Villanova University
Astronomy & Astrophysics
Villanova, Pennsylvania 19085

This report covers the period from 9/95-9/96.

1. PERSONNEL

During the report period, 9/95 - 9/96, the staff included Assistant Professor Carol W. Ambruster, Assistant Professor Jason A. Cardelli, Instructor Laurence E. DeWarf, Professor Edward F. Guinan, Associate Professor Frank P. Maloney, Professor George P. McCook (Chairman), and Professor Edward M. Sion. Dr. Min Huang and Dr. Fu Hua Cheng served as Post-Doctoral Fellows, working with Dr. Sion. Dr. Ulysses J. Sofia served as Post-Doctoral Fellow, working with Dr. Cardelli. Sergio Messina, of Catania University (Italy) was a pre-doctoral fellow, working with Dr. Guinan and Dr. McCook. Dr. Young Woon Kang of the Sejong University (Seoul, Korea) was a sabbatical fellow. Dr. Rex Saffer joined the department as Research Assistant Professor.

Brian Abbott, Kunegunda Belle, Dirk Fabian, Kenneth Guerin, J. Erich Jay, James Marshall, Todd Mahler, Jamison Maley, Steven Margheim, Nicholas Morgan, Quyen Nguyen, and David Stys served as research assistants. Rhiannon Weaver of Penn St. U. was a RUI student researcher under NSF grant AST 93-15365. Dr. Elizabeth R. Jewell served as Department Assistant.

In May 1996, Dr. Jason Cardelli died suddenly and tragically of a massive heart attack. Students and faculty mourn the loss of both his personality and his scholarship.

2. INSTRUMENTATION

2.1 Automated Photoelectric Telescopes

The Fairborn Observatory, home of the Four College APT, has been moved to an new site located in the Palagonia Mountains of AZ (Lat: +31 23 12; Long: -110 41 41). The 0.8-m automated photoelectric telescope is operated by the Four College Consortium(FCC) consisting of The College of Charleston, The Citadel, University of Nevada-Las Vegas, and Villanova University, the FCC-APT is supported by NSF grant AST95-28506. The 0.8M APT is equipped with *UBVRI* wide-band filters as well as *uvby*, Hβ and Hα narrow- and wide-band interference filters.

2.2 Internet Access

The Astronomy & Astrophysics WorldWideWeb (WWW) address is: www.phy.vill.edu/astro. Our email address is: astronomy@ucis.vill.edu. Experimental laboratory work for non-science majors can be found at: http:// astro4.ast.vill.edu. This project is supported by the Pew Charitable Trusts.

2.3 North American Small Telescope Cooperative

Heather Preston of Valdosta St. U. (GA) has assumed responsibility for NASTeC. The web page has been moved to: www.valdosta.peachnet.edu/ preston/sara/nastec.html. NASTeC works to bring the distribution and potential availability of small-to-intermediate size (*e.g.*, 0.4-2m) research telescopes and associated equipment to the attention of the astronomical community through a voluntary listing. NASTeC currently consists of 46 observatories operating 63 telescopes across North America.

3. CURRENT RESEARCH

3.1 Interstellar Matter: Abundances

Cardelli continued his study of interstellar gas-phase abundances using the Goddard High Resolution Spectrograph aboard Hubble Space Telescope, concentrating on data obtained with very high signal-to-noise.

Sofia continues to study the neutral interstellar medium (ISM) as a member of the Interstellar Absorption Profile Spectrograph (IMAPS) Science Team. Sofia and E. Jenkins (Princt.U.Obs.) are studying the abundance and depletion of argon in the neutral ISM using data from the first Space Shuttle flight of IMAPS. As an inert element, Ar is not expected to be incorporated significantly into dust grains; however, substantial depletions from the gas-phase ISM are being found. This work is supported by NASA LTSARP grant NAGW-4607.

Sofia and D. Meyer (NW U.) are continuing the studies of Cardelli and Meyer. These include the study of heavy elements in the ISM, particularly tin and cadmium. The different processes by which the heavy elements are formed, combined with the measured ISM abundances, give information about the stellar processes producing the elements and the efficiency of injection of the species into the ISM. Sofia and Meyer also continue the study of carbon gas-phase abundances in the ISM. Carbon is an extremely important species in the study of dust. These studies are supported by HST-GO-6070.01-94A and HST-GO-06541.01-95A.

Sofia and D. Massa (Hughes, STX) continue the study of Cardelli and Massa into chemical gradients within the Galaxy. These studies will provide information about nucleosynthetic enrichment of the Galaxy, and the efficiencies of vertical and radial mixing of the ISM. This research is supported by HST-GO-05443.03-93A.

3.2 Interstellar Matter: Dust

Cardelli continued his study of the nature of interstellar dust through analysis of *UV* extinction. As part of this work, he has found that variations in the width of the 2175Å extinction bump appear to be related to specific environments, with regions of bright nebulosity exhibiting narrow bumps while cold dark clouds appear to be represented by fairly broad bumps. One argument is that broad bumps are due to surface coatings on graphite grains which are subsequently removed by radiation yielding narrow bumps in regions of

bright nebulosity. This behavior has been further quantified by new results that show that the width of the bump is strongly linearly correlated with the fractional abundance of the molecule CH as well as H_2.

Sofia, C. Joseph (Rutgers U.) and undergraduate D. Fabian (Villanova) are using far *UV* absorption data from IMAPS to study the incorporation of P, Si, and Fe into dust grains in interstellar clouds toward 9 stars. This study will provide information about the physical composition of dust and the efficiency of interstellar processes in destroying grains. This work is supported by NASA LTSARP grant NAGW-4607.

Sofia and undergraduate K. Guerin (Villanova) are using a large sample of Goddard High Resolution Spectrograph data in order to study the incorporation of Si, Mg, and Fe into dust grains. This study focuses on the chemical composition of dust grains in neutral clouds.Support comes from NASA LTSARP grant NAGW-4607.

Sofia is using data from the HST to empirically determine the oscillator strengths for the Mg II 1240 Å doublet. This important value is needed to identify the mineralogy of interstellar silicate grains.

3.3 Planetary Atmospheres

Sofia and Wolff (SSI) are using data from the FOS and WFP cameras on the HST to determine reliable ozone abundances in Mars' atmosphere as a function of season and latitude. This research is supported by HST-AR-06390.01-95A.

3.4 Extra-solar Planet Search: CM Dra

Guinan, McCook and undergraduate S. Wright report the possible photometric detection of a planetary transit eclipse for the dM5+dM5 (P=1.268d) eclipsing binary star CM Dra. CM Dra was selected as a target for a planet search because its orbital plane is seen almost exactly edge-on (see *e.g.*, Doyle *et al.* 1995; BAAS,27,1382). In this case a planet orbiting the binary in the plane of its orbit would transit across the disks of the stars producing a decrease in brightness that is proportional to the relative areas of the planet to the stars. Photoelectric photometry of CM Dra has been conducted from Mt.Hopkins, AZ since 1995 using the Four College Consortium 0.8m APT. This binary has been well behaved, showing the expected mutual eclipses of the two stellar components and nearly constant light between the narrow eclipse phases. On the night of 01 June 1996 UT, during the 3.5hr observing interval from 04:15 to 07:45 UT, CM Dra was fainter by 0.08 mag in the I-band. If it is assumed that this decrease in light is due to a planet transiting one of the dM components of the binary system, the planet would have a diameter of about 0.85D(Jupiter). From the lower limit to the duration of the event, the possible planet would have an orbital period of at least several months. This planetary transit interpretation is a tentative result that needs to be confirmed by more observations. For example, it is possible that this decrease in light was due to the development of a large spot on one of the stars of the binary, but photometry the day before and after the dimming event showed the star to be at its usual brightness. Possible confirmation of a planet orbiting CM Dra was made by Martin & Deeg (IAUC No. 6425) who reported an earlier transit-like event from photometry made during 1994.

In addition, evidence for the existence of a planet around CM Dra is being investigated by searching for small periodic deviations of the eclipse timings of the binary system as it orbits around the mass center of the binary-planet system. A planet of Jupiter's mass at 1AU, would produce about a 17 sec periodic shift in the arrival times of the eclipses of the stars. This shift is small but observable with accurate photometry. This research is supported by an NSF/REU grant (AST-9315365) to Villanova University and to the Four College Consortium for the APT observations.

