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1. INTRODUCTION

This report describes research performed from October 2002 through September 2003 by astronomers at the Computer Sciences Corporation (CSC).

Astronomical research 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 to 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, W. Baggett, G. Bower, D. Chance, A. Conti, M. Corbin, T. Ellis, M. England, L. Evans, D. Fraquelli, F. Hamilton, H. Hart, A. Holm, I. Jordan, D. Kaufmann, W. Kinzel, M. Kochte, H. Lanning, O. Lupie, D. MacConnell, L. Marochnik, R. McCutcheon, 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, 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.

Wells has corrected zero-point wavelength errors in HST Faint Object Spectrograph observations of small planetary satellites Amalthea, Thebe, and Miranda, and analysis of the resulting spectra is underway. The spectra were corrected by comparison to a solar analog star FOS grating spectrum which has been rebinned to the same wavelength scale and resolution. Correction of spectra of Uranian satellites Puck, Portia, and Juliet have proven to be more difficult because of low signal-to-noise and the presence of scattered light from Uranus.

Wells collaborated with A. Storrs, K. Makhoul (Towson U.), M. Gaffey (U. N. Dakota), F. Vilas (NASA HQ), R. Landis (JPL), C. Wood (U. N. Dakota), and B. Zellner (Ga. Southern U.) in HST photometry of binary asteroids 45 Eugenia, 87 Sylvia, and 107 Camilla. WFPC-2 images using the F439W, F673N, and F791W filters showed that the companions of 45 Eugenia and 107 Camilla were similar in color to their primaries, but the companion to 87 Sylvia was definitely bluer.

2.2 Stellar Astronomy and Astrophysics

Lanning, with M. Meakes (STScI), continues his analysis of the Sandage Two-color (U,B) Survey of the Galactic Plane. Plates taken with the 1.2m 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. We continue to examine plates and obtain accurate J2000 coordinates for newly identified UV-bright sources in preparation for the next catalog in the series. Detailed information related to this project (including published works, tables, and finding charts) is available at http://www.stsci.edu/~lanning/index.html.

MacConnell continues his collaboration with R. Wing (Ohio State) and E. Costa (U. Chile) in a survey for distant, cool supergiants in the southern Milky Way. A by-product of this objective-prism-based search is the detection of cool carbon stars, and he published a list of 759 with finding charts and improved coordinates including 289 new ones. A study was made of 2MASS colors and surface distribution of cool carbon stars. MacConnell spent a month at the CDS in Strasbourg working with collaborator W. Osborn (Central Mich. U.) on improving the positions and cross-identifications for the 1100+ carbon stars published by Westerlund in 1971 using an unpublished set of charts made available by him. These improvements will be incorporated into SIMBAD and the carbon star catalogue maintained by the Latvian group.

Parsons continued refining SED analysis and isochrone fits with the aim of deriving the absolute magnitudes of 136 evolved late-type stars which have upper main-sequence secondaries with IUE spectra (see Parsons & Ake 1998, ApJS, 119, 83). Many SED fits are now better constrained with 2MASS magnitudes and Hipparcos/Tycho component photometry. A paper is being submitted for publication on 16 newly deduced triple systems, using several consistency criteria, and 17 confirmed triple systems among this sample.

Parsons, with O. Franz and L. Wasserman (Lowell), continued work on the properties of the G4 II + B9 binary star β Sct observed with HST's FGS3 astrometer in TRANS/POS modes. The POS mode solutions indicate orbital reflex motion of the primary at the level of a mere 5 mas. A paper is nearing completion to publish what can be learned from these measurements.

Proffitt, in collaboration with S. Adelman (The Citadel), G. J. 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 HST/STIS study of the 1487.9 Å N IV hyperfine line in the planetary nebula NGC 3918. This study yielded the first measurment of a transition probability for this class of hyperfine transitions, confirming previous theoretical calculations, and also provided a powerful new diagnostic for very low-density plasmas.

