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1. INTRODUCTION

This report describes research performed from October 2001 through September 2002 by astronomers at the Computer Sciences Corporation (CSC).

Research in astronomy at CSC is primarily performed by members of Science Programs, part of the Civil Group in CSC's Federal Sector. Dr. C. Wu is the Director of Science Programs. Science Programs staff members provide operations support to the Hubble Space Telescope (HST) and Multi-mission Archive at Space Telescope (MAST) at the Space Telescope Science Institute (STScI), science support to NASA's Goddard Space Flight Center (GSFC), and Johns Hopkins University's (JHU) Department of Physics and Astronomy Far Ultraviolet Spectroscopic Explorer (FUSE) Project. In addition to their support work, CSC astronomers are active in a wide range of research activities supported by NASA contracts.

Astronomers and research assistants at CSC during this reporting period were D. Adler, V. Airapetian, T. Ake, M. Allen, R. Arquilla, W. Baggett, J. Baum, M. Bielefeld, G. Bower, M. Calvin, D. Chance, M. Corbin, T. Ellis, M. England, L. Evans, D. Fraquelli, F. Hamilton, H. Hart, A. Holm, C. Imhoff, I. Jordan, D. Kaufmann, W. Kinzel, M. Kochte, H. Lanning, O. Lupie, D. MacConnell, L. Marochnik, R. McCutcheon, J. Mo, R. Parise, S. Parsons, A. Patterson, R. Pitts, C. Proffitt, M. Robinson, R. Robinson, W. Rumpl, F. Schiffer, A. Schultz, J. Scott, D. Smith, M. Smith, C. Sturch, D. Taylor, T. Teays, B. Turnrose, E. Wells, A. Welty, C. Wu, and J. Younger.

2. RESEARCH

2.1 Solar System

Ellis is fitting model comet intensity profiles for C_2 and CN emission and sunlight scattered from dust to his observed intensity profiles for the inner coma of Comet Bradfield (1987s). This method is being used to put constraints on some of the gas and dust parameters.

Evans was a member of the XGRS science team on the NEAR-Shoemaker mission that orbited the asteroid 433 Eros for a year and then landed on the surface. Composition results were obtained from both instruments that indicated Eros is a primitive asteroid with some interesting differences from chondritic meteorites. He is also a member of the GRS science team on the Mars 2001 Odyssey mission that has been in Mars orbit since October 2001. This team reported the first definitive measurements that showed the existence of near-surface water ice on Mars.

Wells continued efforts to correct HST Faint Object Spectrograph observations of small planetary satellites for zero-point wavelength errors. Prism spectra of Jovian satellites Amalthea and Thebe and Uranian satellites Miranda, Puck, Portia, and Juliet have never been fully reduced because of the existence of random wavelength errors that can be as large as 250 Å at 5000 Å and even larger at longer wavelengths. A correction technique has been developed that directly compares the satellite spectra to a solar analog star FOS grating spectrum which has been rebinned to the same wavelength scale and resolution.

Wells collaborated with A. Storrs, K. Makhoul (Towson U.), B. Zellner (Ga. Southern), J. Conan (ONERA), F. Vilas (JSC), R. Landis (JPL), M. Gaffey (North Dakota), and C. Wood (BSI) in a HST WFPC2 Snapshot program to image the 50 largest main belt asteroids. Images were obtained for 28 asteroids. A companion was seen on several images of one visit to asteroid 107 Camilla but not seen on a second visit. Companions of 44 Eugenia and 87 Sylvia were confirmed, and photometric data obtained. Deconvolved images will be published for the subset of asteroids that were resolved. Photometric results and analyses will be published for the entire sample.

Wells collaborated with D. McCarthy, K. Hege, L. Lebofsky (Arizona), R. Binzel (MIT), J. Drummond (Phillips Lab.), A. Storrs, A. Rosenberg (Towson U.), P. Thomas (Cornell), B. Zellner (Ga. Southern), M. Gaffey (North Dakota), and J. Conan (ONERA) in an HST program to obtain resolved near-infrared images of asteroid Vesta at 6 wavelengths between 1 and 2 microns. The data are being used, along with visible wavelength HST observations, to develop a global mineralogical map of the surface of Vesta.

2.2 Stellar Astronomy and Astrophysics

Ake continued to work with A. Dupree, P. Young (CfA), J. Linsky (JILA), B. Wood, S. Redfield (Colorado), and Robinson on the FUSE PI team cool star program. Analyses focused on atomic line identifications, flux measurements, and line profile studies in the FUSE wavelength region (905-1187 Å) of late-type stars. Initial work was completed on Capella (Young *et al.* 2001, ApJL, 555, L121) resulting in a detailed line list of use for the FUSE community (http:// fuse.pha.jhu.edu-/analysis/cool_stars/capella_linelist.html). Although dominated by the resonance lines of C III and O VI, the Capella spectrum exhibits a wealth of weaker lines from the chomospheric, transition, and coronal regions of the stellar components. Identifications were based on the solar spectrum (Feldman & Doscheck 1991, AoJS, 75, 925; Curdt *et al.* 1997, A&A, 126, 281) and predictions using CHIANTI (Dere *et al.* 1997, A&A, 125, 149) using the emission measure distribution and densities from UV and EUV observations of Capella (Brickhouse *et al.* 2000, ApJ, 530, 387). The Fe XVIII 974.85 Å line, formed at temperatures of 6 $\times 10^6$ K, was detected and was found to be associated with the G8 star rather than the more active G1 primary. Further analysis is in progress.