3.5 Photoelectric Photometry of Variable Stars

Photoelectric photometry of the following variable stars was carried out during the reporting period under the supervision of McCook and Guinan with the Jenkins 38-cm reflector at Villanova University Observatory: α Ori, VW Cep, VV Cep, 47 Cas, V711 Tau, AW UMa, and λ And. The following stars were observed with the APTs at Mt. Hopkins during 1995/96: (i) Young Solar Proxies - HD 129333 (EK Dra), HD 134319, κ^1 Cet, χ^1 Ori, π^1 UMa, BE Cet, HN Peg, and 59 Vir; (ii) Pulsating Stars - α Her,Mira, β CMa, HD 135262, and 9 Aur; (iii) - Eclipsing Binaries - β Lyr, R CMa, V380 Cyg, AS Cam, DI Her, V541 Cyg, V471 Tau, CM Dra, and Mu1 Sgr; (iv) Chromospherically-Active Stars - V711 Tau, UX Ari, FK Com, IN Com, AD Leo, HD 82558, HD 152391, and HD 82443; (v) Misc. Variables - R CrB, FG Sge Ω Ori,and AX Mon; (vi) Planetary Transit Candidates - 51 Peg, 70 Vir and CM Dra.

3.6 RS CVn Stars: V711 Tauri

DeWarf and Guinan, with K. Wong (Lower Merion HS), and J.D.Dorren (Edinburgh, Scot.) continue work on the highly active RS CVn binary system V711 Tauri (HR1099, HD22468). V711 Tau is a short period ($P_{rot}=2[h <]ch + 84$) binary consisting of G5 V and K1 IV components; it is highly active in the short-term, with visual photometric flares of over $0^{m}.15$ and large chromospheric and transition-region flares. Ultraviolet and visible light measurements spanning over 15 years have been analyzed to determine long-term systematic variations in light and in the UV chromospheric and transition-region line emissions, which may indicate an activity cycle. The Mg II h+k emission lines (2800Å) have been systematically analyzed for over 100 high dispersion *IUE* archival spectra. C IV (1550Å) and C II (1335Å) emission line fluxes have been extracted from all available low dispersion spectra. The comprehensive data set covers the time interval from 1978 to present. The *IUE* data show there is a complex, systematic long-term (>14 yrs) variation in the stars' chromospheric and transition-region line emissions. Simultaneous multiwavelength photoelectric photometry is obtained at the Villanova University Observatory using the 38 cm reflector and the APTs on Mt. Hopkins, AZ. The optical light variations appear to be positively correlated with the *UV* emissions; *i.e.*, when V711 Tau is visually bright, the *UV* emissions are strong, and vice-versa. It seems

that V711 Tau is similar to our Sun in that the system is optically brightest near the peak of its magnetic activity cycle as inferred from the *UV* line emissions. This implies that faculae and facular network contribute more to the long-term light variations than do the dark starspots. This research was supported by NSF Grant AST- 9315365 and NASA Grant NAG-2160.

3.7 Sun In Time: Rotation-Activity Relations

Guinan and DeWarf, with M. Güdel (PSI & ETHZ, Switzerland) and J.D. Dorren (Edinburgh, Scot.), continue with the Sun in Time project, a coordinated multiwavelength study of several nearby, single, solar-type stars selected as proxies for the Sun at several stages in its evolution from ZAMS (Zero Age Main-Sequence) to TAMS (Terminal Age Main-Sequence). An extensive body of ultraviolet (*IUE*), and X-ray (*Einstein* and ROSAT) observations of late-type stars is employed to investigate the coronal, transition-region (TR), and chromospheric emission of single solar-type stars with spectral types close to solar. By considering only main-sequence stars in a restricted range of spectral types (F5 V - G8 V) with measured rotation periods, they can focus on the role of rotation in determining activity levels, since the exclusion of K stars significantly limits the variation range of other properties such as mass, radius, temperature and, particularly, convection zone depth. There is still a wide spread of rotation rates ($P_{rot} \approx 1.5-40$ days) and ages (70 Myr to 9.5 Gyr), and consequently a wide range of magnetic activity. These stars thus constitute a test of the effect on the stellar dynamo of varying the rotation rate, keeping all other parameters approximately constant. They have derived precise relations between X-ray (corona), C IV (transition region), and Mg II (chromosphere) emission and rotation period for stars in this range of spectral types. Moreover, there appears to be little difference in the relations obeyed by the entire group and those of the subset of G0 V - G5 V stars that are very close to solar. Since this smaller group may be considered to be proxies for the Sun at different ages, they have, in effect, also determined empirical relationships between the historical solar magnetic activity (coronal, TR, and chromospheric) and the Sun's rotation period, which is related to solar age. These results have been combined with existing rotation-age relations to obtain rotation-activity-age relations. In addition, photoelectric photometry of several of these stars shows a correlation between the mean light curve amplitude and the rotation period, which indicates how the photospheric (starspot) activity (areal extent) depends on rotation. The use of rotation period rather than projected rotational velocity significantly reduces the uncertainties in these relations.

3.8 Sun in Time: Coronae of Solar-Type Stars

Guinan, in collaboration with M. Güdel (PSI) and S. Skinner (ISAS, Japan), used the X-ray satellites ASCA and ROSAT to probe the coronae of solar-type G stars at different ages of their main-sequence evolution. The stars are not members of close binary systems and include analogs of the Sun with ages as young as ~70 Myr (EK Dra=HD129333) and as old as 9 Gyr (β Hyi) with rotation periods between 2.7 and ~30 days. These stars cover an X-ray luminosity range between ~ solar and ~500 times higher than that of the quiet solar X-ray corona. In particular, they have focused on the dependence of the temperature structuring and the differential emission measure distribution of coronal plasma on age and stellar rotation period.

In the younger stars, they find a considerable portion of the volume emission measure at very high temperatures, reaching to ~20−30 MK in EK Dra. Such temperatures are comparable to temperatures achieved on the Sun during short flaring episodes. In 2-temperature fits to ROSAT data, the higher temperature decays rapidly within the first few 100 Myr; the decay may be described by an inverse power-law: $T_{hot} \propto \text{age}^{-0.3}$. A reconstruction of the coronal differential emission measure distribution in three of the stars has been made using ASCA data; this indicates a bimodal distribution with the hotter plasma at 12-30 MK and the cooler plasma below 10 MK.

3.9 Eclipsing Binaries: β Lyr

McCook and Guinan, in collaboration with an international team led by P. Harmanec (Astr.I., CZ), have completed a detailed analysis of an extensive collection of interferometric, spectroscopic and photometric observations of the bright eclipsing binary β Lyr. The following main conclusions will appear in A&A:

(1) The bulk of the Hα and He I 6678 emission seems to originate in jets of material perpendicular to the orbital plane of the binary. The jets are associated with the more massive component of the binary and probably emanate from the 'hot spot' in the disk. Some contribution to the emission also comes from a region located between the two stars and from the 'pseudoatmosphere' of the accretion disk around star 1. (2) The 282^d cyclic variation of the light curve of β Lyr is confirmed on the basis of 2852 homogenized *V*-band observations covering an interval of 36 yrs. However, the amplitude and phase of these variations vary with the orbital phase: the long-term modulation of the light curve almost disappears near orbital phases $0\overset{P}{.}25$ and $0\overset{P}{.}50$ (elongation and secondary eclipse). (3) Pronounced line-profile variations of the Hα and HeI 6678 lines on a time scale *shorter than one orbital period* were clearly detected. they may be periodic, with a period near $4[h <]ch + 70-4[h <]ch + 75$, and this periodicity may be related to the 282^d change via the orbital period.

3.10 Eclipsing Binaries: Magellanic Clouds

Guinan, DeWarf, Maloney and P. A. Maurone (Physics Dept.), with D. H. Bradstreet (Eastern Coll.) and Y. W. Kang (Sejong U., Seoul, Kor.), are actively researching eclipsing binaries in the Magellanic Clouds. These systems are important laboratories for studying stellar structure, evolution, and mass loss for stars with reduced metallicity. They have obtained *IUE* SWP (1150-2000Å) spectra of a dozen hot O/B eclipsing systems in the LMC and SMC that have well determined light and radial velocity curves. During Fall 1996 HST FOS and GHRS observations are scheduled for ten of

these systems. The chief purpose of the *UV* spectrophotometry is to determine temperatures and reddenings for these stars. Since these stars radiate most of their energy in the *UV*, the character of the *UV* continuum and the presence of highly ionized elements are sensitive measures of stellar temperatures. The *UV* data have been combined with the *UBV* (or *uvby*) photometry and fit with the most recent version (ATLAS13) of Kurucz model atmospheres at metal abundances appropriate for the LMC or SMC. Ground-based light and radial velocity curves are obtained in collaboration with W. Tobin and J. Pritchard (U. Canterbury, Christchurch, NZ), V. Niemela (La Plata, ARG), A. Giménez (INTA/LAEFF, SP), and J.-V. Claussen (Denmark) and provide masses and radii. These data, when combined with the *UV* spectrophotometry give accurate stellar luminosities. This leads to a first direct Mass-Luminosity relationship, using directly measured masses and luminosities, for stars outside the Milky Way, and extends the parameter space in stellar interior models to chemical compositions different from the Milky Way. These eclipsing binaries can also serve as first class standard candles. Because the uncertainty in the ground-based determination of their temperatures presently contributes the greatest uncertainty in their computed distances, the more precise temperatures obtained from *UV* spectra, combined with the well determined stellar radii, will allow us to compute the distance moduli to these stars to within ± 0.08 mag. This research is supported by NASA grants NAG5-2160 and NSF grant AST-9315365.

