is in press at the *Astrophysical Journal*. Also, in 1999 Henry published (in *ApJ Letters*) a broad review of background radiation at all wavelengths: new results are available in the ultraviolet, visible, infrared, microwave, and gamma ray spectral regions.

Henry was a member of the Scientific Organizing Committee, ‘‘Small Missions for Energetic Astrophysics,’’ J. Robert Oppenheimer Study Center, Los Alamos, February, 1999 where he presented papers on ‘‘The Interstellar Medium,’’ and ‘‘The Intergalactic Medium.’’

Henry continues as Director of Maryland Space Grant Consortium, a NASA program for career advancement of females and underrepresented minorities, education, and public outreach. In this connection, in 1999 Henry was appointed to the Advisory Board, Maryland Mathematics, Engineering, Science Achievement (MESA). Henry also continues as Chair of the National Council of Space Grant Directors (until June 2000) and was a member of the Maryland State Department of Education Review Team for Science, K-12.

Todd J. Henry joined the JHU research staff in September 1999, having arrived from the Harvard-Smithsonian Center for Astrophysics. Current research involves various aspects of stellar astronomy, with effort concentrated on studies of the nearest stars and brown dwarfs, and focused research on determining the masses of objects in multiple systems.

Henry is the Deputy Project Scientist for the NASA Project known as NStars (for Nearby Stars). This position is a consequence of his long term interest in nearby stars as the Director of RECONS (Research Consortium on Nearby Stars). For NStars, he is building the definitive list of all stars within 20 parsecs of the Sun, and providing details about their environments (stellar companions, brown dwarfs, extrasolar planets, dust). Research projects on these neighbors of the Sun include discovering the faint members that are currently missing from the lists of known members (including data from the Sloan Digital Sky Survey) and characterizing each member via the collection of astrometric, photometric, spectroscopic, and multiplicity data. As a group, including several undergraduate students and in collaboration with D. Golimowski (JHU), Henry is effectively providing a map of the nearest stars and being ‘‘geographers’’ of nearby space. Henry will be collecting and publishing data for all stellar systems within 10 parsecs of the Sun (the RECONS sample,

containing 315 objects in 228 systems) in a ‘‘CENSUS 2000’’ paper as an effort to provide a benchmark of the development of the Galactic population for years to come.

With G. Torres (Harvard-Smithsonian CfA), O. Franz (Lowell Observatory) and G. F. Benedict (U. Texas), Henry is also working to define the mass-luminosity relation for all kinds of stars. This work involves ground-based infrared speckle imaging and radial velocity observations as well as imaging and interferometry using the Hubble Space Telescope. By combining such powerful techniques, we can determine masses to better than 5% in many cases and investigate the realm of the lowest mass stars and brown dwarfs.

Mary Elizabeth Kaiser is a co-investigator with the Space Telescope Imaging Spectrograph (STIS) Investigation Definition Team (IDT). Kaiser and collaborators have been pursuing research activities on the kinematics and ionization structure of Seyfert galaxies, the dynamics and kinematics of the near-nuclear regions of normal galaxies, optical jet structure in 3C radio sources, and starburst activity in galaxies.

Kaiser and collaborators Hutchings (DAO), Bradley (JHU), Crenshaw (CUA), Gull (GSFC), Kraemer (CUA), Nelson (UNLV), Ruiz (CUA) and Weistrop (UNLV) have kinematically mapped the full NLR of NGC4151 using medium resolution STIS slitless spectroscopy of the emission line regions. These data reveal a population of high velocity dispersion clouds whose kinematic structure is not the result of interactions with the near-nuclear radio jet in this Seyfert galaxy. Combining the slitless and long-slit data suggests that a wind driven outflow is responsible for the observed kinematic structure. Photoionization modelling is consistent with outflow and provides no evidence for interaction of the NLR clouds with the radio jet.

High spatial resolution observations of M51 with STIS in the visible (collaborators: Bradley (JHU) and Crenshaw (CUA)) and the VLA at 3.6 cm (collaborators: Baan (NFRA) and Bradley (JHU)) have been obtained to determine the near-nuclear kinematic and ionization structure for this Seyfert galaxy.

