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1. INTRODUCTION

This report describes research performed from September 1996 through September 1997 by astronomers at the Computer Sciences Corporation (CSC).

Research in astronomy at CSC is primarily performed by members of Science Programs, System Sciences Division. Dr. C. Wu is the Director of Science Programs, replacing Dr. P. Perry who has retired. Science Programs staff members provide science support to NASA's Goddard Space Flight Center (GSFC). One group, headed by Dr. C. Wu, provides Hubble Space Telescope (HST) operations support at the Space Telescope Science Institute (STScI). A second group, led by Dr. B. Turnrose, supported the International Ultraviolet Explorer (IUE) satellite until the IUE Project ended in October 1997. In addition, staff members work with the ASTRO Ultraviolet Imaging Telescope (UIT), the Goddard High Resolution Spectrograph (GHRS), and the Space Telescope Imaging Spectrograph (STIS) within GSFC's Laboratory for Astronomy and Solar Physics. In addition to their support work, CSC astronomers are active in a wide range of research activities supported by NASA and NSF contracts.

Astronomers and research assistants at CSC during this reporting period were D. Adler, V. Airapetian, T. Ake, S. Anderson, R. Arquilla, W. Baggett, V. Balzano, J. Baum, J. Bedke, M. Bielefeld, R. Bradley, J. Caplinger, D. Chance, G. Chapman, K. Clark, D. Crenshaw, T. Ellis, M. England, L. Evans, G. Fireman, D. Fraquelli, M. Garhart, E. Giovane, M. Goodman, A. Groebner, F. Hamilton, H. Hart, W. Hathaway, J. Hershey, A. Holm, C. Imhoff, R. Jackson, A. Johnston, D. Jones, I. Jordan, D. Kaufmann, D. Kenny, W. Kinzel, M. Kochte, S. Kraemer, V. Laidler, H. Lanning, C. Loomis, O. Lupie, D. MacConnell, L. Marochnik, B. McCollum, G. Menchaca, J. Mo, R. Parise, S. Parsons, A. Patterson, P. Perry, P. Pitts, R. Pitts, K. Plett, C. Proffitt, L. Rawley, K. Reinhart, R. Robinson, J. Rose, J. Sandoval, F. Schiffer, A. Schultz, M. Schlegel, J. Scott, W. Sears, M. Smith, S. Snell, D. Steinberg, S. Streit, C. Sturch, D. Swade, D. Taylor, T. Teays, R. Thompson, B. Turnrose, G. Wahlgren, T. Walker, E. Wells, A. Welty, W. Workman, C. Wu, J. Younger, and D. Zak.

2. RESEARCH

2.1 Solar System

Ellis continued work on data obtained for five comets with J. Neff (Iowa) using a scanning filter photometer. Narrow-band filters were used to isolate molecular emission from C2, C3, and CN, and a pair of filters in the blue and UV continuum were used to study the sunlight scattered by cometary dust. Column densities, production rates, and production rate ratios were found to be consistent with the results of others. The production rate ratios for Comet Bradfield (1987s) were plotted as a function of sun-comet distance, since the data for this comet was obtained over the longest period of time, and it was found to be essentially constant within the uncertainties.

Marochnik has proposed a method for measuring the albedo of bodies populating the Kuiper belt (KB). This albedo likely refers to a primordial substance of the solar system because the KB population was not exposed to significant thermal and gravitational evolution over the lifetime of the solar system. Knowing the albedo of KB bodies, one can estimate the actual sizes of objects which have been observed in recent years by ground-based optical telescopes. The albedo can be directly measured by the location of the maximum of the KB infrared spectrum.