Proffitt, in collaboration with T. Brage (Lund) and 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.

Schultz and many collaborators continue investigations into extra-solar planetary systems. A Fine Guidance Sensor (FGS) onboard HST has been used as a photometer to observe the transits of the close-in, extra-solar planet in the HD 209458 system (Schultz *et al.* 2003). FGS transit results for the orbital inclination and size of the planet are consistent with previously reported observations. To date, none of the analysis indicates the presence of a moon.

M. Smith and C. S. Jeffery (Armagh Obs.) have completed a spectroscopic analysis of BW Vulpeculae, the ''strongest known pulsator in the Galaxy,'' through its radial pulsation cycle by means of high-resolution data obtained recently at the McDonald Observatory and archival UV data from the IUE satellite. Contrary to several earlier reports, Smith and Jeffery find that inferred phase delays in the variations of various line profiles (the so-called ''Van Hoof'' effect) can be ascribed to an optical depth effect during the contraction phase. According to the traditional interpretation, weak lines respond to upward shock waves in the atmosphere before strong lines do. These authors report, instead, that the various lines in the ground-based data respond to shock waves moving through the atmosphere at essentially the same time - only the UV resonance lines are formed in a distinctly different (higher) atmospheric level. This realization should permit the the construction of the first hydrodynamic model atmospheres for BW Vul and other stars with strong, shock-driven pulsations.

2.3 Extragalactic Astronomy

Conti, while a member of the Pittsburgh Computational Astrostatistics Group, analyzed the photometric information contained in individual pixels of galaxies in the Hubble Deep Field North (HDF-N) using a new technique, *pixel-z*, that combines predictions of evolutionary synthesis models with photometric redshift template fitting. Using this technique, Conti derived the star formation and metallicity histories of galaxies in the HDF-N. The results show that the comoving density of star formation rate, determined from the UV luminosity density of sources in the HDF-N, increases monotonically with redshift out to $z \geqslant 5$. He determined that the information contained in individual pixels in a galaxy could be linked to its morphological history.

Corbin, in collaboration with W. Freudling (Space Telescope - European Coordinating Facility) and K. Korista (W. Michigan U.) completed a program to obtain near-infrared spectra of five QSOs in the redshift range $5.3 < z < 6.3$ using the HST's NICMOS. The goal of this program was to search for emission in the broad Fe II complex centered at approximately 2500 Å in the QSO rest-frame and compare its strength to that in the Mg II line at 2800 Å. This in turn allows an estimate of the ratio of the abundances of these elements. Corbin and collaborators find that these QSOS, discovered in the Sloan Digital Sky Survey, have Fe II/Mg II ratios very similar to those measured for QSOs at lower redshifts and are consistent with a metallicity near or above the solar level. If this metal enrichment were produced by Type Ia supernovae, then the progenitor stars likely formed at $z = 20 \pm 10$, in agreement with the results of the WMAP satellite concerning the first epoch of the reionization of the universe. The high metallicity of the objects also indicates that the host galaxies are very massive, possibly the progenitors of giant elliptical galaxies. A press release on these results was issued by the Space Telescope European Coordinating Facility, and an article about them appeared in *Science News* (2003, 163, 278).

Corbin is also serving on the team at STScI, headed by S. Beckwith, that is obtaining HST Advanced Camera for Surveys observations of a region of the Chandra Deep Field South to unprecendented depth ($AB_V \sim 29$). This ''Ultra Deep Field'' will also include observations with the NICMOS detectors and will represent the deepest view of the universe at optical and infrared wavelengths ever made. It may reveal galaxies and their progenitors at redshifts above any currently known. These observations involve 400 HST orbits allocated under Director's Discretionary time. The data will be made available to the public in February 2004 through MAST (and its affiliates in Europe and Canada) without any prior scientific analysis performed by the STScI team involved in obtaining the data.