A small sample of elliptical galaxies, postulated to harbour a central massive black hole, is being imaged with WFPC2 to search for the presence of nuclear gas disks (collaborators: Bower (NOAO) and Green (NOAO)). STIS long slit spectroscopy will be obtained to search for the kinematic signature of the black hole in suitable candidates.

Gerard A. Kriss is an Adjunct Associate Professor in the Department of Physics and Astronomy and an Associate Astronomer at the Space Telescope Science Institute where he is the Spectrographs Group Lead in the Science Support Division.

In collaboration with Dr. Zlatan Tsvetanov (JHU) and graduate student Randal Telfer (JHU), he is studying indicators of the orientation and geometry of broad absorption line QSOs (BALQSOs). HST and HUT observations of the QSO SBS1542+541 reveal broad absorption lines that are only apparent in the most highly ionized atomic species, e.g. Ne VIII, Mg X, Si XI. The broad lines only partially cover the continuum source and there is a correlation between covered fraction and ionization state, with the most highly ionized species covering more of the continuum source. This sug-

gests either a model in which a highly stratified wind, with low ionization gas at its base and more highly ionized gas at larger radii, is viewed by the observer at high inclination, or one in which small, high density, low ionization clumps are embedded in a larger, more tenuous wind.

In an HST snapshot program, Kriss, Tsvetanov and Telfer obtained narrow-band images of BALQSOs using NICMOS in an attempt to detect extended emission line regions. These are to be expected if BALQSOs have geometries similar to Seyfert 2 galaxies in which the obscuring BAL material lies in an equatorial plane and we view it at high inclination (as suggested by spectropolarimetry). Thus, by analogy to Seyfert 2s like NGC 1068, one should see extended “ionization cones” in BALQSOs. None were detected in observations of a sample of a dozen objects, however. This suggests that either little surrounding material is present to be illuminated by the central continuum source, or that the geometry of BALQSOs is even more complex than we think.

Kriss, in collaboration with Richard Green (NOAO) and other members of the FUSE team, Wei Zheng (JHU), Anuradha Koratkar (STScI) and Michael Brotherton (NOAO) is performing a comprehensive survey of the far-ultraviolet through optical spectral energy distribution of the 100 UV-brightest AGN on the sky. FUSE spectra of the sample will cover the 912-1150 Å wavelength region. Contemporaneous HST/STIS spectra in a snapshot program will obtain G140L and G230L spectra covering the longer UV wavelengths from 1150–3200 Å. Ground-based spectra obtained at KPNO and at APO will provide coverage from the atmospheric limit to ~ 1 micron. The full data set on each object will span the continuum across the peak of the “blue bump.” The group will also measure emission lines, absorption lines, and line profiles over a wide range of ionization states, providing a comprehensive data set for understanding the central engine and its environs in the lowest redshift AGN ($z < 0.3$).

Nancy A. Levenson studies Seyfert/starburst composite galaxies, supernova remnants, and the interstellar medium, emphasizing observations at X-ray and near-infrared energies.

Levenson was part of the commissioning team for NIRSPEC, a new near-infrared spectrograph on the Keck II telescope. She created data reduction software for the instrument and is analyzing data from the photodissociation region and starforming galaxy science verification targets.

With Danforth and Blair, Levenson is investigating the shocks of the Cygnus Loop supernova remnant using multi-wavelength observations.

Knox S. Long is an adjunct professor at JHU and an astronomer at STScI. Dr. Long pursues research topics in the ultraviolet characteristics of cataclysmic variables, supernova remnants and the properties of the interstellar medium in nearby galaxies. He is an active investigator with Hubble Space Telescope and is looking forward this year to making his first use of FUSE and AXAF. His instrumentation interests are evolving toward IR wavelengths as a result of his involvement in NGST.

Long and Gilliland (STScI) have completed an analysis of a set of HST/GHRS spectra in U Gem in quiescence, spectra

which are dominated by emission from the white dwarf. The observations permit very accurate determination of the orbital parameters of the U Gem system as well as a direct measurement of the surface gravity. An abundance analysis shows evidence of CNO processing of material now on the surface of the WD.