3.11 Apsidal Motion Studies: Eccentric Eclipsing Binaries

A new apsidal motion determination of the eccentric eclipsing binary V1143 was carried out by J. Burns (USAF), Guinan, and student J. Marshall. The eclipsing binary V1143 Cyg (HR 7484, HD 185912, BD+54deg2193; $V_{max} = +5.86; B-V = +0.46$) consists of a pair of F5V stars moving in an eccentric orbit (e=0.54) and having an orbital period of $P_{orb} = 7.64075d$. The system is detached with both components residing well inside their respective Roche lobes. The orbital and stellar properties of V1143 Cyg are very well determined from the careful study of Andersen *et al.*. One of the interesting aspects of this binary is that its *U,V, W* space velocity components, as given by Andersen of +31, -16, -2 km/s are very close to those of the Hyades cluster (+40, -17, -3). Although the similarity between the space motions of the binary and the Hyades Moving group could be a coincidence, it is more likely that V1143 Cyg is a member. If this is true, then the binary would be coeval with the Hyades, thus having an age of about 600 Myr. Knowing the age of a binary vastly increases its importance for testing stellar structure, opacity laws, and evolution models.

Photoelectric photometry of V1143 Cyg was conducted with the Jenkins 38-cm reflector at Villanova Un. Obs. These observations were made on the nights of 17 and 19 Oct 1987 UT, using intermediate-bandpass blue ($\lambda_{max} = 4530$Å) and yellow $\lambda_{max} = 5500$Å) interference filters. The secondary and primary minima occurred respectively on these nights. These timings were combined with the photoelectric eclipse timings already available up to 1994. Independent linear least squares solutions were made of the primary and secondary eclipses respectively, yielding periods of $P_{minI} = 7.64075095 \pm 0.00000082d$ and $P_{minII} = 7.64072932 \pm 0.00000359d$. The period determination from the primary eclipses is better determined than secondary eclipses because the primary eclipse has twice as many timings. The analysis of all available timings yielded an apsidal motion rate of $\dot{\omega}_{obs} = 3\overset{\circ}{.}52/100yr \pm 0\overset{\circ}{.}72/100$yr. This value is nearly identical to those previously determined. More timings, in particular of secondary eclipses, are necessary to define the apsidal motion rate more precisely, so additional photometry will take place during 1997. This work was supported by NSF grant AST 93-153665 and made use of the SIMBAD data base, operated at CDS, Strasbourg, Fr.

Beginning in Spring 1995, *UBVR* photoelectric photometry of V541 Cyg has been conducted on the Villanova-Fairborn 0.8M APT at Mt. Hopkins by Guinan, McCook and students J. Maley and J. Marshall. During 1995, differential photometry of the star was obtained on 63 nights. Nearly complete light curves have been obtained and new eclipse timings have been made from these data. V541 Cyg is a detached eclipsing binary consisting of a pair of B9.5 V stars having an eccentric orbit (e=0.4740) and an orbital period of $P_{orb} = 15.34$d. Khaliullin was the first to show that this binary could be an important test case for General Relativity (GR) because the apsidal motion expected from GR is significantly larger than the classical apsidal motion arising from the tidal and rotational distortions of the component stars. Using updated values for the internal structure constant from Claret & Giménez, theory predicts a relativistic effect of $\dot{\omega}_{GR} = 0\overset{\circ}{.}77/100yr\pm 0\overset{\circ}{.}05/100$yr and classical effects of $\dot{\omega}_{cl} = 0\overset{\circ}{.}87/100yr\pm 0\overset{\circ}{.}07/100$yr. This result is particularly interesting because in V541 Cyg most of the apsidal motion is expected to arise from GR.

A new determination of apsidal motion was made using timings recorded with the APT along with timings reported in the literature. The analysis yielded an apsidal motion rate of $\dot{\omega} = 0\overset{\circ}{.}52/100$yr $\pm 0.12°/100$yr. This apsidal motion is nearly the same as one found by M. Wolf. These studies confirm that V541 Cyg has an observed rate of apsidal motion significantly less than the theoretically expected apsidal motion. This discrepancy is as difficult to explain as those found for two other eclipsing binaries, DI Her and AS Cam. The plan is to continue photometry of the star with the APT during 1997 to complete the *UBVR* light curves, in particular, to cover fully the primary eclipse. Spectroscopic radial velocity observations of V541 Cyg are currently being conducted by Etzel (SDSU). Once the light and radial velocity curves are complete, a more thorough study of this important binary can be made. This study is supported by NSF grants AST-861362 and AST-9315365 which we gratefully acknowledge. The reduction and analysis of the *IUE* observations were supported by NASA NAG 5-2160. A preliminary report can be found in IBVS 4362.

3.12 Apsidal Motion Studies: DI Her

APT photometry of the eccentric eclipsing binaries DI Her, AS Cam, and V380 Cygni continued through 1996. Em-

phasis focused on obtaining photometry of the eclipses to determine accurate timings as part of an ongoing apsidal motion study. Guinan and astronomy student J. Marshall have carried out a new apsidal motion study yielding a revised rate of $\dot{\omega}_{obs} = 1.18°/100\text{yr} \pm 0.29°/100\text{yr}$. This apsidal motion rate is close to that found earlier by Guinan, Marshall & Maloney (IBVS 4101). Analysis of the residuals shows no evidence of systematic or periodic variations to a level of about ± 0.001 day. No evidence of changes in the inclination of the orbit was found in the constancy of the eclipse depths over time. From this data, there is no support for the suggestion of a perturbing third star in this system.

3.13 V471 Tauri

Guinan and McCook continued photoelectric photometry of the Hyades short period eclipsing binary V471 Tau (K0 V + wd; P = 0.525^d) with the 0.8m Four College APT. Complete multiwavelength light curves were obtained including good coverage of primary eclipse of the white dwarf. Modelling of the light curves reveals the locations and sizes of cool starspots on the dK star. This photometric study was carried out as part of a cooperative study with F. Walter (SUNY-Stonybrook) of HST/GHRS spectrophotometry. Observations of V471 Tau are continuing.

3.14 Hot, Pulsating Variable Stars

Guinan and McCook cooperated with an *EUVE* observation program of D. Cohen and J. Cassinelli (U.Wisc.) of β Canis Majoris by taking extensive photoelectric photometry of this bright prototype pulsating star with the APT during December 1995 and January 1996. The multiwavelength campaign was undertaken to model the pulsation and radiation transfer in the B0 III-IV star's atmosphere. Unlike previous photometry, the present photometry seems to fit satisfactorily with a single period.

3.15 Variable Stars: FG Sge

APT *UBVRI* photometry of FG Sagittae, the central star of planetary nebula He 1-5, was continued by Guinan and McCook during 1996. FG Sge is a unique star that is displaying evidence of stellar evolution on time scales comparable with the human lifetime. During the last quarter of 1992, FG Sge underwent rapid dimming and since then has been behaving as an RCrB variable. Since 1992, FG Sge has undergone several more dimming events and partial recoveries. Photometry obtained during March/April 1996 showed that the star underwent its greatest dimming observed so far, dropping below 15^{th} mag in V. The light variations of FG Sge observed since Fall 1992 seem to be of two types: (1) large dimming events and partial recoveries most likely produced by obscurations of the star by dust; and (2) periodic, low amplitude light variations arising from pulsations of the star. The APT observations were carried out near the time of scheduled infrared observations made with the ISO satellite (B. Montesinos PI, LAEFF-Spain).

3.16 Variable Stars: R Coronae Borealis

McCook and Guinan initiated *UBVRI* photometry of the hydrogen deficient post-AGB variable, R Coronae Borealis (RCrB). The photometry is coordinated with spectroscopy and polarimetry being conducted at the Crimean Observatory by Y. Efremov. The photometry was initiated during February 1996 when the star was near a light minimum at $V \simeq +13.5$ mag. These observations are planned to continue through 1997 to study the star through this major dust formation, light dimming event.