Wells, B. Zellner (Georgia Southern), R. Binzel (MIT), M. Gaffey (RPI), P. Thomas (Cornell), and A. Storrs (STScI) used the HST Plantary Camera to obtain images of asteroid 4 Vesta at eight rotational epochs in late 1994 and at six rotational epochs in May 1996. The 1994 images gave an improved spin pole position, shape, and size, allowed the identification of several albedo features, and gave the first geologic map of the geologically diverse surface. The 1996 images were made near a perihelic opposition when the apparent diameter was 0.6 arcseconds. A large impact crater was discovered near the south pole of Vesta with a diameter of 460 kilometers and a depth of 13 kilometers. The impact excavated about 1 percent of the mass of Vesta and may be the source of the family of small Vesta-like asteroids and the basaltic achondrite meteorites.

Wells, D. McCarthy (Arizona), R. Binzel (MIT), J. Drummond (Phillips Lab), M. Gaffey (RPI), K. Hege (Arizona), L. Lebofsky (Arizona), P. Thomas (Cornell), and B. Zellner (Georgia Southern) used the NICMOS instrument on HST to image asteroid 4 Vesta in six near-IR bands in the range of 0.95-2.2 microns. The images will be used to map the depths of the 1.0 and 2.0 micron mineral bands, which give diagnosic information on the type and amount of pyroxene and feldspar minerals.

Wells, K. Seidelmann (Naval Obs.), A. Bosh (Lowell Obs.), D. Currie (Maryland), D. Pascu (Naval Obs.), J. Rohde (Naval Obs.), A. Storrs (STScI), and B. Zellner (Georgia Southern) used WFPC2 on HST to obtain 36 images of the Neptune system in B, V and I filters. Four of the inner satellites discovered by Voyager 2 have been recovered, and improved orbital elements will be calculated. The images with shortest exposures show extensive clouds that reach almost around the planet in several latitude bands. The ring arcs of Neptune were not visible.

2.2 Stellar Astronomy and Astrophysics

Robinson, Airapetian and K. Carpenter (NASA/GSFC) analyzed and interpreted time series observations of the RS CVn star HR 1099 taken with the GHRS aboard the HST. Physical parameters of the transition region and corona have

been derived. The heating process which involves the damping of MHD turbulence, which might be generated by nonlinear surface Alfvén waves, is discussed. Possible contribution of MHD turbulence and microflares to the atmospheric heating is discussed.

Airapetian and G. Holman (NASA/GSFC) proposed a possible interpretation of an interrelationship between ''quiescent'' soft X-ray (SXR) and microwave luminosities observed in active stars. It can be explained through two possible heating mechanisms. While the quiescent SXR emission has a thermal, coronal-like nature, the quiescent microwave emission is usually nonthermal gyrosynchrotron radiation. This correlation is discussed in terms of the ability of heating mechanisms to accelerate the required number of electrons to mildly relativistic energies. They analyzed the observational signatures of two models involving heating and electron acceleration by electric currents. The first model proposes that the energetic electrons are accelerated by the electric field in classical current sheets within the stellar coronae. The second considers MHD turbulence cascading down to smaller scales in the presence of current sheets, exciting ion acoustic waves. These waves enhance the heating and particle acceleration in the stellar transition zone. Differences between RS CVn and solar-like stars are discussed in terms of these models. Explicit expressions for the SXR – microwave relationship are derived and discussed.

Airapetian, Ofman, J. Davila (NASA/GSFC) and Carpenter (NASA/GSFC) continued 2.5D MHD calculations of stellar winds from luminous late-type stars using an existing, 2.5D, non-linear MHD code recently developed by Ofman and Davila. First calculations have been performed for the stellar wind model from a red supergiant, α Ori. They assume that the wind is initiated in a hydrostatic atmosphere with an isothermal pressure scale height of 0.072 R^* and a ''chromospheric hole'' modeled by a transverse density structure and a radial magnetic field. To ensure that the terminal velocity of the wind is accurately assessed, the calculations were carried out to a height of 20 stellar radii. They find that in the higher density (low Alfvén velocity) regions outside of the ''chromospheric hole'' the Alfvén waves are freely propagating. Ponderomotive forces associated with these waves drive radial, compressive motions and contribute to stellar wind acceleration. The compressive motions then excite slow magnetosonic waves which non-linearly steepen into solitary waves that propagate on top of a background flow. This situation is similar to solar coronal hole models. In the lower density ''chromospheric hole'' region the Alfvén wave are strongly reflected, and produce a substantial outflow. The wind is initiated relatively low in the atmosphere and accelerates to a terminal velocity of about 10 km/s. First results are in qualitative agreement with observational signatures of winds in cool, luminous late-type stars.