Ake presented a paper on the FUSE cool star survey at the 12th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun held in Boulder, CO in July 2001. This survey

includes some of the best prototypical examples of coronal, non-coronal, and hybrid stars. Except for the most luminous, coolest objects, all stars have strong emission lines of O VI 1032,1037 Å and C III 977,1176 Å and weaker lines of C II, N II, N III, S IV, Si III and Si IV. He II, Ne VI, Fe XVIII, and perhaps Fe XIX can be found in the most active dwarfs. The luminous stars show large differences in line ratios and line profiles reflecting their evolutionary status. The coolest luminous object in the survey, the M2 supergiant α Ori, is devoid of all emission except for Fe II fluorescent lines.

Hart, with Schultz, Fraquelli, Hamilton, Kochte, and Swade is preparing a paper ''Reflectance Spectroscopy of the β Pictoris Disk'' based on 1996 HST FOS observations with the 1.″0 paired aperture. Simultaneous spectra of both extensions of the disk of β Pic were obtained at about 1.″3 (25 AU) from the star. A pipeline error found associating the FOS data groups with the source aperture has been corrected and incorporated into the paper.

Lanning, with M. Meakes (STScI), continues his analysis of the Sandage Two-color (U,B) Survey of the Galactic Plane. Plates taken with the 48-inch Oschin Schmidt telescope at Palomar Observatory are being scanned to identify objects bright in the UV, often including white dwarf candidates, CVs, B shell stars, etc. The sixth in the continuing series of catalogs of UV-bright sources was published in the Nov. 2001 issue of PASP bringing the total number of published UV sources to 572. Paper VII is in work. Lanning, with M. Eracleous, R. Wade and M. Mateen (PSU) published a paper detailing a spectroscopic reconnaissance of a selected sample of the Lanning UV sources. Using the Hobby-Eberly 9-m telescope at the McDonald Observatory and the Kitt Peak 2.1m telescope, several new DA white dwarfs were identified as well as a number of sources exhibiting very interesting features characteristic of low-luminosity objects. Detailed information related to this project (including published works, tables, and finding charts) is available on the survey website at `http://www.stsci.edu/lanning/index.html`.

MacConnell presented a poster at the 199th AAS meeting on his near-IR photographic search for carbon stars along the southern galactic plane. He listed 289 new stars with charts, gave improved coordinates of 470 known ones, and made a study of their 2MASS colors. Galactic carbon stars follow a well-defined relation in the $(J-H),(H-K)$ plane with a few interesting exceptions. Analysis of a search within $1'$ of 744 carbon stars within the box $1.0<(J-H)<2.0,0.4<(H-K)<1.2$ shows that C stars can be chosen on the basis of 2MASS colors alone with only about 50% reliability. A paper has been submitted to the PASP.

MacConnell continues collaborating with R.F. Wing (Ohio State) and E. Costa (U. Chile) in a survey for distant, cool galactic supergiants along the southern Milky Way. Slit spectra of over 800 candidates have been classified, and reductions of Wing 8-color, narrow-band photometry of 1560 candidates are underway. About 250 supergiants have been identified including some at large distance and others having unusual spectra and colors.

In a project led by J.E. McClintock (CfA), MacConnell collaborated with J.A. Orosz (SDSU), D.J. Mink (CfA), and R.A. Remillard (MIT) in a search for the optical counterpart of the brilliant transient X-ray source Nova Cen X-2 (1967). A paper has been submitted to the ApJ in which it is argued that the historical X-ray source may be identical to the X-ray nova GS1354-64 (1987, 1997) with a known optical counterpart.

Parsons continued refining SED analysis and isochrone fits toward deriving the absolute magnitudes of 134 evolved late-type stars which have upper main-sequence secondaries with IUE spectra (see Parsons & Ake 1998, ApJS, 119, 83). Since available constraints now indicate several systems considered double to have at least three stellar components, work has focussed on preparing their data for publication. For one of the newly identified triple systems, the middle component is in a short-lived stage of hydrogen exhaustion prior to helium ignition.

Parsons, with O. Franz and L. Wasserman (Lowell), continued work on the mass of the G4 II star HD 173764 observed with HST's FGS3 in TRANS/POS modes. Colors of the reference stars were obtained in order to reduce uncertainties in the solutions due to the FGS lateral color corrections. The POS-mode solutions indicate orbital reflex motion of the primary at the level of 5-6 mas. Parsons is beginning to utilize a general binary star orbital solution program by D. Gudehus (GSU) (2001, BAAS, 33, 850) to find the most robust solutions that incorporate all relevant data.

Proffitt, in collaboration with S. Adelman (Citadel), G. Peters (USC), and G. Wahlgren (Lund), continues work using coadded IUE spectra to study very heavy elements in both normal and chemically peculiar B stars. Improved techniques for the coaddition of IUE high- dispersion spectra have been developed as have procedures for generating detailed spectral atlases of the best-observed, narrow-lined stars.