3.17 Chromospherically Active Stars in the Galactic Bulge

Guinan, M. Güdel (PSI, Switz.), Y. W. Kang, (Sejong U., Kor.), and astronomy student S. Margheim have carried out a study of several hundred possible RS CVn variables that have been detected as part of the OGLE collaboration (see Udalski *et al.*: Acta Astr. 44). The OGLE microlensing survey has serendipitously discovered hundreds of variable stars in the Baade Window in the direction of the galactic bulge. A surprising result is the apparent large fraction (about 30%) of probable spotted, chromospherically active (=CA) stars, also known as RS CVn variables, found in the samples. Like the nearby RS CVn variables, these OGLE variables have low amplitude, periodic light variations with periods of a few days up to several tens of days; they have *V-I* indices and positions in the color-magnitude diagram that indicate that they are late G- to mid K-giants or subgiants. Moreover, the light curves of many of them show changes in amplitude and shape that also are commonly observed in RS CVn stars. Guinan and collaborators have found that the light curves of most of these stars can be modelled with starspots.

It is well known that RS CVn stars are strong coronal X-ray sources with $L_x \sim 1 - 50 \times 10^{30}$ ergs/cm^2/s. They find that the X-ray emission from these stars, when combined with the expected coronal X-ray emission from other variables in the OGLE samples, such as the Algol, W UMa and ellipsoidal binaries, is sufficient to account for a significant fraction of the soft diffuse X-ray background (DXBG) emission observed by Snowden *et al.* (APJ, 454, 643) with ROSAT from the central regions of the Galaxy. From Snowden *et al.*, the estimated diffuse X-ray flux (0.5 - 2.0 keV) is 7.6×10^{-15}ergs cm^{-2}s^{-1} arcmin^{-2} while the estimated X-ray flux expected from the chromospherically active variables in the bulge is about $3.1 \pm 2 \times 10^{-15}$ ergs cm^{-2}s^{-1}arcmin^{-2}. Preliminary results will appear in the 12^{th} IAP Astrophysics Colloquium: *Variable Stars and the Astrophysical Returns of Microlensing Surveys* (eds. R. Ferlet & A. Vidal-Madjar). The confirmation that these variable stars are CA stars can be made by observing the chief indicators of magnetic chromospheric activity – Ca II H & K or Hα emission in their spectra. Spectra of a small sample of these OGLE variables have been requested from KPNO to search for chromospheric activity using a multi-fiber-feed spectrograph.

3.18 Photometry

R. Wasatonic (LVAAS, VU research consultant) carried out photoelectric photometry on the SRc supergiant α Her A as part of a continuing program with the National Solar Observatory to collaborate radial velocity studies with photometrically generated light curves. This photometry was combined with APT photoelectric photometry obtained by Guinan and McCook to construct a more complete coverage of α Her A's light variations. The resultant light curves proved to be more complex than anticipated, and subsequent studies and period analyses by Guinan and Wasatonic indicate the presence of 93-day and 126-day periods. These two periods give rise to a beat period of 355 days. This period ties in well with a 350-day RV period obtained by M. Smith-(CSC) using the NSO's McMath telescope.

Wasatonic also conducted photoelectric photometry of the bright red supergiants and giants α Ori, α Tau and the Mira-type variables *o* Ceti and RT Cygni photometrically in the visual (5500 Å) and in the near IR (7190 Å , 7450 Å , and 10400 Å). The IR filters are a subset of an 8-color system developed by Dr. Robert Wing at OSU. Their central wavelengths were picked so that a TiO index can be calculated from the standardized magnitudes obtained through each filter; this TiO index can then be used as a M-star spectral-subtype indicator. Additionally, IR light curves can be generated and compared against the visual light curve to characterize photometric differences that arise from the different wavelength regions.

No significant light variations have yet been found in α Tau from about two months of monitoring. However, both *o* Ceti and RT Cygni have decreased in brightness from August to October 1996 by 2 magnitudes in the visual, about one magnitude in the 7190 Å and 7450 Å regions, and only a few tenths of a magnitude in the 10400 Å region; these are indications of atmospheric expansion and cooling that can result in TiO formation, causing a drop in visual light that is greater than any IR loss. It should be emphasized that these observations spanned only 2-3 months, and that a longer time interval is needed before complete visual and IR light curves can be generated to characterize all photometric features.

As a pilot study, Wasatonic, in collaboration with Guinan, is carrying out photometry of the bright RS CVn star λ And (V = 3.86; G8 IV-III; P = 54.5d). The observations are being made with a subset of the Wing TiO filters to attempt to measure the manifestation of large cool starspots that may cause changes in the TiO indices as they rotate. Observations are planned through March 1997.

3.19 Chromospherically Active Stars: Proxima Centauri

Guinan and senior N. Morgan studied Proxima Centauri using both photometric and *IUE* data. At a distance of 4.3 LY, Proxima Centauri (= α Cen C; V645 Cen) is the nearest known star to the Sun. This M5 V flare star is the faintest member of the α Cen triple star system (or moving group) and lies about 1400 AU nearer to the Earth than its brighter G2V and K2V companions. Because of its proximity and its membership in the triple system, Proxima has well determined physical properties that include an age of 5-6 Gyr. In spite of its old age, Proxima is a chromospherically active star with strong Mg II h+k (280nm) emission as well as being a flare star. This star is of great importance to magnetic dynamo theory because it is expected to have a fully convective envelope. One quantity, not well determined yet vital to understanding Proxima's magnetic behavior, is its rotation period.

During May-August 1995, Proxima was observed about twice a week with *IUE*. Low resolution LWP (200-320nm) spectra were obtained chiefly to observe the chromospheric Mg II emission and use it to measure Proxima's rotation period as active plage regions on the star's surface rotate in and out of view. The *IUE* data have been analyzed and the Mg II emission shows $20-25\%$ variations with a period of 31.5 ± 1.5 days. This period is assumed to be the star's rotation period. In addition, several flare events were observed and evidence was found for rather fast changes (on a timescale of weeks) in the plage activity and distribution. Also, the analysis of the *IUE* archival data indicates the probable presence of a long-term activity cycle.

This study is supported from NASA grant NAG 5-2160 and NSF grant AST-9315365 which we gratefully acknowledge.

3.20 Single Chromospherically Active Stars: HD 82443

Guinan, Ambruster and s. Messina (Vill. U. & U. Catania) are working with A. F. Lanza (Catania Obs., IT.) on a study of HD 82443 in the Pleiades Moving Group and the results of a long-term photometric monitoring of the young Pleiades moving group member have been submitted to A&A. A sequence of eleven optical light curves obtained from 1989 to 1995 confirms the presence of a rotational modulation with a period of 5.40^d attributable to cool photospheric spots. The Maximum Entropy and the Tikhonov regularization criteria have been applied to compute maps of the photospheric spot pattern. They show that the total spotted area is subject to changes as large as 10% of the star's surface over time scales of 1-2 years, but without any indication of a cyclical behavior. The overall spot pattern migrates at a variable rate in the sense of the stellar rotation, suggesting the presence of a latitudinal differential rotation with relative amplitude $\frac{\Delta\Omega}{\Omega}\simeq0.01$. Nearly simultaneous *UV* observations obtained in 1991 by Ambruster show the presence of chromospheric and transition region plages which do not seem to be in close spatial association with the photospheric spots. This research was supported under grants from NSF and NASA.

3.21 ZAMS K Dwarfs

Ambruster, and collaborators A. Brown (CASA, U. of Co.) and F.C. Fekel (Tenn.St.U.) completed the last spacecraft observations of an 8-year long effort to obtain spectra from all levels of the upper atmospheres of a select sample of six solar-neighborhood, Pleiades Moving Group K dwarfs. The observations this year were made with the Goddard High Resolution Spectrograph on HST (all six stars), *EUVE* (two stars), and *IUE* (one star). The main goal of the re-

search, which includes ground-based high resolution spectra from the KPNO coude feed by Fekel, is to construct the first models of the upper atmospheric structure of Zero-Age-Main Sequence (ZAMS) stars as a function of rotation.

The six stars have spectral types between K0 and K2 V, are single, share Pleiades Moving Group space motions, and have near-primordial lithium abundances, confirming their extreme youth. They form an essentially homogeneous sample: the only variable is rotation rate, which ranges from 8 hr to ~7 days. Similar early K dwarfs in the Pleiades are just coming onto the Zero-Age-Main Sequence (ZAMS), *i.e.*, they have just started to burn hydrogen. While the Pleiades is the nearest cluster containing cool ZAMS stars, its 125 pc distance makes spacecraft spectroscopic observations of transition region and coronal lines prohibitive. As a result, the initial atmospheric structure of a cool ZAMS star is still unknown.