Goodman continued to develop MHD models to support the proposition that the solar chromospheric network, and possibly the internetwork, is heated by resistive dissipation of large scale electric currents associated with magnetic loops in weakly ionized plasma. The currents have typical scale heights of several hundred kilometers, and are dissipated in magnetic loops with horizontal spatial extents of several thousand kilometers. Although it is generally believed that the heating mechanism in the network is MHD, there is controversy as to whether the heating mechanism in the internetwork is primarily hydrodynamic or MHD. Recent observations of 500 G magnetic fields in the photospheric internetwork and theoretical and observational evidence of a spatial correlation between regions of internetwork heating (bright points) and magnetic elements suggest that the bright points are MHD phenomena.

Goodman developed an MHD model of the transition region (TR) which includes the classical thermoelectric and conductivity tensors, and electron pressure gradient effects in Ohm's law. The results of the model indicate that: heating by large scale current dissipation is insignificant; the magnetic field aligned electron heat flux driven by the temperature gradient between the corona and TR is sufficient to heat the TR; thermoelectric and electron pressure gradient effects, usually neglected, are important in determining currents and thermal energy flux; the TR may not be force free, contrary to what is usually assumed; and anomalous transport processes are not important in determining the large scale properties of the TR. Here large scale refers to height ranges of 100 - 1000 km. The results on heating are consistent with the view that the TR is heated by a combination of thermal energy flux from the corona, and in situ heating due to small scale current dissipation.

Lanning has continued his analysis of the Sandage two-color (U,B) survey of the galactic plane from plates taken with the 48-inch Oschin Schmidt telescope at Palomar Observatory. Objects with U-B colors bluer than 0.0 are identified in search of white dwarf candidates, CVs, etc. A fourth catalog of UV-bright sources was submitted for publication in September 1997, and two additional lists of objects are in work. M. Meakes (STScI) is assisting in the extraction of images from the HST Guide Star Plate Archive and processing of finding charts. A poster paper was presented at the Third Conference on Faint Blue Stars describing the current status of the survey analysis, including updated lists of objects and a discussion of overlapping surveys and pointed observations such as those obtained with ROSAT and EUVE. Most material related to this project including published works, tables, and finding charts has been posted on the WWW site devoted to the survey at http://scivax.stsci.edu/~lanning/index.html.

MacConnell continues collaboration with R. F. Wing (Ohio State) and E. Costa (Chile) analyzing near-IR, 8-color photometry obtained at CTIO and CCD spectra from CTIO, Las Campanas, and La Silla of about 1500 K and M galactic supergiant candidate stars found on southern, near-infrared, objective-prism plates. Over 140 cool supergiants have been identified thus far some of which may be 5-6 kpc from the Sun. MacConnell has started a collaboration with J. Hershey to automate classification of the spectra.

MacConnell, W. H. Osborn and R. Miller (Centr. Mich.) have completed their reduction of data from the HST Fine Guidance Sensors to determine trigonometric parallaxes of the two subluminous, high-velocity stars, Ross 50 and Wolf 624. The parallaxes are close to the spectrophotometric ones

and support a value for the galactic escape velocity of about 475 km/sec at the solar circle.

MacConnell hosted a visit of K.V.K. Iyengar (Indian Inst. of Astrophysics) for the purpose of studying the correlations of IRAS colors with the M spectral types determined for about 10,000 Point Sources. They find that the color indices increase with later type indicating thicker circumstellar envelopes (CSE) around the later M stars. These fainter sources also have thicker CSE than do mid-M stars in the BSC.