2.4 Instrumentation & Instrument Design

Fraquelli, with A. Schultz, H. Hart, H. Bushouse (STScI), and P. Vener (Loyola College) submitted a paper to PASP on coronagraphy with HST's NICMOS. Coronagraphy is a special mode of NICMOS that has been used to detect companions and disks about stars and to observe the structure about AGNs. A coronagraphic observing program should be structured differently for detecting companions than for imaging disks or surrounding structure. The technique of rolling the HST within a single orbit to allow the target to be used as its own PSF standard is preferred when imaging faint, point sources close to bright targets. The authors find that a roll of the spacecraft in mid-orbit between exposures yields a gain of ~ 0.5 magnitude in light supression in the wings of the PSF as compared to images obtained in consecutive orbits,

with a spacecraft roll between the orbits. Imaging disks or surrounding nebulosity is best performed by observing separate PSF standard stars.

Schultz, with I. Jordan, M. Kochte, H. Hart, F. Hamilton, D. Fraquelli (CSC), R. Lyon, K. Carpenter, J. Leitner, D. Starin (NASA/GSFC), F. Bruhweiler, C. Miskey (IASC/CUA), M. Rodrigue, M. Fadali (U. Nevada-Reno), K.-P. Cheng (CSUF), and D. Skelton (Orbital) continues to explore an alternate concept, a free-flying external occulter, for the Terrestrial Planet Finder (TPF) program. Current work involves optical simulations performed at GSFC using the Optical Systems Characterization and Analysis Research (OSCAR) software package. The combination of an external occulter and apodization yields the required contrast ($>10^{10}$ in light suppression) in the null regions of the PSF essential for exo-planet detection. A space-based, free-flying occulter-type mission has several important advantages when compared to other proposed TPF missions: (i) starlight is reduced before entering the telescope, (ii) light scatter within the telescope is reduced due to less star light entering the telescope as well as fewer obstructions within the telescope, and (iii) the optical tolerances are obtainable with current technology (i.e., HST-type optics).

2.5 Education and Outreach

A. Schultz was an invited speaker at an astronomy class for middle school teachers which was held in Columbia, MD. He spoke on the search for extra-solar 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 and high school teachers which was held at U. Nevada-Reno. The U. Nevada teachers' workshop was held as part of a HST Education and Public Outreach proposal.

3. ACKNOWLEDGMENTS

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PUBLICATIONS

This list includes papers published or submitted between October 2002 and September 2003 by CSC staff. Some papers cited here may have been included as *submitted* or *in press* in the previous annual report.

Adler, D.S., Taylor, D.K., & Patterson, A.P. 2002, ''Twelve years of planning and scheduling the Hubble Space Telescope: process improvements and the related observing efficiency gains,'' Proc. SPIE, 4844, 111.

Boynton, W.V., Taylor, G.J., Evans, L.G. & 9 coauthors 2003, ''Results from the Mars Odyssey Gamma-Ray Spectrometer: Distribution of Volatile and Rock-forming Elements,'' BAAS, 35, 924 (abstract).

Brage, T., Judge, P.G., & Proffitt, C.R. 2002, ''Determination of Hyperfine-Induced Transition Rates from Observations of a Planetary Nebula,'' Phys. Rev. Lett., 89, 1101.

Conti, A., Connolly, A.J., Hopkins, A.M., Budavári, T., Szalay A.S., Csabai, I., Schmidt, S.J., Adams, C., Petrovic, N. 2003, ''The Star Formation History of Galaxies from Individual Pixels: I. The Hubble Deep Field North,'' astro-ph/0307470, AJ, in press.

Davies, J., Goudfrooij, P., Bohlin, R.C., Stys, D.J., Brown, T.M., Walborn, N.R., & Proffitt, C.R. 2003, ''Flux Calibration of the STIS CCD: Correcting for Charge Transfer Inefficiency and Time-Dependent Sensitivity,'' BAAS, 202, 407 (abstract).

