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This report describes research performed from September 1999 through September 2000 by astronomers at the Computer Sciences Corporation (CSC).

1. INTRODUCTION

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 Hubble Space Telescope (HST) operations support and Multi-mission Archive at Space Telescope (MAST) support at the Space Telescope Science Institute (STScI), science support to NASA's Goddard Space Flight Center (GSFC) and Johns Hopkins University (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, S. Anderson, R. Arquilla, W. Baggett, J. Baum, J. Bedke, M. Bielefeld, J. Caplinger, D. Chance, G. Chapman, D. Christian, K. Clark, T. Ellis, M. England, L. Evans, D. Fraquelli, E. Giovane, A. Groebner, F. Hamilton, H. Hart, W. Hathaway, J. Hershey, A. Holm, C. Imhoff, D. Jones, I. Jordan, D. Kaufmann, D. Kenny, W. Kinzel, M. Kochte, V. Laidler, H. Lanning, C. Loomis, O. Lupie, D. MacConnell, L. Marochnik, G. Menchaca, J. Mo, R. Parise, S. Parsons, A. Patterson, P. Pitts, R. Pitts, C. Proffitt, M. Reinhart, M. Robinson, R. Robinson, J. Rose, W. Rumpl, F. Schiffer, A. Schultz, K. Scollick, J. Scott, D. Smith, M. Smith, C. Sturch, D. Swade, D. Taylor, T. Teays, R. Thompson, B. Turnrose, T. Walker, E. Wells, A. Welty, C. Wu, J. Younger, and D. Zak.

2. RESEARCH

2.1 Sun and Solar System

Christian, C. Lisse (STScI) and collaborators have reported the detection of charge exchange emission (CXE) between cometary neutrals and solar wind minor ions from Comet LINEAR 1999 S4 using the Chandra Advanced CCD Imaging Spectrometer (ACIS). The ACIS spectrum shows strong lines from O^{6+} and $N^{5+/6+}$ as well as several other weaker lines and it can be fit with a Mewe *et al.* (MEKAL) multiple line emission spectrum using solar elemental abundances with enhanced oxygen and nitrogen abundances, and a plasma temperature of 0.17 keV. Extreme Ultraviolet Explorer (EUVE) observations were coordinated with the Chandra observations. The EUVE light curve in the 100 Å

bandpass showed a large increase in the count rate (six times the average) correlated with the strong solar event on July 15.

Ellis began a comparison of modeled and observed column density profiles for comet Bradfield (1987s) in order to put constraints on some of the cometary gas parameters such as molecular lifetimes. Results of filter photometry of five comets obtained by Ellis and J. Neff (U Iowa) from 1985-1988 were published. Using this data, molecular column densities and production rates were found for comets Bradfield (1987s), Furuyama (1987f1), and P/Borrelly (1987p). The derived production rates for comet Bradfield were found to be consistent with an inverse square dependence on heliocentric distance. There were not enough observations of the other comets to determine this relationship. Production rate ratios for comets Bradfield and Furuyama were found to be consistent with the ratios expected for a "normal" comet, and had no significant dependence on heliocentric distance. For P/Borrelly no production rate ratios were found, since only the emission from CN molecules was observed.

2.2 Stellar Astronomy and Astrophysics

Ake, with A. Dupree (CfA), P. Young (CfA), J. Linsky (JILA), and N. Griffiths (UCB), worked on FUSE Early Release Observations of the rapidly rotating pre-main sequence star AB Doradus. This was the first cool star observed by FUSE. The integrated spectrum showed clearly resolved, rotationally broadened, chromospheric and transition region emission lines, with the strongest features being C III 977, 1175 Å and O VI 1032, 1037 Å. Many weaker lines were identified by comparing the spectrum with SUMER/SOHO solar limb data. Since the data were taken in time-tagged mode, time-variability studies were possible. Several small flares were seen in the strongest emission lines, one of which was bright enough to extract a spectrum. A broad, redshifted component extending to +600 km/sec was found in both O VI components during the flare. In addition, rotational modulation during the 12-hr. period of the star was found for the C III and O VI lines, with the features being brightest at minimum visual light, as would be expected for a spotted star. These observations demonstrated the excellent potential of FUSE for cool star studies.

Christian and T. Berghoefer (Hamburger Sternwarte) have been studying the stellar population in the young open cluster NGC 2244 in the Rosette Nebula. A successful observing run was carried out in February 1999 at the Kitt Peak National Observatory using the 0.9 meter and Mosaic imager (eight 2048 x 4096 CCDs arrayed to serve as a single large 8192 x 8192 detector). Multiple dithered images of the central position and 4 offset positions were obtained in B, V, R, I and H- α filters. Over 20,000 stars were detected down to a magnitude limit of 19.5 in the I band. Initial results indicate a substantial number of the cluster's members are still in the

pre-main sequence phase. Further analysis will allow study of the cluster's initial mass function, and the spectral types and extent of the x-ray emitters detected with ROSAT.