Parsons continued to work on a study of more than 100 cool plus hot binary star pairs. IUE data are used to yield spectral classification and UV-optical flux fitting. In addition, new data, including Hipparcos-Tycho parallax and photometry data and newly published binary separations and magnitude differences, are being incorporated into the study.

Parsons and O. Franz (Lowell Obs.) are obtaining HST observations of the G4 II star HD 173764 with the FGS in TRANS/POS modes to resolve the secondary stellar component and determine both components' masses. From IUE observations and analysis of the total UV-optical energy distribution, Parsons determined that the secondary has a spectral class of B9 and a difference in visual luminosity of about 3.3 mag. Using the spectroscopic period of 832.5 days and isochrone fitting, he obtained estimates of 5 and 2.5 solar masses for the G4 and B9 components, and 0.023 arcsec for the projected major axis of the system. This combination of separation and magnitude difference pushes the current limits of HST astrometry, prior to scientific use of the FGS-1 replacement unit. Taking careful account of color and other effects, analysis of two observation sets near apastron produce clear non-single-star results which can be fitted to an orbit having the above major axis.

Proffitt and Wahlgren with D. S. Leckrone (NASA/GSFC), J. Brandt (Colorado) and T. Brage (Univ. of Lund) have continued to work on HST/GHRS spectra of the chemically peculiar stars χ Lupi and HR 7775. This work includes extensive non-LTE and radiative force calculations for mercury and other heavy elements, and has lead to improved understanding of the causes of line profile anomalies observed in these stars.

Proffitt is also engaged in a study of the B III resonance line in early B stars, using HST/GHRS and IUE data. The goal of this work is to determine boron abundances for a large number of such stars, and to measure the boron isotope ratio in two of the most slowly rotating ones.

Schultz, Hart, Hamilton, Hershey, and Kochte in collaboration with J.C. Brandt (Colorado), F. Benedict (McDonald Obs.), F. Bruhweiler (CUA), J. Caldwell, C.C. Cunningham (York), O.G. Franz (Lowell Obs.), and C.D. Keyes (STScI) have completed a direct detection search for faint companions about six nearby stars using the Faint Object Spectrograph (FOS) onboard HST in coronagraphic mode. New orbital elements were derived for the calibration target Wolf 424AB. A possible companion was detected about the nearest star to the Sun, Proxima Centauri.

Schultz in collaboration with S. Baum, M. Clampin, S. Hulbert, M. McGrath (STScI), F. Allard (WSC), and F. Bruhweiler (CUA) STIS CCD optical spectra of the brown dwarf Gl 229B following the HST Second Servicing Mission February 1997. The optical spectrum of Gl 229B is quite different from late M-dwarfs or the hotter brown dwarfs recently discovered in the field.

In a study of λ Eri, Smith, Plett, and colleagues D. Cohen, J. MacFarlane (Wisconsin), I. Hubeny (USRA), G. Basri (California/Berkeley), and C. Johns (Texas) have found that the appearance of transient emission in the 6678 Å singlet line within the photospheric absorption profile is matched by transient emission of similar strength in the analog 5876 Å triplet line. Smith's group simulated these features with models of elevated model slabs with a variety of geometrical and radiative properties. They find that the illumination of high energy (EUV/X-ray) flux sources such as flares depletes the HeI column density, rendering HeI features undetectable. Detectable features can be produced when the model slab has a high density ($10^{12} cm^{-3}$) and a moderately large optical depth in the optical HeI lines. The key to producing this emission is for the plasma slab to feel its own Lyman continuum radiation (causing a partial depopulation of the HeI atom's ground state and an overpopulation of the first few excited states) and a high plasma density (which ensures efficient cascading of recombining electrons to excited states). These two properties produce a kind of ''Lyman-pumped recombination'' which relies on the Lyman continuum being marginally optically thick in the slab. These results are consistent with HeI studies of planetary nebulae, symbiotic nebulae, and AGNs, and may have bearing on other ''detached atmospheres'' problems as well.