Long and Knigge (Columbia U.) have continued to develop a Monte Carlo spectral synthesis program which models the spectra of high state cataclysmic variables in the far and extreme ultraviolet. Beginning with a kinematic description of the wind, the ionization state of the wind is then determined, followed by a synthesis of the spectrum. In an initial application of the program, Long and Knigge were able to create spectra which mimic the observed spectrum of U Gem in outburst with EUVE, which supports the hypothesis that most of the features in this spectrum are created by scattering in the wind.

Long, Greeley (JHU), Blair (JHU) and Raymond (SAO) have completed the analysis of HUT spectra of the polar AM Her. The spectra are not well-modelled in terms of simple WD atmospheres, presumably because of the effect of radiation from the accretion column on the photosphere and/or the contribution of the accretion column to the continuum. Large (50%) variations in the flux on time scales of 10 s were observed, which poses significant challenges for models of the accretion flow in which blobs are thermalized well below the WD photosphere.

Long, Dubus (Amsterdam) and Charles (Oxford) have completed the analysis of HST imaging of the nucleus of M33 in an attempt to identify the counterpart to the brightest X-ray source in the Local Group. The observations show that the nucleus is bluer than expected from the A-F spectrum seen in the visible. More than half of the UV luminosity arises from the inner 0.1“ of the nucleus. However, a identification of the X-ray source requires HST spectroscopy. These observations are scheduled for late 1999.

Long and Winkler(Middlebury) have continued their work on SN1006, using optical spectroscopy to identify 5 additional objects (4 stars and 1 quasar) which lie behind the SNR. HST UV spectroscopy is now scheduled to use these objects as probes of unshocked material in the ejecta of SN1006.

Stephan R. McCandliss’ primary work involves the preparation and calibration of FUV sounding rockets with unique optical designs that utilize state-of-the-art instrumentation for making unique astronomical observations. During his most recent flight, launched from White Sands Missile Range on NASA Sounding Rocket 36.136 UG on 14 June 1999, he and his team successfully made 912 – 1400 Å spectroscopic observations of the central star and surrounding nebular emissions of M27 (the Dumbbell) a planetary nebula in the constellation of Vulpecula. Nebular emission lines from C II, C III, He II have been positively identified. The team is currently engaged in the identification of other emission lines and determining the absolute fluxes of the lines and the central star in the post-flight calibration phase of the mission. Work continues with his design of a high dynamic range dual order spectrograph. This spectrograph will double the effective area normally realized in a

low scattered light Rowland circle design by using both \pm orders of a holographically ruled concaved grating. It achieves high dynamic range through the use of a MCP detector in one order and a UV sensitive CCD in the other. This work is being carried out with Eric Burgh and Paul Feldman.

McCandliss continues to work on characterizing the output of his vacuum FUV pinhole lamps. Along with Brian Espey and co-investigators he was recently granted guest investigator time on FUSE to study FUV absorption lines created by cool star atmospheres that eclipse hot white dwarf companions in symbiotic binary systems. He has also recently acquired, at Apache Point Observatory (APO), echelle spectra of several symbiotic systems along M and K giant standards which will be useful for comparison with abundances obtained from the FUSE observations. With Kurt Rutherford and co-investigators he recently used the APO echelle to observe the Jovian moon Europa in eclipse. Emissions of Na, K and S were detected.

Gerhardt Meurer is an associate research scientist working for the Advanced Camera for Surveys team. His primary functional responsibility is pre-flight calibration and testing of ACS. Meurer wrote the calibration plan for ACS during its first thermal vacuum test which took place in February and March 1999. Meurer and (computer programmer) J. McCann are expanding the ACS calibration web pages (<http://adcam.pha.jhu.edu/cal/>) which will have links to all pre-flight calibration documentation.

G. Meurer's research concerns various aspects of galaxy evolution. Meurer, Heckman and D. Calzetti (STScI) refined a technique for measuring the ultraviolet (UV) dust absorption of starburst systems from their UV color alone. The relationship is based on the observed reddening correlated redistribution of UV radiation to the far infrared in local starburst galaxies. Applying this calibration to Lyman break systems (U-dropouts) they estimate that dust absorbs about 80% of the UV light at 1600\AA in these systems. Corrected for dust absorption the cosmological star formation density is $0.18 \mathcal{M}_{\odot} \text{ yr}^{-1} \text{ Mpc}^{-3}$ at $z = 3$ ($H_0 = 50 \text{ km s}^{-1} \text{ Mpc}^{-1}$, $q_0 = 0.5$).