In a project led by M. Livio (STScI), Proffitt is analyzing deep STIS/CCD images that target the brightest clump in the sub-mm disk around the nearby star ϵ Eri with the intent of setting constraints on the dust properties and of cataloging objects visible in the field.

In collaboration with T. Brage (Lund) and P. Judge (HAO-NCAR), Proffitt contributed to a recently completed STIS/HST study of the 1487.9 Å N IV hyperfine line in the planetary nebula NGC 3918. This study yielded the first measurement of a transition probability for this class of hyperfine transitions, confirming previous theoretical calculations, and also providing a powerful new diagnostic for very low-density plasmas.

Proffitt, in collaboration with T. Brage (Lund), F. Rogers, and C. Iglesias (LLNL), continues theoretical work on the radiative acceleration of heavy elements in stellar envelopes and atmospheres. Improved techniques for radiative acceleration calculations in stellar atmospheres are also being developed, and large-scale model atoms of gallium and other very heavy elements are being implemented for use in non-LTE calculations.

Robinson, in collaboration with M. Smith (CSC) and G. Henry (Tenn. State), completed a study of X-ray and optical variability of the classical Be star γ Cas. Quasi-periodic B and V band optical variations were found with a peak-to-

peak amplitude of about 3% and a cycle time which varied from 55 to 93 days. As the optical intensity increased, the $(B-V)$ color was also found to increase suggesting that the variations originated in the massive stellar disk. Cyclic X-ray flux variations (obtained with the RXTE satellite during 2000) were also found. These varied by a factor of 2 and had a period near 70 days. Detailed comparison with the optical variations suggests that the optical and X-ray fluxes are strongly correlated. It was suggested that both variations are driven by a magnetic dynamo operating in the stellar disk. The observations appear to be incompatible with the hypothesis that the X-rays originate from mass accretion onto a degenerate companion of γ Cas. An approximate 1 solar mass companion has recently been discovered, but it has a period of 203.4 days, much longer than the timescale of the X-ray variations.

Robinson collaborated with E. Böhm-Vitense (Washington), K. Carpenter (NASA/GSFC/LASP), and J. Mena-Werth (Nebraska) on a study of FUV spectra of Hyades F stars taken with the HST and FUSE satellites. Emission-line fluxes for a wide range of temperatures (including Mg II, C II, C III, CIV, and O VI) all show higher emission for the early F when compared to the late F stars, with an abrupt change occurring between $(B-V)$ values of 0.42 and 0.45 (near spectral type F5) where the Li surface abundances show a deep minimum. The flux levels for early and late F stars also have different dependences on the stellar rotation rate, with the early type stars showing an increase in emission with increasing rotation velocity and the late F stars being relatively independent of rotation rate. This is opposite to the behavior observed in the older field stars which typically show a rotational effect in the cooler stars. This suggests that there are at least two heating mechanisms operating in these stars with one dominating in early and another in the late F stars. Further, since magnetically related heating is generally associated with a magnetic dynamo which depends on the stellar rotation rate, we have evidence that magnetically related heating operates in the early F stars, contrary to previous expectations.

Robinson collaborated with T. Ake, A. Dupree (SAO), and J. Linsky (JILA/Colorado) on a study of FUV observations of the active K dwarf AB Doradus obtained with the FUSE satellite in Oct and Nov of 1999. During a total of 29 hours of observing, they observed two large flares and >10 smaller events in the FUV continuum and the integrated C III (1175 Å) and O IV (1032/1037 Å) line fluxes. For one of the large events, the continuum increased by a factor of >100 while the line enhancement was more than an order of magnitude lower. While the continuum and CIII fluxes decayed to the background level in just 6 minutes, the O VI enhancement lasted for nearly an hour. In the second event, the continuum and line enhancements were compatible. Again, the durations depended upon temperature with the continuum having the shortest and the O VI having the longest duration. The smaller flare events are much more evident in the lines than in the continuum and are of relatively long duration lasting 5 minutes or more. This is in contrast to microflare events seen in dMe stars which typically last only 10-20 seconds.

Robinson continued a collaboration with K. Carpenter (NASA/GSFC/LASP) in determining the wind properties of cool, luminous stars. High-quality Fe II line profiles of the M giants μ Gem and γ Cru (obtained with the HST) were empirically modeled using the SEI radiative transfer code. This analysis shows a terminal velocity of 11 km/s and 19 km/s, a log mass loss rate of -10.13 and -9.3 solar masses per year, and an average turbulent velocity of 9 and 14 km/s for μ Gem and γ Cru, respectively.

Schultz continues his investigations into extrasolar planetary systems with collaborators using the Fine Guidance Sensor onboard the HST to perform astrometry of the 55 ρ^1 Cnc system (with McGrath (STScI) *et al.* (2002)) and as a photometer to observe the transits of the close-in planet in the HD 209458 system. Results to date show that the astrometric wobble due to orbiting bodies is below the 0.5 mas detection limit of the FGS thus indicating that the object is either a low-mass brown dwarf or a planet. Preliminary results from the photometric study of the transits of HD 209458b indicate a possible change in the planetary orbital inclination. This could simply be due to the different data set than was obtained using the HST/STIS to observe the transits (Brown *et al.* 2001) or possibly due to other unknown factors.