Díaz-Miller, R.I., Kim Quijano, J., Valenti, J., Proffitt, C.R., Sahu, K.C., Bohlin, R.C., Brown, T.M., & Lindler, D. 2002, ''Recent Improvements to the STIS Pipeline Calibration'' in 2002 HST Calibration Workshop, STScI, Baltimore, MD, eds. S. Arribas, A. Koekemoer, & B. Whitmore, p. 190.

Evans, L.G., Reedy, R.C., & Boynton, W.V., 2003, ''Effects of Solar Particles on the Mars Odyssey Gamma-Ray Spectrometer,'' 34th Annual Lunar and Planetary Science Conference, Mar. 17-21, League City, Texas, abst. no.1591.

Evans, N.R., Carpenter, K.C., Robinson, R., Kienzle, F. & Dekas, A. 2003, ''High Mass Triple Systems: The Classical Cepheid Y Car,'' BAAS, 35, 755 (abstract).

Fraquelli, D.A. Arquilla, R., Ellis, T., Hamilton, F.C. Holm, A., & Kochte, M. 2002, ''Feedback loops from the Hubble Space Telescope data processing system,'' Proc. SPIE, 4844, 528.

Fraquelli, D.A., Schultz, A.B., Bushouse, H., Hart, H.M., & Vener, P. 2003, ''NICMOS Coronagraphy,'' submitted to PASP.

Freudling, W., Corbin, M.R., & Korista, K.T. 2003, ''Iron Emission in $z\sim6$ QSOS,'' ApJ, 587, L67.

Gebhardt, K., Richstone, D., Tremaine, S., Lauer, T.R., Bender, R., Bower, G. & 9 coauthors 2003, ''Axisymmetric Dynamical Models of the Central Regions of Galaxies,'' ApJ, 583, 92.

Grady, C.A., Proffitt, C.R., Malumuth, E.M., Woodgate, B.E., Gull, T.R., Bowers, C.W., Heap, S.R., Kimble, R.A., Lindler, D., & Plait, P. 2002, ''Coronagraphic Imaging with HST and STIS'' in 2002 HST Calibration Workshop, STScI, Baltimore, MD, eds. S. Arribas, A. Koekemoer, & B. Whitmore, p. 137.

Grady, C.A., Proffitt, C.R., Malumuth, E., Woodgate, B.E., Gull, T.R., Bowers, C.W., Heap, S.R., Kimble, R.A., Lindler, D., Plait, P., & Weinberger, A. 2003, ''Coronagraphic Imaging with the Hubble Space Telescope and the Space Telescope Imaging Spectrograph,'' PASP, 115, 1036.

Holm, A.V. 2002, ''Additional Information on Dorrit Hoffleit's 'Maria Mitchell Observatory','' JAAVSO, 30, 151.

Jordan, I.J.E., Wu, C.-C., Schultz, A.B., Kochte, M., & Hart,

H.M. 2003, ''NOME: Modifying Nexus into an Occulter for use with NGST,'' JBIS, 56, 218.

Jordan, I.J.E., Hart, H.M., Schultz, A.B., Starkman, G., Copi, C., & Lyon, R. 2003, ''The Advantages of Multiple Coronagraphic Vehicles in Occulter Missions,'' in Proc. AIAA Space 2003, Long Beach, CA, ed. J. Ling, in press.

Kochte, M., Schultz, A.B., Bruhweiler, F., Fraquelli, D., Lyon, R., Jordan, I.J.E., Carpenter, K.G., DiSanti, M., Miskey, C., Rodrigue, M., Fadali, M.S., Skelton, D., Hart, H.M., & Cheng, K.-P. 2003, ''Imaging Terrestrial Planets,'' in The Search for Other Worlds, Oct. 13-14, 2003, U. Maryland, eds. S.S. Holt and D. Deming, in press.