Meurer, L. Staveley-Smith and N. Killeen (Australia Telescope National Facility) examined the HI distribution around the blue compact dwarf (BCD) galaxy NGC 1705. The HI extends out nearly 2.5 times further than the stellar distribution and is predominantly located in a rotating disk. The rotation curve yields a mass distribution dominated by the usual dark matter halo, but with an unusually high core density. In a related work, A. Marlowe (graduate student), Meurer and Heckman finished their study of a sample of twelve nearby BCDs. Their CCD images show that starbursts are modest events that contribute only a few percent to the stellar mass of the system, which is dominated by an older star forming population, but can contribute up to around twice the luminosity of this population. Typically the BCD host galaxies have significantly higher surface brightnesses than dwarf irregular galaxies, even after subtracting the starburst contribution. There is a significant correlation between host surface brightness and dark matter central density. This suggests that dark matter halo density is critical for regulating the morphology of dwarf galaxies by setting the thresh-

old intensity for self regulated star formation.

Warren Moos is the Principal Investigator for the Lyman Far Ultraviolet Spectroscopic Explorer. Warren Moos also participates as a Co-Investigator in the analysis of data from the Space Telescope Imaging Spectrograph. Moos is also Principal Investigator of the DOE-supported "XUV Diagnostics Based on Layered Synthetic Microstructures for Magnetically Confined Fusion Plasmas."

Eric H. Neilsen, Jr. (defended: March 11, 1999) used Hubble Space Telescope archive images to measure precise distances to 15 elliptical and lenticular galaxies in the Virgo cluster using surface brightness fluctuations (SBF), and to identify the globular clusters associated with these galaxies to a limiting magnitude significantly fainter than the peak of the globular cluster luminosity function (GCLF). Because the GCLF can also be used as a standard candle, these images provide independent distance measurements from the same data. In addition, the color distributions of the globular clusters provide an indication of the globular cluster formation history.

This study produced the several interesting results. The distances derived using SBF measurements in these images agree well with other distance measurements, including SBF measurements from the ground, measurements using the GCLF and measurements using the fundamental plane relation, and are of higher precision. Many galaxies in the sample have distances similar to that of M87, the central galaxy of the largest Virgo cluster cloud. Several galaxies (M59, NGC 4660 and NGC 4550) are ahead or behind the large cloud centered on M87, revealing extension along the line of sight. A few additional galaxies, particularly M86, NGC 4365 and NGC 4476, have significantly larger distances and are clearly not part of the M87 cloud.

Among those galaxies for which a suitably large sample of GC's could be measured, most had GC populations with clearly bimodal color distributions. The two peaks were found near $V - I = 1.0$ and $V - I = 1.2$ in most cases. The fraction of globular clusters in each park varied significantly. In one case (M86) only the blue peak was present, while in others (such as M49), there were more GC's in the red peak than the blue peak.

In addition to continuing his work with SBF and globular clusters in elliptical galaxies, Neilsen is working on the Sloan Digital Sky Survey (SDSS), for which he is observing with the Photometric telescope at Apache Point Observatory and developing software to automate these observations.

David Neufeld's primary research interests lie in the field of molecular astrophysics. The past year has seen the successful launch of the Submillimeter Wave Astronomy Satellite (SWAS), a NASA Small Explorer Mission on which he is a co-investigator. The SWAS satellite has operated perfectly during the first nine months of its life, producing a wealth of data that probe the chemistry of interstellar molecular clouds and its relation to star-formation. SWAS observations have led to the detection of water vapor in several dozen interstellar sources as well as the coma of Comet C/1999 H1 (Lee) and the atmospheres of Mars, Jupiter and Saturn. Water vapor is a potentially important reservoir of oxygen and a potentially dominant coolant of dense molecu-

lar clouds. In addition, large scale maps of submillimeter emissions from CI and ^{13}CO have been obtained for several photodissociation regions, and stringent upper limits placed upon the abundance of interstellar O_2 . An analysis of the implications of these data for our understanding of the chemistry and thermal balance in molecular clouds is currently under way. Neufeld has also continued to analyse and interpret earlier observations of water vapor obtained with the ISO satellite, including a complete mid-infrared spectral scan of the supergiant star VYCMa, and to work on theoretical models for emissions from the massing circumnuclear gas found in active galaxies.