Schultz with Suchkov (STScI) and Lisse (Maryland) investigated the characteristics of F stars using the combined published 2MASS and *uvby* data sets. All of the F stars with Doppler-detected planetary companions, except for an old system, are relatively young (<1 Gyr) and are metal rich (Suchkov and Schultz 2001). In addition, a population of metal-rich F stars with possible circumstellar disks has been identified (Suchkov, Schultz, Lisse 2002)

M. Smith reviewed the X-ray and related optical and UV variations of the unique, high-mass source γ Cas (B0.5eIV) as an example of periodic, cyclical, and chaotic processes at the July conference on variable stars, ''Periodic, Cyclic, and Stochastic Variability.'' Most of this related variability, including an apparently regular 1.1-day period in UV continuum and line flux, 7-hour cycles in X-ray and in UV-line flux, chaotic ''shots'' in the X-rays, and a variety of undulating patterns in the X-ray and UV, can best be explained by the X-ray flare sources residing near the Be star. However, a $\sim$70-day cyclic and correlated variation of X-ray and optical fluxes cannot be so readily explained by near-surface generation - nor by accretion in a binary component. Thus, Smith and his collaborators, R. Robinson and G. Henry (Tenn. State), were led to a unique picture in which these variations arise from a dynamo excited in the Be disk. If this interpretation holds, this will be the first known dynamo operating in a circumstellar disk.

2.3 Extragalactic Astronomy

Bower, as a member of both the Nuker team (led by D. Richstone, Michigan) and HST STIS GTO team, continued to investigate supermassive black holes in the centers of galaxies. These studies rely heavily on HST data. The team discovered evidence for supermassive black holes in 12 additional galaxies which raises the total number of galaxies with such evidence to over 30. They also discovered that, if

the nearby spiral galaxy M33 contains a supermassive black hole, its mass must be $< 1500\ M_{\odot}$. This upper limit is far below the black hole mass expected from the galaxy velocity dispersion. These discoveries have definitive implications for the relationship between galaxy black hole mass and velocity dispersion (that the Nuker team discovered in 2000) that suggests a link between galaxy formation and black hole growth. In particular, the slope of this relation is now more constrained, and the relation is now known to apply only to galaxy bulges and not disks.

Bower, as part of the Nuker team, helped identify six unusual, early-type galaxies with HST WFPC2 surface brightness profiles having local minima within the central 20 pc rather than having profiles that decline with increasing distance from the nucleus as is the case for most galaxies.

Bower also collaborated with J. Ruiz, M. Crenshaw, S. Kraemer (Catholic U. of America), T. Gull (NASA-GSFC), J. Hutchings (Herzberg Institute of Astrophysics, National Research Council of Canada), M. E. Kaiser (JHU), and D. Weistrop (Nevada-Las Vegas) on an analysis of the kinematics of ionized gas in the Seyfert galaxy Markarian 3. It was found that the HST STIS slitless spectral observations and measurements are consistent with a model in which the ionized gas is being accelerated radially outward from the galaxy nucleus and then decelerated at larger distance from the nucleus as the gas interacts with the ambient interstellar medium. This is similar to other Seyferts that exhibit radial outflow of ionized gas close to the nucleus.

Corbin, in collaboration with M. Rieke and E. O'Neil (Arizona) completed a study of HST NICMOS images of the core of the nearby radio galaxy M 87. These images are free of the strong emission lines found in the optical region of the galaxy's spectrum and trace the underlying population of evolved stars within the core region. The images reveal a highly symmetric distribution of stars around the nucleus, consistent with models that predict that gravity of the nuclear supermassive black hole in the galaxy will produce such a distribution on a short timescale ($<10^8$ years). The NICMOS images in combination with archival WFPC2 images also show no clear evidence of a dusty torus around the nucleus, consistent with recent studies that have found little mid-infrared emission from the nucleus.

In collaboration with W. Vacca (MPIEP, Garching), Corbin completed an HST study of the ''ultracompact'' blue dwarf galaxy POX 186. The HST images, obtained with the Planetary Camera of the WFPC2 instrument, confirm this object to be extremely small with a maximum size of $\sim$ 300 pc. However, it shows a strikingly asymmetric morphology with what appears to be a tidal arm of material on its western side in which stars are still forming. This morphology and star formation suggest that POX 186 represents a recent (within 100 Myr) collision between two small ($\sim$ 100 pc) clumps of stars, and that, dynamically speaking, this object may be a very small dwarf galaxy that is still in the process of formation. It also resides in a void ruling out the possibility that it formed from the tidal debris of larger galaxies. Articles on these results have appeared in the online version of Science magazine and in Science News (2002, 162, 164).

D. Smith collaborated with D. Calzetti, J. Harris (STScI), J. Gallagher (Wisconsin), and C. Conselice (Caltech) in studies of nearby starburst galaxies. The group is estimating the ages and masses of clusters in several systems to determine if starburst events are synchronized or propagate through the host galaxy. D. Smith is leading the investigation of NGC 2903, a hot-spot spiral galaxy. D. Smith has reduced HST WFPC2 and NICMOS observations of this galaxy and obtained photometry of several clusters in the U, V, and I bands as well as the Hα and Pα recombination lines. The cluster properties are consistent with a reddened, instantaneous burst of star formation.