In a second study of λ Eri, Smith, T. Murakami (ISAS, Japan), and B. G. Anandarao (PRL, India) have completed an optical/UV/X-ray study consisting of ground-based, IUE, Voyager 2, ROSAT, and ASCA satellite data in March 1995 at an epoch when the star was at the peak of its mass ejection phase. Although λ Eri exhibited an X-ray flare in 1991, no new flares were recorded in the 1995 campaign. However, several marginally statistically significant X-ray excursions were obtained in March which were not observed in a secondary campaign in September. Moreover, unusual activity, which appears not be correlated with the X-ray fluctuations, were observed in H-α, HeI 6678, HeII 1640, CIV 1548-52, and CIII 977A (Voyager). The helium line activity suggests that a mass ejection occurred at the base of the wind whereas the CIV line behavior imples that shock interactions occurred in the wind flow. The Voyager UltraViolet Spectrometer also observed ''ringing'' in the far-UV light curve of λ Eri which decayed over three 3-hr. cycles. The amplitude of these fluctuations was 50% at 1000 Å, decreased rapidly with wavelength, and faded to nondetection at 1300 Å. These fluctuations appear to be due to a time-dependent flux deficit in the 950-1200 Å region, possibly attributable to time-variable absorption by the CI edge in a medium above the star alternately heated and cooled. Also, suddenly increased H-α emission hints that 50,000K plasma near the star's surface can influence the circumstellar disc $12R^*$ away by its increased Lyman continuum flux.

Smith, Robinson and R. Corbet (USRA) conducted a large optical/UV/X-ray campaign on the prototypical B0.5e star γ Cas in January and March of 1996. In the first of these campaigns optical spectroscopy was obtained on several sites

around the globe along with UV spectroscopy from the IUE satellite. In March the HST GHRS monitored the SiIV doublet near 1400 Å and surrounding continuum nearly continuously for over 21 hours, while the RXTE (soft X-ray) satellite also monitored it for 27 hours. A UV continuum flux curve from the GHRS spectra shows two light dips separated by about 10 hours and amplitudes of about 1%. The RXTE data show two timescales of modulations, the first of which is the rotational timescale of near 1 day. The UV flux curve shows undulations with emission peaks which coincide with the occurrence of the dips in the UV flux curve. The X-ray flux show fluctuations called ''shots'' on rapid timescales from several minutes down to perhaps a second. Close examination shows that these shots are loosely clustered, and their incidence and amplitudes are correlated with the UV flux dips. The rapid evolution of shots implies that the plasma density of the X-ray emitting sites is very high, of order $10^{14} cm^{-3}$. Contemporaneous ASCA data by Corbet, Murakami, and colleagues together with our RXTE data suggests that the X-ray undulations repeat with a period of 1.125 days. By phasing the GHRS UV flux curve from 32 IUE spectra two months earlier, it is possible to refine this period to 1.123 days. This suggests that the X-ray emission is modulated by the star's rotation from sites on the surface.

Wu, Schiffer, and Crenshaw finished the third installment of the IUE Ultraviolet Spectral Atlas (Addendum II). This contribution contains 181 stars with spectral type from O5 to M7. It is based on the IUE low dispersion spectra processed with the old processing system IUESIPS.

Wu, Mo, Schiffer, and Crenshaw continued to work on a comprehensive ultraviolet spectral atlas of standard stars. This atlas will have 550 stars from O3 to M7 which are widely distributed across the HR diagram. This atlas is based on the data from the IUE Final Archive. Therefore the data were uniformly processed with the NEWSIPS system. Compared to the earlier atlases, it will have higher signal to noise ratio and more accurate fluxes and wavelengths.