David Sahnou is the instrument scientist for the Far Ultraviolet Spectroscopic Explorer. He has spent much of the past year preparing for the FUSE launch as part of the integration and test team at Goddard Space Flight Center and Cape Canaveral Air Station. Since launch, he has been involved in the In Orbit Checkout and Science Verification phases of the mission in order to help characterize the instrument's on orbit performance.

Paolo Tozzi is a Postdoctoral Fellow working primarily on X-ray clusters of galaxies. In collaboration with S. Borgani, P. Rosati and C. Norman, he investigated the constraints on the cosmological models given by the Rosat Deep Cluster Survey (Rosati *et al.* 1998). This work confirms that the deepest data on clusters favour low densities, possibly flat models with a cosmological constant, while a critical universe is significantly disfavoured. However, the work emphasizes the point that such results are sensitively dependent on the X-ray luminosity evolution of clusters. In particular, the relation between the X-ray luminosity and the temperature of the emitting gas can change with redshift. The set of data currently available on distant clusters does not allow one to determine if and how such relation changes with epoch; this uncertainty leaves room for cosmologies with higher densities.

Starting from these considerations, Tozzi and Norman developed a semi-analytical model to predict in detail the emission and temperature profiles of the X-ray emitting gas in cluster of galaxies, with strong emphasis on their evolution with cosmic epoch. At present, analytical models constitute an invaluable tool since hydrodynamical simulations are still limited by numerical resolution. In particular, this model is the first attempt to include in a comprehensive view all the relevant ingredients that ultimately shape the Intra Cluster Medium: infall of the baryons in the dark matter halos, shock heating, adiabatic accretion, radiative cooling and non-gravitational heating from star formation processes. The aim is to establish a clear link between the thermodynamical history of the baryons and their observational properties in the X-ray band. In particular, the effect of non gravitational processes, like SNe heating, is investigated for different star formation histories. For a wide range of parameters describing the star formation processes, the model is able to reproduce the local luminosity-temperature relation, the entropy floor observed in groups, the mild temperature gradient observed in large clusters, and the flat density cores in clusters and groups. This framework is meant to provide a solid framework to interpret the spatially and spectroscopi-

cally resolved observations from the X-ray satellites Chandra and XMM, which can remove the degeneracy presently affecting structure formation scenario and cosmological tests.

As a contiguous line of research, Tozzi realized simulated observations of the Chandra Ultra Deep Field in preparation to interpret the data from the Chandra satellite. Such observation (PI R. Giacconi) is expected to identify X-ray sources down to low fluxes ($F \approx 10^{-16} \text{ erg s}^{-1} \text{ cm}^{-2}$) especially in the high-energy band (2.5 – 10 keV) where present data are very scanty. The results will be crucial for the unified models of AGN, which generally predict the presence of a population of source missing in the low-energy band (due to neutral Hydrogen absorption), but visible in the high-energy band. These sources would resolve the high-energy X-ray background which, in fact, shows a spectrum harder with respect to that of the X-ray sources detected in the low-energy band. The successful launch of the Chandra satellite and the imminent release of the data make this line of research particularly important for the physics of the AGN and in general for the X-ray astronomy, including the study of distant clusters of galaxies.

Alan Uomoto continues to work on the Sloan Digital Sky Survey (SDSS), a catalog of 1/4 of the sky in five broad band colors. This year saw the successful installation and testing of the two SDSS fiber optic spectrographs, designed and built at Johns Hopkins University, on the SDSS 2.5 m reflector at Apache Point Observatory. These instruments will measure one million galaxy redshifts to create a unique three-dimensional map of the universe.