2.4 Instrumentation & Instrument Design

Hart and Ake, with D. Christian, B. Roberts, J. Kruk, W. Blair, and H. Moos (JHU), presented papers at the June 2002 AAS meeting on the FUSE attitude control system which lost 2 of 4 reaction wheels late in 2001. Since late Jan 2002, the FUSE satellite has employed an innovative and groundbreaking technique for attitude control: two non-orthogonal reaction wheels and a set of magnetic torquer bars which interact with the geomagnetic field. The change in control method has modified the execution of slews and static pointing which in turn affects target acquisition and maintenance of pointing control during science exposures. Motions around two axes are well-controlled, but large maneuvers around the axis controlled by the geomagnetic field can have larger errors and can take longer to complete. Once a slew has settled, however, the positional accuracy is as good as with the previous four-wheel control law. For static pointing, the variations are small enough that full spectrograph resolution can be achieved. Routine monitoring of the in-orbit performance of slews and static pointing is providing the data necessary to develop and improve attitude control algorithms and mission planning.

Jordan, in collaboration with Schultz, Kochte, Fraquelli, and Hart, combined their expertise in free-flying occulter architectures with Lyon, Hollis, and Carpenter's (GSFC) imaging and science program definition experience to propose an optimized architecture for an opaque, free-flying occulter to be used in conjunction with an apodized, square-aperture space telescope. This design differs from previously proposed free-flying occulters in that it combines the best features of apodization, square apertures, and external occultations to achieve the goal of high-order nulling of a stellar point spread function to allow detection and measurement of faint objects near bright stars. This allows leveraging a potentially different option for the NASA Origins goal of measurement of nearby extrasolar planetary properties using high contrast imaging. A poster outlining the technique was displayed at the 199th AAS meeting (Jan 2002) in addition to a SPIE paper presented in Aug 2002.

Schultz, as an STScI NICMOS team member, worked to re-activate the NICMOS infrared instrument onboard HST following the successful installation and activation of the NICMOS Cooling System (NCS) during Servicing Mission 3B. This involved monitoring the focus of the three NICMOS cameras, recommending focus changes, and helping to provide new calibration reference files for NICMOS observers (Schultz et al. 2002).

Schultz and Lyon (NASA/GSFC) organized and co-chaired a SPIE conference ''High Contrast Imaging for Exoplanet Detection'' held in conjunction with SPIE's conference on Astronomical Telescopes and Instrumentation, Aug 21-28, 2002, Waikoloa, Hawaii. Over 50 papers and posters were presented during the three-day conference. The sessions were well received as the conference was moved to a larger room to accommodate the over flow of interested individuals. The conference provided a forum for the interchange of ideas, methods, and architecture techniques to achieve high-contrast imaging and spectroscopy both from the ground and with space-based telescopes.

2.5 Education and Outreach

Schultz was an invited speaker at an astronomy class for middle school teachers which was held at the Hagerstown Community College, Hagerstown, MD. He spoke on the search for extrasolar planets. The class was sponsored under the JHU Space Grant Consortium program. He presented a similar talk at the Northern Nevada Teachers Workshop for grammar, middle, and high school teachers held at U. Nevada, Reno, NV. The U. of Nevada teachers' workshop was held as part of an HST Cycle 10 Education and Public Outreach proposal.

Teays served as the Director of NASA's Origins Education Forum, and D. Smith as the Forum Scientist. The Origins Education Forum helps missions and research programs in the Origins Science Theme to translate their science and technology for education and public outreach. In this capacity, Teays also served on the NASA Office of Space Science (OSS) Education/Outreach Advisory Council. Forum staff hosted a meeting of this group at STScI in August. The Origins Forum also operates an extensive product evaluation service for Origins E/PO missions and hosts the Space Science Education Resource Directory (SSERD), a user-friendly search engine tailored for educators on behalf of NASA. D. Smith also serves as a team scientist for the HST's Formal Education program.

The Origins Forum supported NASA at several major education meetings and sessions including the National Science Teachers Association, the National Council of Teachers in Mathematics, and the AAS. Forum staff also presented several workshops for educators throughout the year. Forum staff gave invited presentations at the NASA Space Science Education Products Workshop, held Nov 15-17 at Goddard Space Flight Center. The workshop featured outstanding education products from the 2001 OSS Product Review conducted by the Institute for Global Environmental Studies on behalf of OSS. Products were reviewed by both professional educators and scientists with products of outstanding pedagogy and scientific content being recommended for broad distribution. The workshop targets audiences that regularly promote the use of space science products in the classroom including representatives from the NASA Educator Resource Center Network (ERCN), the Aerospace Education Services Program (AESP), the Teaching from Space (TFS) program, and the NASA OSS Broker/Facilitators. Teays and HST Formal Education staff showcased the ''Hubble Space Telescope Deep Field Lesson Package,'' an *Amazing Space* hard-copy product. D. Smith presented ''Discovery of Infrared Light,'' a version of the Herschel Experiment developed for classroom use by the SIRTF education and public outreach program.

As a result of the OSS Education Product Workshop, D. Smith was invited to present a talk at Space Science XVII: Cosmology - Voyages to the Frontiers of Space and Time, a workshop held at the Wright Center for Innovative Science Education at Tufts University. Two educational activities developed by Origins missions were presented: ''Discovery of Infrared Light'' and ''Star Light, Star Bright.'' The latter is an interactive, on-line HST activity that allows students to explore the relationship between energy, frequency, wavelength, temperature, and color. It is is part of the HST's *Amazing Space* formal education program. The Wright Center's Space Science workshops are held annually to provide professional development for master science educators.