2.3 Nebulae and Interstellar Matter

Wu, Crenshaw, A. Hamilton (Colorado), R. Fesen (Dartmouth), M. Leventhal (Maryland), and C. Sarazin (Virginia) continued the study of the remnant of supernova 1006 AD using the FOS data from HST. The study confirmed the redshifted Si lines first discovered with the IUE. The FOS data allowed a more accurate measurement of wavelength, strength, and profile of these Si lines. Together with the Fe II lines reported earlier, a reasonable model was derived for the SNR 1006.

2.4 Galaxies and Extragalactic Astronomy

Adler, with D. Westpfahl (New Mexico Tech) and B. Wakker (Wisconsin), continues his multi-wavelength study of the interstellar medium in the face-on spiral galaxy M74 (NGC 628). They have gathered HI, H-α, CO, and far-UV images to measure spiral density wave characteristics and determine what role (if any) the density wave plays in the star formation process. The high resolution and sensitivity of the images will also allow the search for evidence of large scale dissociation of molecular gas in the disk of the galaxy.

Baggett, with S. Baggett (STScI) and K. Anderson (NMSU), continues studying the nature of inner-truncated spiral galaxy disks. The bulge-disk decomposition of 659 brightness profiles has been completed, and work continues to analyze statistically meaningful samples of objects from the set of fits. Conclusions from the various preliminary reports continue to be supported by the well-defined samples.

3. ACKNOWLEDGMENTS

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PUBLICATIONS

Airapetian, V., Holman, G. 1996, BAAS, 189, 119.01, ''Atmospheric Heating and Quiescent Radio Emission in Active Stars''

Binzel, R.P., Gaffey, M.J., Thomas, P.C., Zellner, B.H., Storrs, A.D., Wells, E.N. 1997, Icarus, 128, 95. ''Geologic Mapping of Vesta from 1994 Hubble Space Telescope Images''

Goodman, M.L. 1997, ApJ, in press. ''Quantitative MHD Modeling of the Solar Transition Region''

Goodman, M.L. 1997, A&A, 324, 311. ''Convection Driven Heating of the Solar Middle Chromosphere by Resistive Dissipation of Large Scale Electric Currents''

Goodman, M.L. 1997, A&A, 325, 341. ''Convection Driven Heating of the Solar Middle Chromosphere by Resistive Dissipation of Large Scale Electric Currents - II ''

Hamilton, A.J.S., Fesen, R.A., Wu, C.-C., Crenshaw, D.M., and Sarazin, C.L. 1997, ApJ, 482, 838. ''Interpretation of Ultraviolet Absorption Lines in SN 1006''

Lanning, H.H. and Meakes, M. 1996, *Third Conference on Faint Blue Stars*, Schenectady, NY, in press. ''The Sandage Two-color Survey of the Galactic Plane: The Continuing Search for Low-Luminosity Objects and Other Interesting Sources''

Lanning, H.H. and Meakes, M. 1997, PASP, in press. ''A Finding List of Faint UV-Bright Stars in the Galactic Plane. IV''

MacConnell, D.J. 1997, Baltic Astron., 6, 105. ''The Dwarf Carbon Stars - Where Are They All?''

MacConnell, D.J., Osborn, W.H., Miller, R.J. 1997, AJ, 114, 1268. ''HST-FGS Parallaxes of Two High-Velocity Stars''

Osborn, W.H., MacConnell, D.J. 1997, Baltic Astron., 6, 119. ''FGS Observations of Two High-Velocity Stars''

Pascu, D., Rohde, J.R., Seidelmann, P.K., Wells, E.N., Kowal, C.T., Zellner, B.H., Storrs, A., Currie, D.G., Dowling, D.M. 1997, *Dynamics and Astrometry of Natural and Artificial Celestial Bodies*, eds. I.M. Wytrzyszczak, J.H. Lieske, and R.A. Feldman, 517. ''Astrometry of Faint Planetary Satellites with WFPC2 of Hubble Space Telescope''

Proffitt, C.R. 1997, *Fundamental Stellar Properties: The Interaction between Observation and Theory: Proceedings*

of the 189th Symposium of the International Astronomical Union, eds. T. R. Bedding, A. J. Booth, J. Davis, Kluwer: Dordrect, p. 355. ''The Importance of Helium and Metals Diffusion in Stars''