In Sep 1995, Ambruster and seniors D. Fabian, J. Marshall, and J. Maley travelled to Goddard Space Flight Center for observations of HD 1405 with *IUE*. These observations had been arranged to be simultaneous with a 200 ksec *EUVE* observation of the star, and contemporaneous with the HST observation. HST also observed HD 220140 in Sep. 1995; HD 82443 and HD 197890 in Nov. 1995; HD 17925 in Jan. 1996; and HD 82558 in Apr. 1996. Both medium and low dispersion spectra were obtained for each star.

Besides the 200 ksec *EUVE* observation of HD 1405 in Sep. 1995, a 200 ksec *EUVE* observation of HD 82443 was obtained in Dec. 1995 - Jan. 1996. Other *EUVE* observations of stars in the sample have been obtained since 1993.

Ambruster, Brown, and Fekel presented a poster paper at the Jan. 1996 San Antonio meeting of the AAS, reporting on preliminary reductions of the HST data in hand by that time. The medium-dispersion spectra clearly showed rotational broadening in the four stars presented (rotation periods: 0.3 - 5.4 days). Mg II/C IV flux ratios revealed a not-unexpected decline in the relative strengths of high temperature (TR) lines as rotation slows. However, an unexpected and still not understood correlation was found between the C III (λ1175)/Si III(λ1206) ratio and rotation, in the sense that the ratio decreases as rotation slows.

The complete set of HST data were fully reduced by Ambruster and senior Fabian at CASA (U. of CO) in August 1996. The *EUVE* data remain to be reduced. An in-depth analysis of the full set of observations will then be undertaken and, finally, volume emission measure models for each star will be constructed and compared. This research is supported by NASA grants NAG5-980, NAG5-2279, NAG5-2413, and NASA HST grant GO-06065.01-94A.

Ambruster, and seniors K. Belle, Q. Nguyen, D. Fabian, J. Marshall, and J. Maley reduced and analyzed *UBVRI* photometry of HD 1405 from the T6 APT on Mt. Hopkins, AZ. The observations, which included extensive *U*-band flare monitoring, were concentrated in Sep. - Oct. 1995 in order to overlap the HST, *EUVE*, and *IUE* observations of the star in late September. Several small flares were observed. The light curve shows some change from the 1994 data but, since there were fewer *BVRI* observations (because of the time devoted to flare monitoring), spot modelling of the *BVRI* light curves did not produce a unique starspot configuration.

The 2.5 mag neutral density filter, needed for the check star, was calibrated, and other systematics of the T6 were investigated. This was necessary since only the check star (but unfortunately not the comparison star) had published *UBV* photometry. Once *UBV* magnitudes for the comparison star are deduced, flare energies and a preliminary time-averaged flaring luminosity for HD 1405 will be computed, and compared with published time-averaged flaring luminosities for M-dwarf flare stars. This work is continuing, as a collaboration between Ambruster and Fabian. A final paper will be submitted to a refereed journal in early 1997.

3.22 Archaeoastronomy

Ambruster and collaborator A.B. Hull (OCA Applied Optics, CA) presented a paper at the invitation-only Oxford 5 Archaeoastronomy Conference (Santa Fe, NM, 3-10 Aug. 1996) on their recent work on an early (18th century) Navajo site in Chaco Canyon, NM. This site provides the first solid evidence that the Navajo practiced horizon astronomy, *i.e.*, the use of rising or setting positions of the Sun on the horizon to mark a yearly calendar. They documented a compelling winter solstice sunrise (WSSR) alignment between a foreground, rock art-covered, boulder and a prominent feature on the distant horizon. After the sun rises in this notch, it proceeds, over the next 2-3 hours, to ascend along the sloped ridge of the foreground boulder, that is, the angle of the ridge happens to be the same as the rising sun's angle to the horizon, ~50deg at this latitude. Also located were probable, but less dramatic, alignments to prominent horizon features at both Equinox and Summer solstice from two other rock-art covered boulders in the immediate vicinity.

It is rarely possible to interpret rock art. However, on the WSSR boulder, there is a horned Sun Shield, as well as two drilled renditions of the traditional Navajo constellation for November (a part of Corvus) and at least one incidence of the traditional December constellation (part of Scorpius); both constellations rise heliacally in those months. Moreover, the rock involved with the summer solstice alignment is incised with corn plants, the agricultural staple of the Southwest.

Ambruster and Hull are continuing their systematic survey of the vicinity, which will ultimately be tied in to geodetic coordinates and deposited with the chief archaeologist at Chaco Culture National Historical Monument.

3.23 Database of Spectroscopically Identified White Dwarfs

McCook and Sion completed the fourth edition of the *Villanova Catalog of Spectroscopically Identified White Dwarfs* during the report period. The new catalog contains 2,279 white dwarfs which have been identified spectroscopically through 1996 April. For each degenerate star, the following data entries with references are provided: (1) a catalog coordinate designation or WD number, in order of right ascension; (2) the right ascension and declination for epoch 1950.0; (3) the spectral type based upon the new system;(4) a catalog symbol denoting the binary membership; (5) a list

of most names known to exist for a given star; (6) proper motion and position angle; (7) broad-band *UBV* photometry, *V, B-V, U-B*; (8) multichannel spectrophotometry, *V(MC), g-r*; (9) Strömgren narrow-band photometry *y, b-y, u-b*; (10) an absolute visual magnitude based upon the best available color-magnitude calibration or trigonometric parallax; (11) the observed radial velocity uncorrected for gravitational redshift or solar motion ; and (12) the trigonometric parallax with mean error when available. A Notes section for unusual or peculiar stars and a coded Reference Key alphabetized by the first author's last name are presented, as well as an expanded table cross-referencing all names to catalog WD number. An introduction and full descriptions of the entries is provided in the preface text. Further additions and updates are being made while the catalog is in the refereeing stage. Stellar statistical and kinematical studies of the expanded catalog database are in progress at Villanova.

3.24 IUE Archival Studies of Cataclysmic Variables

Sion with students K. Belle, Q. Nguyen, D. Fabian continued studies of *IUE* far-*UV* archival spectra of cataclysmic variables. The *IUE* archive contains numerous low resolution spectra of dwarf novae in outburst but relatively little synthetic spectral analyses of them using realistic accretion disk models with spectral lines. They have examined a series of previously unstudied archival *IUE* low resolution SWP spectra of the SU UMa-type dwarf nova T Leonis in outburst, describing its outburst spectra, characterizing its line spectrum, the shape of its energy distribution, its wind outflow and evidence of temporal wind variability using their grid of optically thick accretion disk models for white dwarf masses 0.6 and 1.0 $M_{\odot}$, accretion rates 10^{-11} to $10-7$ $M_{\odot}$/year, and for disk inclination angles of 40^{o} and 80^{o}. They carried out preliminary synthetic accretion disk spectral fitting, with their best-fitting model yielding $M_{wd}=0.6M_{\odot}$, $i\simeq 40^{o}$, $\dot{M}\simeq 10^{-9}M_{\odot}$/yr with an inner disk temperature of 30,000 K and an outer disk temperature of 14,000 K.

Sion, with undergraduates Nguyen, Fabian, and Belle, continued studies of exposed white dwarfs in dwarf novae and nova-like variables. In many dwarf novae during quiescence, the underlying white dwarf dominates the flux in the far ultraviolet. By observing these exposed degenerate stars with HST GHRS and FOS, the white dwarf rotation rates can be determined, or be constrained, by fitting synthetic spectra broadened by rotation. Using TLUSTY and SYNSPEC (Hubeny 1988) they presented a grid of rotationally broadened white dwarf synthetic spectra, convolved with the resolution of Hubble GHRS (G140L, G160M), FOS (G130H) and *IUE* low resolution SWP spectra, computed for log $g=8$, solar composition, and $T_{eff}=15{,}000$, 25,000 and 50,000K, and rotational velocities of 0 to 5000 km/s. They examined the predicted appearance of accreted solar composition white dwarf atmospheres in the context of determining or constraining the white dwarf rotational velocities. They presented model grids which demonstrate this capability, including the first application of these grids to the SWP low resolution spectra of the white dwarf in the nova-like variable TT Arietis, exposed during the very low brightness state of that system. They ruled out the possibility that the absence of Lyman-α absorption in many CVs in quiescence (specifically those containing white dwarfs with $T_{eff}=15-20{,}000$K) could be due to rotational velocities of the white dwarf near breakup.