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, including white dwarf candidates, CVs, B shell stars, etc. The fifth in the continuing series of catalogs of UV-bright sources was published, providing a list of 108 additional UV sources. To date, 13 additional plate scans have been completed; the results are being prepared for publication.

Lanning and R. Wade (Penn State U) have obtained low-resolution spectroscopy of a number of Lanning UV sources found in the Sandage Two-color Survey of the Galactic Plane. These data were collected using the Hobby-Eberly 9-m Telescope at McDonald Observatory in Texas via the service observing program. Several sources exhibit very interesting features characteristic of low-luminosity objects and are currently being analyzed in detail.

MacConnell continues a collaboration with R. F. Wing (Ohio State) and E. Costa (U Chile) on analysis of near-IR, 8-color, narrow-band photometry and CCD slit spectra of 1560 stars identified on southern near-infrared objective-prism plates as possible supergiants. The aim is to identify, classify, and obtain distances and reddenings for distant, cool supergiants to better define the spiral arms in the Galaxy. About 250 supergiants have been identified including some which are 5-6 kpc from the Sun. A new collaboration started with David Alves (STScI) who obtained Q-scheduled V,I photometry at CTIO for 80 of the M supergiants during semester 2000A. The data are being analyzed for variability with the hope of determining periods for use in the period-luminosity relation found by Pierce *et al.* for red supergiant long-period variables. This would provide an independent check on distances derived from the 8-color photometry. As a by-product of the survey, four new S stars were found among the slit spectra and were published separately. Carbon stars are also marked on the plates; accurate positions have been obtained and charts made for 410 of them of which 164 are new. The list is being prepared for publication.

Parsons explored a spectral-class dependence of up to 2.5 mag in deviations found when comparing 21 absolute magnitudes derived for binary systems with Wilson-Bappu Ca II emission absolute magnitudes. Incorporating Hipparcos distances for about 360 giants and bright giants having Ca II K-line emission measurements, he recalibrated the Wilson-Bappu effect with spectral class corrections for emission widths greater than 60 km/s. With a precision of 0.6 mag, this extends the applicability of the Wilson-Bappu technique to absolute visual magnitudes of about -5 or distances of order 20 kpc.

Proffitt, with M. Quigley (U Wisc), has completed a study of boron abundances in early-B stars using the B III resonance doublet as observed in IUE high dispersion spectra. A roughly solar boron to iron ratio was found for most stars, but about one third of the sample, including all stars with enhanced nitrogen abundances, showed evidence for sub-

stantial boron depletion. As boron is destroyed by nuclear reactions at temperatures lower than those at which CN cycling takes place, the results support deep mixing in the stellar envelope as the cause of the observed nitrogen enhancements and boron depletion.

Proffitt is performing a detailed non-LTE study of carbon in the HgMn star χ Lupi. The goal is to check the consistency of non-LTE calculations by comparing them with the flux at far UV wavelengths where neutral carbon is the dominant opacity source, and with high resolution observations of UV lines from the lower levels of C I.

Proffitt has initiated a study of the radiative acceleration of very heavy elements (zinc through lead) in stellar envelopes in collaboration with F. Rogers and C. Iglesias (LLNL). This project uses state of the art opacity calculations to study the origins of the abundance anomalies seen in chemically peculiar stars. Observational work on the abundances of very heavy elements in both normal and chemically peculiar B stars also continues in collaboration with D. Leckrone (NASA/GSFC), G. Wahlgren (Lund U), and S. Adelman (Citadel).

Schultz, Hart, and Kochte in collaboration with F. Bruhweiler, M. DiSanti, C. Miskey (Catholic U), K.-P. Cheng (CSUF), and G. Schneider (U Arizona) have obtained HST WFPC2 observations of six nearby bright infrared excess stars. Preliminary results indicate the suspected circumstellar disks have not been detected in long exposure F555W filter observations, which places constraints on the disk grain sizes and/or inclination of the disk.

Schultz has worked with P. Kalas (STScI) on analysis of WFPC2 images of β Pictoris. The results support modeling of the disk as a series of spiral arms. Schultz and Kalas are also searching for the disk perturber by combining the WFPC2 observations with first epoch ground based CCD observations.