Schultz, A.B., Allard, F., Clampin, M., McGrath, M., Bruhweiler, F., Valenti, J.A., Plait, P., Hulbert, S., Baum, S., Woodgate, B.E., Bowers, C.W., Kimble, R.A., Maran, S.P., Moos, H.W., Roesler, F. 1998, ApJLett, in press. ''First Results From the Space Telescope Imaging Spectrograph: Optical Spectra of Gl229B''

Schultz, A.B., Hart, H.M., Hershey, J.L, Hamilton, F.C., Kochte, M., Bruhweiler, F.C., Benedict, G.F., Caldwell, J., Cunningham, C.C., Franz, O.G., Keyes, C.D., Brandt, J.C. 1997, PASP, in press. ''HST/FOS Imaging of Wolf 424AB: Is this Binary a Double Brown Dwarf System?''

Schultz, A.B., Hart, H.M., Hershey, J.L, Hamilton, F.C., Kochte, M., Bruhweiler, F.C., Benedict, G.F., Caldwell, J., Cunningham, C.C., Wu, N., Franz, O.G., Keyes, C.D., Brandt, J.C. 1998, AJ, in press. ''A Possible Companion to Proxima Centauri''

Schultz, A.B., Hart, H.M., Hamilton, F.C., Kochte, M., Bruhweiler, F.C., Benedict, G.F., Caldwell, J., Cunningham, C.C., Franz, O.G., Keyes, C.D., Brandt, J.C. 1997, *Proceedings of Planets Beyond the Solar System and the Next Generation of Space Missions*, ed. D.R. Soderblom, in press. ''Lessons Learned from an HST Faint Companion Search Program''

Smith, M.A., Cohen, D.H., Hubeny, I., Plett, K., Basri, G., Johns-Krull, C.M., MacFarlane, J.J., and Hirata, R. 1997, ApJ, 481, 467. ''Dynamic Processes in Be Star Atmospheres. V. Helium Line Emissions from the Outer Atmosphere of λ Eridani''

Smith, M.A., Murakami, T., Ezuka, H., Andandarao, B.G., Chakraborty, A., Corcoran, M.F., Hirata, R. 1997, ApJ, 481, 479. ''Dynamic Processes in Be Star Atmospheres: VI. Simultaneous X-ray, Ultraviolet, and Optical Variations in λ Eridani''

Thomas, P.C., Binzel, R.P., Gaffey, M.J., Zellner, B.H., Storrs, A.W., Wells, E.N. 1997, Icarus, 128, 88. ''Vesta: Spin Pole, Size, and Shape from HST Images''

Thomas, P.C., Binzel, R.P., Gaffey, M.J., Storrs, A.D., Wells, E.N., Zellner, B.H. 1997, Science, 277, 1492. ''Impact Excavation on Asteroid 4 Vesta: Hubble Space Telescope Results''

Wahlgren, G.M., Leckrone, D.S., Brage, T., Johansson, S., Proffitt, C.R. 1996, BAAS, 189, 78.11. ''Defining the χ Lupi Abundance Peak Among the 5d and 6p Elements''

Wu, C.-C., Crenshaw, D.M., Hamilton, A.J.S., Fesen, R.A., Leventhal, M., and Sarazin, C.L. 1997, ApJ, 477, L53. ''Far-Ultraviolet Absorption Lines in the Remnant SN 1006''

Wu, C.-C., Schiffer, F.H., 3rd, and Crenshaw, D.M. 1997, NASA IUE Newsletter, in press. ''The IUE Ultraviolet Spectral Atlas, Addendum II''

Zellner, B.H., Albrecht, R., Binzel, R.P., Gaffey, M.J., Thomas, P.C., Storrs, A.W., Wells, E.N. 1997, Icarus, 128, 83. ''Hubble Space Telescope Images of Asteroid 4 Vesta in 1994''

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