3.25 HST Studies of Dwarf Novae in Outburst

Sion, with Cheng, P. Szkody (U.WA), Huang, J. Provencal (U.DE), W. Sparks (LANL), Villanova graduate B. Abbott (now at U.Toledo), I. Hubeny (NASA GSFC), J. Mattei (AAVSO), and H. Shipman (U.DE) obtained Hubble GHRS medium resolution (G160M grating) phase-resolved spectroscopic observations of the prototype dwarf nova U Geminorum during different stages of two different outbursts. The spectral wavelength ranges were centered upon three different line regions: N V (1238, 1242), Si III (1300) and He II (1640). The dataset corresponding to the early decline phase of outburst number 1 was essentially featureless except for weak N V absorption and narrow interstellar lines while the dataset at the peak of outburst number 2 revealed broad emission peaks separated by narrow central absorption. There is no far ultraviolet evidence of an outflowing wind from U Geminorum in outburst. The double-peaked emission line profile structure with low velocity central absorption seen in the second outburst suggests a disk origin but the emission velocity widths appear narrower than the widths of the optical disk emission features. They interpret the high excitation emission lines, with central absorption below the continuum, to be due to photo-ionized material (coronal?) above the disk plane with the thickened outer disk absorbing the boundary layer or inner disk radiation. The N V absorption velocity versus orbital phase traces the motion of the white dwarf but the He II absorption velocity appears to deviate from the white dwarf motion. They found evidence of low level, far UV flickering during both outbursts. During both outbursts, the N V and He II regions are consistent with a constant far-*UV* light source but Discrete Fourier Transforms (DFTs), calculated for the Si III region during both outbursts, reveal probable power at approximately 360s and 65s in both DFTs. They presented the results of synthetic accretion disk spectral fitting to the data of both outbursts and derived accretion rates for the two outbursts of $6\times 10^{-10}M_{\odot}$/yr and $2\times 10^{-9}M_{\odot}$/yr.

3.26 HST Studies of Exposed White Dwarfs in Dwarf Novae During Quiescence

Sion, with Cheng, Huang, I. Hubeny, and P. Szkody obtained and analyzed Hubble FOS observations of VW Hydri one day after the end of a normal dwarf nova outburst. The spectra revealed a heated white dwarf with deep broad Lyman-α, narrow metallic absorption features and evidence of a hotter Keplerian-broadened component manifested in quiescence as a broad continuum hump. Their best reduced χ^2 fit to the data reveals (1) a DAZQ white dwarf with $T_{\rm eff}$ = 22,500$\pm$ 500 K, log g = 8, and photospheric abundances C = 0.5 solar, N = 5.0 solar, O = 2.0 solar, Si = 0.2 solar, Fe = 0.5 solar with all other metals being 0.3 solar and; (2) a rapidly spinning accretion belt with $V_{\rm rot}$ = 3350 km/s, $T_{\rm belt}$

= 26,000± 1000 K, log g = 6.0, with a fractional belt area of approximately 11%. Their earlier FOS spectrum obtained 10 days after superoutburst revealed a cooler DAZQ white dwarf (20,500± 1000), relatively lower metal abundances and a smaller fractional area (3%) for the accretion belt. Thus one day after outburst, the white dwarf is ≈2000K hotter, the accretion belt fractional area is a factor of three greater, the accretion belt temperature appears to be cooler than at 10 days post-superoutburst and the accreted atmosphere has relatively higher metal abundances. Finally, the accretion belt maintained during quiescence may provide a natural explanation for the 14s soft X-ray oscillations, does require a deeper source of heating (compression and shear mixing) and implies a lower limit to the viscous spindown timescale of 10 days.

Cheng, together with K. Horne, T. Marsh, and I. Hubeny, used HST observations of the eclipsing dwarf nova OY Car after its 1992 April superoutburst to isolate ultraviolet spectra (1150–2500Å at 9.2Å FWHM resolution) of the white dwarf, the accretion disk, and the bright spot. The white dwarf spectra had a Stark-broadened photospheric Lyα absorption, but were veiled by a forest of blended Fe II features that we attribute to absorption by intervening disk material (*curtain*). Spectral fittings gave white dwarf temperatures changing from ~ 19,700 K just 27 days after the superoutburst to ~ 18,000 K around 3 months after the superoutburst; The decay time of white dwarf temperature was 66 days. The *curtain* temperatures were between 10,000 K and 11,000 K, and looked likely to rise at ~ 3 months after the superoutburst; The surface density of the outer disk, the electron density and the velocity dispersion of the intervening disk material had similar variations with the curtain temperature; the length and the column density of the intervening disk material had inverse variations; the length of the intervening disk material was less than one white dwarf radius. The scale factor proportional to the square of the white dwarf radius obtained from the fitting decreased ~10% during the decline. Since the distance is unchangeable, it indicates that the radius of the white dwarf three months after the superoutburst reduced to 90% of the radius 27 days after the superoutburst, but all the radii after the superoutburst were smaller than that on 1991 December 4, four months prior to the superoutburst.

The decay times of mean flux of white dwarf at bandpass 1940 Å to 1980 Å and of the white light counts of white dwarf were 49 and 26 days respectively; The mean disk flux at bandpass 1300 Å to 2100 Å did not show any tendency during the decline, but that at bandpass 2100 Å to 2500 Å showed a tendency to decrease. There was no correlation between the curtain temperature and the mean disk flux at the above two bandpasses. No direct evidence supports the disk instability model which predicts a slowly increasing accretion rate through quiescence.

Cheng and Sion, together with K. Horne, S. D. Vrtilek, and I. Hubeny, used archival HST/FOS observations of U Gem to reveal a heated white dwarf with deep broad Lyα, narrow metallic absorption features and evidence of a hotter Keplerian-broadened component manifested in quiescence as a broad continuum hump. Their best reduced χ^2 fit to the data reveals (1) For U Gem at 13 days after outburst, a white dwarf with T_{eff} = 37000± 500 K, log g =8, photospheric solar abundances, and a rapidly spinning accretion belt with V_{rot} = 3200 km/s, T_{eff}= 45000± 2200 K, log g = 7.0, with a fractional belt area of 17.4%. (2) For U Gem at 70 days after outburst, a white dwarf with T_{eff} = 33000± 250 K, log g =8.0, photospheric solar abundances, and a rapidly spinning accretion belt with V_{rot} = 3200 km/s, T_{eff} = 39000 ±2000 K, log g = 7.0, with a fractional belt area of 11.2%. Results not only confirmed the cooling of white dwarf by Long *et al.* (1994), but also unveil the cooling of the accretion belt.

Cheng also worked with Vrtilek on the observations of the binary X-ray pulsar system Hercules X-1/HZ Herculis taken with the *IUE* and several ground-based observations as part of a multiwavelength campaign conducted in 1993 August. Comprehensive modeling of the *UV* and optical continuum flux suggests that the *UV* and optical light curves can be reproduced by assuming variations in accretion rate alone; however, changes in accretion rate are insufficient to account for the observed drop in X-ray flux. Shifts in disk inclination angle and changes in accretion rate can consistently explain the observed changes in X-ray, *UV* and optical fluxes. Changes in accretion rate and disk inclination angle may be related to shifts in the 35 day precession period. The rapid fluctuations in soft X-ray flux, observed several times during the campaign, may be caused by rapid variation of the accretion rate.

3.27 Studies of Hot White Dwarfs

Sion, with J.B. Holberg (U.AZ), M. Barstow (U.Leicester, UK) and Villanova student M. Scheible (now at Dartmouth) analyzed four high resolution far ultraviolet spectra of the hot, peculiar DO white dwarf KPD0005+5106 obtained with the Short Wavelength Prime (SWP) spectrograph aboard the *IUE* spacecraft. These spectra reveal weak, probably variable, peculiar absorption and emission transitions of ultra high excitation C V and N V in the 1615-1623 Å region, O VIII variable coronal emission, variable line structure at He II (1640), and essentially constant photospheric/ circumstellar/interstellar blended N V, Si IV and C IV resonance absorption. The four *IUE* echelle spectra confirm the high excitation C IV absorption feature at 1230.55A but reveal little evidence of the high excitation C IV features at 1351 Å and 1353 Å seen most strongly in the PG1159 degenerates. Moreover, high excitation O VI and C IV transitions are at most very minor contributors to the broad absorption at 1640 Å . They found distinct evidence of a moderately dense neutral cloud along the line of sight to KPD 0005. This cloud, if near the white dwarf, may interact with the stellar wind to produce a zone of shock-induced high ionization. The non-photospheric interstellar/circumstellar components of the N V resonance doublet in KPD0005 yield a column density Log N (N V) = 13.8, a factor of 8-10 higher than the value which might be expected from the diffuse ISM. The non-photospheric components of N V in the PG1159 object RXJ2117+3412 have a similar velocity (50 km/s) relative to the photospheric rest frame and are markedly stronger. Both objects exhibit strong O VIII emis-

sion, a possible marker of mass loss. These characteristics provide compelling evidence that the non-photospheric N V absorption is locally associated with these two hot degenerates and almost certainly ejected.