Uomoto also moved a 20-inch telescope from Johns Hopkins University to Apache Point Observatory for use by SDSS. The new SDSS Photometric Telescope will be used to calibrate imaging data obtained with the SDSS 2.5 m telescope.

Ethan T. Vishniac is currently working on problems connected with magnetic fields in astrophysical objects, and the structure of accretion disks. In collaboration with Alex Lazarian, now at U. Wisconsin, Vishniac has studied the process of magnetic field reconnection in dense plasmas. This work has led to an understanding of how weak turbulent motions mediate 'fast' reconnection, i.e. changes in the magnetic field topology at rates which do not depend on the plasma resistivity. With Pin-Gao Gu, a PhD student from U. Texas, Vishniac has collaborated on modeling the structure of accretion disks when the effects of turbulent transport (due to magnetic field instabilities) on convection are included. With Insu Yi, currently at Korea Institute for Advanced Studies, Vishniac has studied the phenomenon of torque reversal in magnetized accretors. Finally, Vishniac has pursued numerical studies of the of MHD turbulence in collaboration with Jungyeon Cho, a PhD student from U. Texas.

Vishniac serves as a Science Editor of the *Astrophysical Journal*.

Vishniac was named Director of CAS, effective 7/1/99.

Harold Weaver is a Research Scientist and is also working part-time on the FUSE mission. Regarding the latter, he serves as the deputy to the FUSE Project Scientist, George Sonneborn (GSFC), and also works with the JHU Mission

Planning Team to implement planetary observations with FUSE.

Weaver, with P. Feldman (JHU) and several other colleagues, published their results from HST post-perihelion observations of Comet Hale-Bopp. These were the first cometary observations using STIS and allowed the team to map the spatial distribution of the OH emission at 0."1 resolution. The peak of the OH spatial brightness profile was offset by ~ 3200 km from the peak in the continuum spatial profile, probably because of asymmetric production of water molecules from the nucleus. The anomalous flattening of the OH profile in the vicinity of the nucleus during the August 1997 observations can be explained by optical depth effects, rather than the production of OH from a population of icy grains in the coma.

Weaver and P. Lamy (LAS/Marseilles) wrote a review article summarizing all of the available observational evidence relating to the size of the nucleus of Comet Hale-Bopp. Their conclusion was that the nucleus had a radius of ~ 35 km, assuming that the optical albedo is 4%. Subsequent analysis by Lamy and several others, including Weaver, of thermal infrared observations of Hale-Bopp by ISO, indicates that the albedo of Hale-Bopp's nucleus is $\sim 2\%$, which means that the radius is ~ 50 km. In any case, it is now firmly established that the nucleus of Hale-Bopp was exceptionally large and was at least 10 times larger than that of Comet Hyakutake, the other very bright comet of this decade.

In an ongoing HST program led by P. Lamy (LAS/Marseille), Weaver has been helping to measure the sizes, shapes, and rotational periods of cometary nuclei. This group previously obtained excellent results on 8 comets and are currently pursuing an additional 14 comets during their HST Cycle 8 program. This investigation will significantly improve our understanding of the size distribution of cometary nuclei, which is a basic parameter that must be explained by any complete theory for the formation of the solar system.

Weaver has been continuing to pursue an infrared spectroscopic program on comets, in collaboration with several colleagues. In late October 1998, they observed Comet 21P/Giobolini-Zinner (GZ) from both the *IRTF* and the *UKIRT*. They made the first direct detection of water in GZ and also detected fluorescence from methanol. The methanol abundance in the nucleus of the comet was $\sim 1\%$, which is at the low end of the range of values observed in other comets. They did not detect ethane and found that its abundance is depleted by at least a factor of 10 relative to that observed in comets Hale-Bopp and Hyakutake. The upper limit on the CO abundance in GZ was $\sim 2\%$, which is very low but is expected for this short-period comet. The results from P/GZ can be contrasted to those for C/Lee (C/1999 H1), which is a long-period comet discovered in April 1999 and subsequently observed extensively from the *IRTF* and the *UKIRT* by Weaver and colleagues. C/Lee was rich in ethane ($\sim 0.7-0.9\%$) and methanol ($\sim 3-4\%$) but seems to have been relatively underabundant in methane and CO. These infrared observations of comets are part of a systematic program to study the volatile composition of many comets to

determine their formation environment and relationship to the interstellar medium.