Kochte, M., Scott, J., Parsons, S., Kenny, D., & Giovane, E. 2002, ''Evolution of science data processing for the Hubble Space Telescope: a user's perspective,'' Proc. SPIE, 4844, 204.

Kruk, J.W., Class, B.F., Rovner, D., Westphal, J., Ake, T.B., Moos, H.W., Roberts, B.A., & Fisher, L. 2003, ''FUSE in-orbit attitude control with two reaction wheels and no gyroscopes,'' Proc. SPIE, 4854, 274.

Lauer, T.R., Gebhardt, K., Richstone, D.. Tremaine, S., Bender, R., Bower, G. & 12 coauthors 2002, ''Galaxies with a Central Minimum in Stellar Luminosity Density,'' AJ, 124, 1975.

MacConnell, D.J. 2003, ''Southern Cool Carbon Stars Found on Near-Infrared Objective Prism Plates,'' PASP, 115, 351.

Oliversen, R.J., Morgenthaler, J.P., Scherb, F., Woodward, R.C., Smyth, W.H., & Lupie, O.L. 2002, ''Ground-based Observations of Io [O I] 6300 Å Emission During the Galileo I24, I25, and Cassini Encounters,'' American Geophysical Union, Fall Meeting 2002, abst. P21B-0377.

Parsons, S.B. 2002, ''Finding Triple Stars Among Cool + Hot Binaries,'' BAAS, 34, 1224 (abstract).

Pinkney, J., Gebhardt, K., Bender, R., Bower, G. & 10 coauthors 2003, ''Kinematics of 10 Early-Type Galaxies from Hubble Space Telescope and Ground-based Spectroscopy,'' ApJ, 596, 903.

Proffitt, C.R., Davies, J.E., Brown, T.M., & Mobasher, B. 2002, ''Absolute Flux Calibration of STIS Imaging Modes,'' in 2002 HST Calibration Workshop, STScI, Baltimore, MD, ed. S. Arribas, A. Koekemoer, & B. Whitmore, p. 202.

Proffitt, C.R., Goudfrooij, P., Brown, T.M., Davies, J.E., Díaz-Miller, R.I., Dressel, L., Kim Quijano, J., Maíz-Apellániz, J., Mobasher, B., & 9 other coauthors 2002, ''STIS Calibration Status,'' in 2002 HST Calibration Workshop, STScI, Baltimore, MD, eds. S. Arribas, A. Koekemoer, & B. Whitmore, p. 97.

Redfield, S., Linsky, J.L., Ake, T.B., Ayres, T.R., Dupree, A.K., Robinson, R.D., Wood, B.E., & Young, P.R. 2002, ''A Far Ultraviolet Spectroscopic Explorer Survey of Late-Type Dwarf Stars,'' ApJ, 581, 626.

Redfield, S., Ayres, T.R., Linsky, J.L., Ake, T.B., Dupree, A.K., Robinson, R.D., & Young, P.R. 2003, ''A Far Ultraviolet Spectroscopic Explorer Survey of Coronal Forbidden Lines in Late-Type Stars,'' ApJ, 585, 993.

Reedy, R. C., Evans, L. G., Brückner, J., Kim, K.J., & Boynton, W.V. 2003, ''Gamma Rays in a Spectrum from the Mars Odyssey Gamma-Ray Spectrometer,'' 34th Annual Lunar and Planetary Science Conference, Mar. 17-21, League City, Texas, abst. no.1592.

Sahnow, D.J., Dixon, W.V., Fullerton, A.W., Kaiser, M.E., Dupuis, J., Robinson, R.D., Barrett, P.E., Hsu, J.C., & Massa, D. 2002, ''A New Design for the FUSE Science Data Calibration Pipeline,'' BAAS, 34, 1203 (abstract).