3.28 Helium Transfer Cataclysmics

Sion and J-E. Solheim (Tromso, Norway) obtained HST GHRS G140L and G160M spectra of the prototype helium transfer cataclysmic AM CVn. Many pulsational and photometric characteristics suggest a link between the accreting central object in AM CVn systems and single DB white dwarfs. Sion and Solheim obtained the first high resolution *IUE* spectrum of the helium-rich, cataclysmic variable star AM CVn. The broad He II(l640 Å) absorption profile with blue shifted emission core has a remarkably similar overall structure to the He II(l640 Å) broad absorption trough in the *IUE* spectrum of the prototypical cool DO white dwarf HZ 21. On closer examination, they noted that the weak absorption superimposed on the broad emission, remarked upon in Fritz *et al.* (1990, AJ), is also present in the AM CVn profile. These findings have been confirmed by the recently obtained HST spectra. This supports the possibility that AM CVn, a helium-rich nova-like cataclysmic binary, consisting of two interacting helium-rich degenerates, may have an evolutionary link to a ''single'' DO star like HZ 21 and to the DB stars.

3.29 Theoretical Studies of Accretion Physics

Sion continued theoretical studies of the accretion process in cataclysmic variable and its effects on the white dwarf. He continued his studies of the thermal response of the underlying white dwarf in a cataclysmic variable to accretional heating (see Sion 1995, ApJ, 438, 576) by the dwarf nova outburst and cooling during dwarf nova quiescence. During the report period, Sion's code was updated with OPAL opacities and an outer boundary modification that allows for including the kinetic energy of the accreting matter and inward boundary layer irradiation as well as compressional heating.

3.30 Accretion Belts

The physical processes implied by the existence of accretion belts (Huang *et al.* 1996, Sion *et al.* 1996, Gansicke & Beuermann 1996) may provide a new mechanism (see Sion 1995 and Sparks *et al.* 1993) to account for the long puzzling *missing boundary layer*. The method of analysis we have developed can be applied to detect such belt structure in other CVs to obtain physical information of white dwarf-disk interaction in their boundary layer. One of the key assumptions made in the standard disk theory model (Pringle 1981) is a boundary condition of the disk at its inner radius: the rotational speed of the disk should match that on the surface of the primary. For a slow or non-rotating white dwarf, this implies a small emitting area of the boundary layer, $A_{WD}/\mathscr{M}^2$, where $\mathscr{M}$ is the Mach number ($\sim 10^2$) of the Keplerian rotating speed at the white dwarf surface, and thus a rather high effective temperature ($\geq$100,000K). The fact that a boundary layer with such high effective temperatures has not been observed is often referred as missing boundary layer problem. Our new results show that this assumption may be incorrect: in VW Hyi, we found that it is *the surface of the white dwarf which matches the rotational speed of the Keplerian disk*, and *the emitting area of the boundary layer is much larger, thus the effective temperature of the boundary layer is much lower* than the values predicted by the theory. Our method of analyzing the high S/N, high resolution HST spectra in the far-*UV* during the quiescence of CVs opens a new window for probing boundary layer physics. We are currently applying this method to detect belt structures in other CVs.

3.31 Theoretical Model of Shear Mixing

Sion, Huang and Cheng are developing a dynamic model for white dwarf-disk interaction in the boundary layers, which is urgently needed to quantitatively understand the properties of the observed accretion belts. By applying the energy criteria characterized by the *Richardson number*, $\mathscr{R}i$, we found that in a differentially rotating envelope of the white dwarf, the mixing caused by the forced convection is most efficient on *equi-potential surfaces*, along which $\mathscr{R}i \equiv 0$. To simulate these mixing processes, we use the equipotential surfaces as one family of our coordinate surfaces. Since the rotational speed distribution as well as the shape of the surfaces in the white dwarf envelope varies with time, so do our coordinate surfaces. Further results from our code using this *time-dependent zoning* technique will be reported in due time.

4. MODEL FOR HIGH/LOW STATE OF AM HERS

Collaborating with W.M. Sparks (LANL) and S. Howell (U.WY), Huang investigated the mechanism of the high and low state activities of AM Hers (Sparks, Howell & Huang 1996). The material from the secondary is accreted along the magnetic field lines, deposits its angular momentum onto the primary, which is temporarily spun up relative to the system's orbital motion. Through the magnetic field lines connecting the primary and the secondary, the primary exerts magnetic torque back to the secondary, slightly spins up the binary system, and increases the binary separation, a. We examined a simplified model: when a exceeds a critical value a_c, the secondary is detached from the Roche lobe, the accretion is terminated, and the system is in its low state. Without accretion flow from the secondary to the primary, the magnetic field lines oscillate around their equilibrium positions with frequency $\omega = \sqrt{\frac{K}{I}}$ where I is the moment of inertia of the white dwarf, and $K = \frac{\partial J}{\partial \theta}$ with J being the magnetic torque and θ the angular displacement of a magnetic line relative to its equilibrium position. The binary separation also oscillates around its average value, $\overline{a}$, accordingly. Assuming that $\overline{a} \approx a_c$, and the time scale for the secondary to re-attach with its Roche lobe is long enough, then the duration of the low state should roughly be the duration of $a > \overline{a}$. With typical values of K and I, this duration can be estimated as $\frac{\pi}{\omega}$, which is about a year, matching the ob-

served average duration of AM Her's low states. Although the relative displacement/distortion of the magnetic field lines is too small to be observed, a future survey on the AM Her systems should be able to test the relation described above.

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5. CONFERENCES & APPOINTMENTS

Ambruster and Jewell attended the Fifth Oxford Archaeoastronomy Conference in Santa Fe, NM. Cardelli served on the AAS National Nominating Committee for 1995-1997; he chaired a special AAS session on policy at the January meeting.

During 1995/96 Guinan continued to served as the chair of the AAS Committee on Employment and vice president of IAU Commission 42 – Close Binary Systems. He is on the editorial advising committee for the Information Bulletin of Variable Stars. Guinan served on the SOC for the Third Pacific Rim Meeting on Close Binary Stars (Chiang Mai, Thailand, Oct 1995) and gave an invited paper. Guinan attended the AAS Meetings in San Antonio, TX and Madison, WI. At the Texas meeting he chaired a special AAS session: *Jobs and Careers for Astronomers*. Guinan served on the Gemini Fellowship Committee, the April science careers meeting at the American Institute of Physics, and the EUVE User Committee in Madison, WI. He presented seminars at PSI (Switz.), the Astronomy Institute of the Czech Academy of Sciences, and the 12th Institut d'Astrophysique de Paris Astrophysics Colloquium (Paris). He is the co-chair of the SOC for IAU Joint Discussion on '' Stellar Evolution in Real Time'' that will be held at the IAU General Assembly in Kyoto, Japan during August, 1997.

Sion was appointed Associate Editor of The Astrophysical Journal. During the report period Sion presented invited review talks at: the Conference *Symbiotic Variables and Related Objects* in Koninki, Poland, at the Symposium *Stellar Ecology* (Island of Elba, Italy) in honor of the 65th Birthday of Professor Icko Iben, Jr.. He gave a paper at *10th European Workshop on White Dwarfs* in Blanes (Barcelona), Spain. Sion and Huang presented papers at the Conference *Accretion Phenomena and Associated Outflows* held in Port Douglas, Australia. He was an extended visitor at the European Space Agency (Vilspa, Spain) where he presented a colloquium, at the U. of Gottingen (Germany) and at the Center for EUV Astrophysics at UC, Berkeley where he also presented a colloquium. Sion chaired a panel for the Stars and Stellar Evolution Peer Review of the National Science Foundation and served on the Hubble Space Telescope Peer Review Panel for *Hot Stars and Star Formation*.

Dr. Sofia presented an invited paper at the ASP Symposium *From Stardust to Planetesimals*.

5.1 Association of Research Astronomers

Derck Massa (Applied Research Corporation) has assumed responsibility for Association of Research Astronomers (ARA), an organization primarily of research astronomers in non-faculty positions, particularly those supported by grants and contracts. The ARA was created to provide a forum for open discussion of the issues of concern to researcher astronomers. As part of its mission, the ARA has tried to provide useful feedback to the community. Information on the ARA can be found on the WorldWideWeb: www.phy.vill.edu/astro/faculty/ara/ara_home.htm.