3. ACKNOWLEDGMENTS

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PUBLICATIONS

This list includes papers published or submitted between October 2001 and September 2002 by CSC staff. Some papers cited here may have been included as *submitted* or *in press* in the previous annual report.

Ake, T.B., Class, B.F., Roberts, B.A., Kruk, J.W., Blair, W.P., & Moos, H.W. 2002, ''Recovery of FUSE Attitude Control With Two Reaction Wheels and Magnetic Torquer Bars,'' BAAS, 34, 671 (abstract).

Anderson, K.S.J., Baggett, S.M., & Baggett, W.E. 2002, ''The Distribution of Disk Stars in Type II Galaxies,'' BAAS, 34, 711 (abstract).

Böhm-Vitense, E., Robinson, R., Carpenter, K. & Mena-Werth, J. 2002, ''What Is Happening at Spectral Type F5 in Hyades F Stars?,'' ApJ, 569, 941.

Boynton, W.V., Feldman, W.C., Squyres, S.W., Prettyman, T.H., Brückner, J., Evans, L.G., Reedy, R.C., Starr, R., Arnold, J.R., Drake, D.M., Englert, A.J., Metzger, A.E., Mitrofanov, I., Trombka, J.I., d'Uston, C., Wänke, H., Gasnault, O., Hamara, D.K., Janes, D.M., Marcialis, R.L., Maurice, S., Mikheeva, I., Taylor, G.J., Tokar, R., & Shinoharal, C. 2002, ''Distribution of Hydrogen in the Near Surface of Mars: Evidence for Subsurface Ice Deposits,'' Science, 2975, 81.

Brandt, J.C., Heap, S.R., Beaver, E.A., Boggess, A., Carpenter, K.G., Ebbets, D.C., Hutchings, J.B., Jura, M., Leckrone, D.S., Linsky, J.L., Maran, S.P., Savage, B.D., Smith, A.M., Trafton, L.M., Walter, F.M., Weymann, R.J., Snow, M., & Ake, T.B. 2001, ''Goddard High Resolution Spectrograph Observations of NGC 4151,'' AJ, 121, 2999.

Carpenter, K.G.& Robinson, R.D. 2001,''Estimation of Mass-Loss Rates for M Giants from UV Emission Line Profiles,'' BAAS, 33, 1441 (abstract).

Chae, K.-H., Turnshek, D.A., Schulte-Ladbeck, R.E., Rao, S.M., & Lupie, O.L. 2001, ''Hubble Space Telescope Ob-

servations of the Gravitationally Lensed Cloverleaf Broad Absorption Line QSO H1413+1143: Imaging Polarimetry and Evidence for Microlensing of a Scattering Region,'' ApJ, 561, 653.

Corbin, M.R., O'Neil, E., & Rieke, M.R. 2002, ''Hubble Space Telescope Imaging of the Core of M87,'' AJ, 124, 183.

Corbin, M.R.& Vacca, W.D. 2002, ''POX 186: A Dwarf Galaxy in the Process of Formation?,'' astro-ph/0208369, to appear in Dec. 20, ApJ.

Dupree, A.K., Young, P.R., Lobel, A., Ake, T.B., Linsky, J.L., & Redfield, S. 2001, ''FUSE Survey of Cool Luminous Stars,'' BAAS, 33, 1328 (abstract).

Eracleous, M., Wade, R.A., Mateen, M., & Lanning, H.H. 2002, ''A Spectroscopic Reconnaissance of UV-bright Stars,'' PASP, 114, 208.

Evans, L.G., Starr, R., Brückner, J., Reedy, R.C., Boynton, W.V., Trombka, J.I., Goldsten, J.O., Masarik, J., Nittler, L.R., & McCoy, T.J. 2001, ''Elemental Composition from Gamma-ray Spectroscopy of the NEAR-Shoemaker Landing Site on 433 Eros,'' Meteoritics and Planetary Science, 36, 1639.

Feldman, P.D., Ake, T.B., Berman, A.F., Moos, H.W., Sahnow, D.J., Strobel, D.F., Weaver, H.A., & Young, P.R., 2001, ''Detection of Chlorine Ions in the Far Ultraviolet Spectroscopic Explorer Spectrum of the Io Plasma Torus,'' ApJL, 554, L123.

Gebhardt, K., Lauer, T.R., Kormendy, J., Pinkney, J., Bower, G.A., Green, R., Gull, T., Hutchings, J., Kaiser, M.E., Nelson, C.H., Richstone, D., & Weistrop, D. 2001, ''M33: A Galaxy with No Supermassive Black Hole,'' AJ, 122, 2469.

Gebhardt, K., Richstone, D., Tremaine, S., Lauer, T.R., Bender, R., Bower, G., Dressler, A., Faber, S.M., Filippenko, A.V., Green, R., Grillmair, C., Ho, L.C., Kormendy, J., Magorrian, J., & Pinkney, J. 2002, ''Axisymmetric Dynamical Models of the Central Regions of Galaxies,'' astro-ph/0209483, ApJ, in press.