Schultz, A.B., Kinzel, W., Kochte, M., Jordan, I.J.E., Hamilton, F., Henry, G., Vogt, S., Bruhweiler, F., Storrs, A., Hart, H.M., Bennum, D., Rassuchine, J., Rodrigue, M., Hamilton, D.P., Welsh, W.F., & Taylor, D.C. 2003, ''HST/FGS Photometry of Planetary Transits of HD 209458b,'' in The Search for Other Worlds, Oct. 13-14, 2003, U. Maryland, eds. S.S. Holt & D. Deming, in press.

Schultz, A.B., Lyon, R.G., Kochte, M., Jordan, I., Bruhweiler, F., Carpenter, K.G., Fraquelli, D.A., Leitner, J., DiSanti, M.A., Miskey, C., Starin, S.R., Rodrigue, M., Fadali, M.S., Skelton, D., Hart, H.M., & Hamilton, F. 2003, ''Imaging terrestrial planets with a free-flying occulter and space telescope: an optical simulation,'' in Techniques and Instrumentation for Detection of Exo-Planets, Proc. SPIE, in press.

Schultz, A.B. and the STScI NICMOS Group 2003, ''Post-NCS Performance of the HST NICMOS,'' in IR Space Telescopes and Instruments, ed. J.C. Mather, Proc. SPIE 4850, 858.

Schultz, A.B. and the STScI NICMOS Group 2002, ''NICMOS Status,'' in 2002 HST Calibration Workshop, STScI, Baltimore, MD, eds. S. Arribas, A. Koekemoer, & B. Whitmore, p. 215.

Schultz, A.B. & Bushouse, H. 2002, ''Combining NICMOS Parallel Observations,'' in 2002 HST Calibration Workshop, STScI, Baltimore, MD, eds. S. Arribas, A. Koekemoer, B. Whitmore, p. 271.

Siopis, C., Aller, M.C., Bender, R., Bower, G. & 13 coauthors 2002, ''A Comparison of Estimates of the Black Hole Mass in the Maser Galaxy NGC 4258,'' BAAS, 34, 1219 (abstract).

Slee, O.B., Willes, A.J., & Robinson, R.D. 2003, ''Long-duration Coherent Radio Emission from the dMe Star Proxima Centauri,'' PASA, 20, 257.

Smith, M.A. 2003, ''Far-UV Analysis of Bp Stars with Co-rotating Disks,'' Conf. on Magnetic Fields in O, B, & A Stars, eds. L. Balona, H. Henrichs, & T. Medupe, ASP Conf. Ser. 305, p. 310.

Smith, M.A. & Robinson, R.D. 2003, ''Periods, Cycles, and Chaos in the High-Energy Emissions of γ Cas,'' in Interplay of Periodic, Cyclic, and Stochastic Variability in Selected Areas of the H-R Diagram, ed. C. Sterken, ASP Conf. Ser. 292, p. 263.

Smith, M.A. & Jeffery, C.S. ''Spectral Response of the Pulsationally Induced Shocks in the Atmosphere of BW Vulpeculae,'' MNRAS, 341, 1141.

Storrs, A.D., Makhoul, K., Wells, E.N., Gaffey, M.J., Vilas, F., Landis, R.R., Wood, C., & Zellner, B. 2002, ''Imaging Asteroidal Companions with the Hubble Space Telescope (HST),'' BAAS, 34, 861 (abstract).

Stys, D.J., Walborn, N.R., Busko, I., Goudfrooij, P., Proffitt, C., & Sahu, K. 2002, ''Sensitivity Monitor Report for the STIS First-Order Modes,'' in 2002 HST Calibration Workshop, STScI, Baltimore, MD, eds. S. Arribas, A. Koekemoer, B. Whitmore, p. 206.

Wakker, B.P., Savage, B.D., Sembach, K.R., Richter, P., Meade, M., Jenkins, E.B., Shull, J.M. Ake, T.B., & 13 coauthors 2003, ''The Far Ultraviolet Spectroscopic Explorer Survey of O VI Absorption in and near the Galaxy,'' ApJS, 146, 1.

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