In March 1999, Weaver became an Assistant Editor of *Icarus*, the international journal of solar system studies. He will handle all of the cometary papers and is the first editor of *Icarus* who is not affiliated with Cornell University.

Jennifer J. Wiseman is continuing as a Hubble Fellow at JHU and studies active regions of star formation within local molecular clouds. In particular, Wiseman is studying the dense molecular gas surrounding the equatorial accretion region of forming protostars using radio interferometry. She is also studying the larger-scale disruption of dense gas where jets and outflows from protostars disrupt it. In 1999, her VLA observations of ammonia emission in the protostellar outflow sources HH111 and HH211 were completed, following up on an initial study of the equatorial gas in HH212 in 1998. Collaborators include A. Wootten, H. Zinnecker, G. Fuller, and M. McCaughrean. Both HH211 and HH212 are so young and deeply embedded that their outflowing jets are optically invisible and are only detected in near-infrared shock line emission. HH111 is a more massive flow region with an optically visible jet. Wiseman's preliminary results for all three of these sources show that the equatorial gas is flattened in morphology, extending several thousand AU from the embedded source, with the major axis perpendicular to the jet axis. In each case, the ammonia emission reveals a velocity gradient across the disk as evidence for rotation. These discoveries illustrate an important stage in the star formation process where angular momentum has not yet been fully shed from the condensing gas.

Wiseman is currently looking for evidence of Keplerian rotation signatures and infall in the disk gas kinematics around these protostars. She has detected evidence for heating of this gas by the escaping protostellar jets as they chisel through the environment. She has also begun a comparative study of protostellar jets with extragalactic jets with collaborator J. Biretta, looking for similar processes on these vastly differing scales.

An invited assessment of the current state-of-the-art of multi-field imaging and mosaic construction at the VLA was presented by Wiseman at a conference on "Imaging at Millimeter and Sub-Millimeter Wavelengths" in Tucson this year. Wiseman has also presented talks on astronomy and space exploration to elementary schools and adult science groups.

Rosemary F.G. Wyse actually had clear weather at the AAT and obtained first data for the large project she has undertaken (in collaboration with Gerry Gilmore (Cambridge), John Norris (Canberra) and Ken Freeman (Canberra)), to deepen our understanding of the evolution of the Milky Way Galaxy by obtaining radial velocities and metallicities for a large sample of stars in the thick disk/halo interface. They are using the 2dF spectrograph, a well-known 'rainmaker'. Preliminary analysis provides the exciting possibility of their having detected the remnant of the satellite that created the thick disk.

The first results from her study, with HST, of the faint stellar luminosity function in the Ursa Minor dwarf spheroidal galaxy (Co-Is Gallagher (Madison), Gilmore (Cam-

bridge) and Smecker-Hane (UC Irvine); postdocs Feltzing (Cambridge) and Houdashelt (JHU) were published (Feltzing, Gilmore & Wyse 1999). This was based on the WFPC2 data, and revealed a perfectly normal stellar IMF down to $0.4 M_{\odot}$, despite this being a very dark-matter dominated galaxy. The STIS data are being analysed by Houdashelt, with preliminary results in agreement with the WFPC2 luminosity function, and the group awaits the acquisition of the last data this November (1999).

Together with graduate student Bing Zhang, Wyse is investigating the evolution of disk galaxies, with a current emphasis on models in which viscosity in the disk plays an important role. A paper describing their models and applying them to the origin of the disk Hubble sequence will appear in MNRAS.

Mark L. Houdashelt, R. Bell (Maryland) and A. Sweigart (Goddard) have continued a program to synthesize the spectra of galaxies using evolutionary synthesis. As part of this larger project, improved opacity data has been incorporated into the model atmosphere and spectral synthesis routines, leading to the calculation of updated color-temperature relations and bolometric corrections of cool stars. In collaboration with R. Wing, the spectral synthesis code has also been revised to better treat the absorption of radiation by TiO, which has greatly improved the computed synthetic spectra of M giants.

7. ACKNOWLEDGEMENTS

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