Harris, J., Calzetti, D., Gallagher, J.S. III, Smith, D.A., & Conselice, C.J. 2001, ''A Comparative Study of Star Cluster Populations in Nearby Starburst Galaxies,'' BAAS, 33, 1372 (abstract).

Hart, H.M., Ake, T.B, Christian, D.J., Roberts, B.A., Kruk, J.W., Blair, W.P., & Moos, H.W. 2002, ''FUSE In-orbit Performance with the New Attitude Control System,'' BAAS, 34, 672 (abstract).

Herbig, G.H., Aspin, C., Gilmore, A.C., Imhoff, C.L., & Jones, A.F. 2001, ''The 1993-1994 Activity of EX Lupi,'' PASP, 113, 1547.

Imhoff, C.L., Hart, H.M., Grady, C.A., Chase, H.L., & Nachlas-Gabin, I. 2001, ''Young Space Explorers: IDEAS in the Library,'' BAAS, 33, 1346 (abstract).

Kochte, M., Schultz, A.B., Jordan, I., Hamilton F., Bruhweiler, F., DiSanti, M.A., Burns, R.D., Carpenter, K., Hollis, J.M., Leitner, J., Lyon, R.G., Starin, S., Fadali, M.S., Rodrigue, M., Skelton, D.L., & Hart, H.M. 2001, ''Free-flying Occulters for Use with Space Telescopes,'' BAAS, 33, 1367 (abstract).

Kruk, J.W., Class, B.F., Rovner, D., Westphal, J., Ake, T.B., Moos, H.W., Roberts, B., & Fisher, L. 2002, ''FUSE In-orbit Attitude Control with Two Reaction Wheels and No Gyroscopes,'' Proc. SPIE, vol. 4854, paper 72.

Lanning, H.H.& Meakes, M. 2001, ''A Finding List of Faint UV-Bright Stars in the Galactic Plane. VI.,'' PASP, 113, 1393.

Lauer, T.R., Gebhardt, K., Richstone, D., Tremaine, S., Bender, R., Bower, G., Dressler, A., Faber, S.M., Filippenko, A.V., Green, R., Grillmair, C.J., Ho, L.C., Kormendy, J., Magorrian, J., Pinkney, J., Laine, S., Postman, M., & van der Marel, R.P. 2002, ''Galaxies with a Central Minimum in Stellar Luminosity Density,'' AJ, 124, 1975.

Lisse, C., Suchkov, A.A., & Schultz, A., 2001, ''Tracing Recent Star Formation in and around the molecular ρ Oph with F stars from the 2MASS and uvby Surveys,'' BAAS, 33, 1308 (abstract).

Lisse, C., Schultz, A., Fernandez, Y., Peschke, S., Ressler, M., Gorjian, V., Djorgovski, S.G., Christian, D.J., Golisch, B., & Kaminski, C. 2002, ''Discovery of an Extremely Red Object in the Field of HD 155826,'' ApJ, 579, 779.

MacConnell, D.J. 2001, ''7000 Galactic Carbon Stars and Counting,'' BAAS, 33, 1495 (abstract).

Makhoul, K., Storrs, A., Conan, J.M., Zellner, B., Wells, E., Vilas, F., Landis, R., & Gaffey, M., 2001, ''Results from the HST Main Belt Asteroid Survey,'' BAAS, 33, 1402 (abstract).

McClintock, J.E., Orosz, J.A., MacConnell, D.J., Mink, D.J., & Remillard, R.A, 2002, ''A Search for X-ray Nova Cen X-2 (1967) and its Relationship to X-ray Nova GS1354-64 (1987, 1997),'' submitted to ApJ.

McGrath.M.A., Nelan, E., Black, D.C., Gatewood, G., Noll, K., Schultz, A., & Lubow, S. 2002, ''An Upper Limit to the Mass of the Radial Velocity Companion to ρ^1 Cancri,'' ApJL, 564, L27.

Moos, H.W., Sembach, K.R., Vidal-Madjar, A., York, D.G., Friedman, S.D., Hébrard, G., Kruk, J.W., Lehner, N., Lemoine, M., Sonneborn, G., Wood, B.E., Ake, T.B., André, M., Blair, W.P., Chayer, P., Gry, C., Dupree, A.K., Ferlet, R., Feldman, P.D., Green, J.C., Howk, J.C., Hutchings, J.B., Jenkins, E.B., Linsky, J.L., Murphy, E.M., Oegerle, W.R., Oliveira, C., Roth, K., Sahnow, D.J., Savage, B.D., Shull, J.M., Tripp, T.M., Weiler, E.J., Welsh, B.Y., Wilkinson, E., & Woodgate, B.E. 2001, ''Abundances of Deuterium, Nitrogen, and Oxygen in the Local Interstellar Medium: Overview of First Results from the FUSE Mission,'' ApJS, 140, 3.

Oliversen, R.J., Scherb, F., Smyth, W.H., Freed, M.E., Carey Woodward, R., Jr., Marconi, M.L., Retherford, K.D., Lupie, O.L., & Morgenthaler, J.P. 2001, ''Sunlit Io Atmospheric [O I] 6300 Å Emission and the Plasma Torus,'' Journal of Geophysical Research, 10626, 1830.