Smith, Robinson, and colleagues have continued work on the B0.5e star γ Cas, a star which shows unusual properties of ubiquitous X-ray flaring and an extraordinary high plasma temperature ($\approx 10^8$ K). Their work over the previous two years was based on a program of simultaneous Hubble/GHRS and X-ray (RXTE) satellite observations of this star lasting a full day. These investigators concluded that (1) the X-rays are emitted from primarily two X-ray active regions on or near the star's surface, and (2) UV continuum flux minima at these same times are caused by the occultation of the star by a pair of clouds forced into co-rotation over the star with a 1.123 day period. In another study based on the same GHRS data, Cranmer, Smith, and Robinson have examined the dependence of the high-velocity Discrete Absorption Components ("DACs") of the star's Si IV 1394-1403 Å resonance lines. These authors have derived densities for the DAC-forming region that are intermediate between that of the star's equatorial decretion disk and mid-latitude, ambient wind. They also find that subfeatures appear at low velocities and evolve to the blue with time, suggesting a spiral-shaped opacity enhancement which probably emanates from one of the two activity centers mentioned above. Several correlations of X-ray and UV flickering have been found in the data which can be found also in archival IUE and

Copernicus satellite data. The GHRS, IUE, and Copernicus data demonstrate that the silicon and iron ionization equilibria in the wind shifts to higher ionization states at times of increased X-ray flux. This is consistent with two major X-ray activity aggregates rotating into view, illuminating the wind in our line of sight.

Robinson and Smith have obtained additional X-ray (RXTE) data for γ Cas over two 1.1-day cycles. They found the X-ray fluxes repeat only roughly from one cycle to the next, implying that portions of archival X-ray data cannot be used to refine this ephemeris. The amplitudes of the flare-like “shot” component of this flux follow an exponent distribution, which is distinctly different than the power-law distribution observed for flares in active cool stars. In addition, these investigators find brief but robust interruptions every ≈ 7.5 hours in flare occurrences. The cause of this cycle is not yet understood. However, an unexpected discovery was that a 7.5-hour pattern was found in the blue-wings (DACs) of the resonance lines of Si IV and C IV of spectra of γ Cas. These wings are formed in the wind of this Be star, within a few stellar radii of its surface. This discovery demonstrates once again that the X-rays must be formed close to the stellar surface.

Smith finished work as editor of the proceedings of the IAU Colloq. No. 175 (“The Be Phenomenon in Early-Type Stars”). The proceedings were published as Vol. 214 of the ASP Conference Series.

2.3 Instrumentation

Ake presented a paper about the in-orbit performance of FUSE target acquisition and guide star tracking at a special session of SPIE Conference 4139 on Instrumentation for UV/EUV Astronomy and Solar Missions. While the FUSE flight software has performed as designed, problems have been encountered due to the small field of the Fine Error Sensor (FES), positional errors in the HST Guide Star Catalog, and stray light in the telescope baffles. Early in the mission, acquisitions were failing due to inaccuracies in the error-nulling maneuver when attempting to find guide stars in their expected positions. The problem was traced to the imprecise determination of spacecraft roll angle due to the small FES field of view (FOV) coupled with errors in the guide star catalog. Using different populations of stars in the FOV, roll errors as large as 1 degree are possible. This necessitated a change to the interface to the attitude control system, such that an additional small maneuver is performed when guide stars are first acquired. Other characteristics of the FES image processing, star identification, and guidance activities were summarized based on in-orbit data.

Schultz, Jordan, Hart, Fraquelli, Hershey, Hamilton, and Kochte, in collaboration with F. Bruhweiler, M. DiSanti, C. Miskey (Catholic U), K.-P. Cheng (CSUF), and M. Rodrigue, B. Johnson, M.S. Fadali (UNR) are involved in designing a Discovery or Explorer class space mission using a free flying occulter (UMBRAS). The goal of the project is to image extrasolar Jovians and possibly terrestrial planets about the nearest stars. Current spacecraft designs focus on a 1-2 meter telescope with an occulter craft for a 2-3 year mission. Diffraction studies are planned for the coming year.

2.4 Education and Outreach

Imhoff and Hart, with C. Grady (NASA/GSFC), are presenting several astronomy and space-related programs at the Howard County (Maryland) Library under a NASA IDEAS grant. The programs are intended for first- and second-grade students, and are given several times at the various branch libraries. Work is underway to create and distribute kits of astronomy-related materials which can be checked out and used for science exploration by the children.

Teays continued to serve as the Manager of the Education Group at the Space Telescope Science Institute and the Manager of the Origins Education Forum (currently serving as the Acting Director of the Forum). A major milestone for the Origins Education Forum this past year was the completion of the first version of the Space Science Education Resource Directory, which will be operated for NASA by STScI. This Directory contains a user-friendly interface which allows educators and scientists working on education projects to search by grade and topic or key word for education resources from NASA’s Office of Space Science.

3. ACKNOWLEDGMENTS

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