Proffitt, C.R. 2002, ''UV C I Lines in the HgMn Star χ Lupi,'' ApJ, 571, 955.

Robinson, R.D., Smith, M.A., & Henry, G.W. 2002, ''X-Ray and Optical Variations in the Classical Be Star γ Cassiopeia: The Discovery of a Possible Magnetic Dynamo,'' ApJ, 575, 435.

Rosenberg, A., Storrs, A., Conan, J.M., McCarthy, D.W.,

Binzel, R.P., Drummond, J., Gaffey, M., Hege, K., Lebofsky, L., Thomas, P., Wells, E., & Zellner, B., 2001, ''Mineralogical Mapping of Asteroid 4 Vesta,'' BAAS, 33, 1402 (abstract).

Ruiz, J.R., Crenshaw, D.M., Kraemer, S.B., Bower, G.A., Gull, T.R., Hutchings, J.B., Kaiser, M.E., & Weistrop, D. 2001, ''Kinematics of the Narrow-Line Region in the Seyfert 2 Galaxy Mrk 3,'' AJ, 122, 2961.

Schultz, A.B., Hamilton, F., Hershey, J., Jordan, I., Kochte, M., Henry, G., Vogt, S., Bruhweiler, F., Storrs, A., Hart, H.M., Rodrigue, M., Hamilton, D.P., Welsh, W.F., Taylor, & D.C. 2001, ''HST/FGS High Speed Photometry of the Transiting Planet HD 209458b,'' BAAS, 33, 1304 (abstract).

Schultz, A.B., Kochte, M., Kinzel, W., Hamilton, F., Jordan, I., Henry, G., Vogt, S., Hart, H.M., Bennum, D., Rassuchine, J., Rodrigue, M., Hamilton, D.P., Welsh, W.F., Wittenmyer, R., & Taylor, D.C. 2002, ''Monitoring the Planetary Transits of HD 209458b,'' in Proceedings of Scientific Frontiers in Research on Extrasolar Planets, ASP Conf. Series, D. Deming ed., in press.

Schultz, A.B., Bergeron, L.E., Calzetti, D., Böker, T., Dickinson, M., Holfeltz, S.T., Malhotra, S., Noll, K., Roye, E., Sosey, M., Xu, C., & Mazzuca, L., 2002, ''Post-NCS Performance of the HST NICMOS,'' in IR Space Telescopes and Instruments, J. Mather ed., Proc. SPIE, 4850, in press.

Schultz, A.B., Jordan, I.J.E., Kochte, M., Fraquelli, D., Bruhweiler, F., Hollis, J.M., Carpenter, K.G., Lyon, R.G., DiSanti, M., Miskey, C., Leitner, J., Burns, R.D., Starin, S.R., Rodrigue, M., Fadali, M.S., Skelton, D., Hart, H.M., Hamilton, F., & Cheng, K.-P., 2002, ''UMBRAS: A Matched Occulter and Telescope for Imaging Extrasolar Planets,'' in IR Space Telescopes and Instruments, A.B. Schultz & R. Lyon, ed., Proc. SPIE, 4860, in press.

Smith, M.A., Robinson, R.D., & Henry, G.W. 2001, ''Correlated X-ray and optical variations in γCas (B0.5e),'' BAAS, 33, 1524.

Smith, M.A. & Robinson, R.D. 2002, ''Periods, Cycles, and Chaos in the High-Energy Emissions of γCas,'' ASP Conf. Series, ed. C. Sterken, in press.

Storrs, A.D., Makhoul, K., Gaffey, M.J., Landis, R., Vilas, F., Wells, E.N., Wood, C., & Zellner, B., 2001, ''Initial Analysis of HST Snapshot Images of Asteroids,'' BAAS, 33, 1117 (abstract).

Suchkov, A.A. & Schultz, A.B. 2001, ''Evidence for a Very Young Age of F Stars with Extrasolar Planets,'' ApJL, 549, L237.

Suchkov, A.A., Schultz, A.B., & Lisse, C. 2001, ''Candidate Dust Disk Systems from 2MASS–uvby data for F Stars,'' BAAS, 33, 1399 (abstract).

Suchkov, A.A., Schultz, A.B., & Lisse, C.M. 2002, ''Candidate PreMain-Sequence F Stars with Circumstellar Dust Identified Using Combined 2MASS and uvby Data,'' ApJL, 570, L29.

Taylor, D.K., Chance, D.R., Jordan, I.J.E., Patterson, A.P., Stanley, M., & Taylor, D.C. 2001, ''The Planning and Scheduling of HST: Improvements and Enhancements since Launch,'' BAAS, 33, 1316 (abstract).

Tremaine, S., Gebhardt, K., Bender, R., Bower, G., Dressler, A., Faber, S.M., Filippenko, A.V., Green, R., Grillmair, C., Ho, L.C., Kormendy, J., Lauer, T.R., Magorrian, J., Pinkney, J., & Richstone, D. 2002, ''The Slope of the Black-Hole Mass Versus Velocity Dispersion Correlation,'' ApJ, 574, 740.

Young, P.R., Dupree, A.K., Wood, B.E., Redfield, S., Linsky, J.L., Ake, T.B. & Moos, H.W 2001, ''Far Ultraviolet Spectroscopic Explorer Observations of Capella,'' ApJ, 555, 121.

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