PUBLICATIONS

Refereed Journals

Ambruster, C.W., Fekel, F.C., Guinan, E.F., & Hrivnak, B.J. (1996). The Extremely Active Single Giant 1E1751 +7046 = ET Dra: Revised Properties and a Reevaluation of its Evolutionary Status, ApJ, in press

Cardelli, J. (1996). The Job Market: Soft Money, Hard Times. Mercury, 25, 30

Cardelli, J. A., Meyer, D. M., Jura, M., & Savage, B.D.(1996). The Abundance of Interstellar Carbon. ApJ, 467, 334

Fabian, D., & Usher, P.D. (1996). Optical Morphology of Bright Quasars on Images Taken with 1.2 m Schmidt Cameras, AJ, 111, 645

Harmanec, P., Morand, F., Bonneau, D., Jiang, Y., Yang, S., Guinan, E.F., Hall, D. S., Mourard, D., Hadrava, P., Bozic, H., Sterken, C., Tallon-Bosc, I., Walker, G.A.H., McCook, G.P., Vakili, F., Stee, Ph. & Contel, J.M. (1996). Jet-Like Structures in Beta Lyr: Results of Optical Interferometry, Spectroscopy, and Photometry. A&A 312, 879

Hrivnak, B.J., Guinan, E.F., & Wenxian, L. (1995). A Study of The Chromospherically Active, Short-Period Binary VZ Piscium. ApJ, 455, 300

Holberg, J.R., Barstow, M.A, Bruhweiler, F., & Sion, E.M. (1995) The EUVE and IUE Spectra of the Hot DA White Dwarf GD659, ApJ, 453, 313

Huang, M., Sion, E.M., Hubeny, I., Cheng, F.H., & Szkody, P., 1996, The Accretion Disk (Belt?) During the Quiescence of VW Hydri, AJ, 111, 2386

Huang, M., Sion, E.M., Hubeny, I., Cheng, F.H., & Szkody, P. (1996) Hubble Space Telescope/FOS Spectroscopy of VW Hydri in Superoutburst, ApJ 458, 355

Jenkins, E.B., Reale, M.A., Zucchino, P.M., & Sofia, U.J. (1996), High Resolution Spectroscopy in the Far UV: Observations of the Interstellar Medium by IMAPS on ORFEUS-SPAS, Exp.Astr., in press

Jura, M., Meyer, D.M., Hawkins, I. & Cardelli, J.A. (1996). The Interstellar Boron Abundance toward Orion, ApJ, 456, 598

Kim, K., & Kang, Y.W. (1996), Homogeneous Solution for SW Lacertae, Kor.J.A.Sp.Sci., 13, 1

Linsky, J.L., Wood, B.E., Brown, A., Giampapa, M. S., & Ambruster, C. W. (1995). Stellar Activity at the End of the Main Sequence: GHRS Observations of the M8 Ve Star VB 10, ApJ., 455, 670

Sion, E.M., Cheng, F., Huang, M., Hubeny, I., & Szkody, P. (1996). The Cooling White Dwarf in VW Hydri After Nornal Outburst and Superoutburst: HST Evidence of a Sustained Accretion Belt, ApJ, in press

Sion, E.M., Cheng, F., Szkody, P., Provencal, J., Sparks, W., Mattei, J., Abbott, B., Hubeny, I., & Shipman, H. (1996) Hubble Space Telescope GHRS Spectroscopy of U Geminorum During Two Outbursts (1996), ApJ, in press

Sion, E.M., Holberg, J.B., Barstow, M.A., & Scheible, M.P. (1996). Ongoing Mass Ejection in the Peculiar Hot DO Degenerate KPD0005+5106, AJ, in press

Szkody, P., Long, K., Sion, E.M., & Raymond, J. (1996) ASCA Observations of U Geminorum, ApJ, 469, 834

Szkody, P., Silber, A., Downes, R.A., & Sion, E.M. (1996). The Cooling White Dwarf in AL Com (1996), AJ, in press

Vrtilek, S.D. & Cheng, F.H., 1996. The ultraviolet/optical continuum of Hercules X-1/HZ Herculis, ApJ, 465, 915

Conference Proceedings, Symposia, & Colloquia

Bradstreet, D.H., Baliunas, S.L., & Guinan, E.F. (1996). Physical Properties of the Contact Binaries of the Old Open Cluster NGC 188, in *Binaries in Clusters*, eds., E.F. Milone & J.-C. Mermilloid (ASP CS vol. 90), p. 135

Cardelli, J.A. (1995). Revisiting Diffuse Interstellar Bands in The Satellite Ultraviolet with the Goddard High Resolution Spectrograph, in *The Diffuse Interstellar Bands*, eds., AGGM Tielens and T.P. Snow (Kluwer), pp. 53-63

Cardelli, J. A. (1996). Current status of High Resolution/high Signal-to-Noise Interstellar Spectroscopy: Capabilites, Successes, and Needs. in *Laboratory and Astronomical High Resolution Spectra* (ASPCS: 81), eds. A. J. Sauval, R. Blomme, & N. Grevesse (ASP: San Francisco), pp. 411-426

Guinan, E.F., Bradstreet, D.H., & DeWarf, L. E (1996). Eclipsing Binaries in the Magellanic Clouds; Fundamental Properties and Distances, in *Binaries in Clusters*, eds., E.F. Milone & J.-C. Mermilloid (ASP CS vol. 90), p. 196

Kang, Y.W. (1996). Light Curve Analysis of Four Eclipsing Binaries in M31, in *The Origins, Evolutions and Destinies of Binary Stars in Clusters*, eds. E.F. Milone & J.C. Mermilliod (ASP CS vol. 90), p. 226

Kang, Y.W., & Kim, J. (1996). Roche Configuration of R Canis Majoris, in *Proceedings Seventh KSEA Northeast Regional Conference*, p. 38

Landsman, W., Sofia, U.J., & Bergeron, P. (1996), GHRS Observations of Interstellar Deuterium toward HZ 43, in *Science with the Hubble Space Telescope – II*, eds. P. Benvenuti, F.D. Machetto, & E. J. Schreier (STScI), p. 454

Huang, M., Sparks, W.M., and Sion, E.M., (1996). Clues and Modelling for Missing Boundary Layer in Cataclysmic Variables in Proceedings of IAU 163: *Accretion Phenomena and Associated Outflows*, in press

Sion, E.M. (1995), The White Dwarf Descendants of Wolf-Rayet Planetary Nuclei, in *Wolf-Rayet Planetary Nuclei*, eds. E. Jurlander and B. Bjorkmann, (Kluwer: Dordrecht), Astr.Sp. Sci. 238, 131

Sion, E. M. (1995). The Helium-rich White Dwarfs: Statistics and Classification Ten Years Post-Mysore, in *Hydrogen Stars and Related Objects*, eds. S. Jeffery and U. Heber, (PASP Conf. Series), in press

Sion, E. M. (1996). Hubble Space Telescope Studies of Exposed White Dwarfs in Dwarf Novae. JAAVSO, 24, 1-8

Sion, E.M. (1996) Preliminary Analysis of a Hubble FOS Spectrum of VW Hydri in Quiescence: A DAQZ White Dwarf and Accretion Belt/Ring, in *Cataclysmic Variables and Related Objects*, eds. A. Evans & J.H. Wood, (Dordrecht: Kluwer), 249

Sparks, W. M., Howell, S. & Huang, M. (1996). A Model for the Low/High State Activity of AM Hers, in Proceedings of IAU 163, *Accretion Phenomena and Associated Outflow*, in press

Sofia, U.J. (1996), The Composition of Interstellar Dust, in *Changing Perceptions of the Morphology, Dust Content, and Dust-Gas Ratios in Galaxies*, (Kluwer: Dordrecht), in press

Sofia, U.J. (1996), Depletions and Interstellar Dust, in *From Stardust to Planetessimals*, (ASP: San Francisco), in press

Sofia, U.J., Cardelli, J.A., & Savage, B.D. (1996). Empirical Determinations of f-Values from Interstellar Lines, in *Laboratory and Astronomical High Resolution Spectra* (ASPCS: 81), eds. A. J. Sauval, R. Blomme, & N. Grevesse (ASP: San Francisco), pp. 462-466

Abstracts, Bulletins & Poster Papers

Ambruster, C.W., Brown, A., & Fekel, F.C. (1995). GHRS Observations of Solar Neighborhood ZAMS K Dwarfs, BAAS 27, 1430

Belle, K., Nguyen, Q., Fabian, D., Huang, M., & Sion, E. M. (1995). A Comparative Synthetic Spectral Analysis of the Low Resolution IUE Spectra of Two Dwarf Novae in Outburst: RX Andromeda and T Leonis, BAAS 27, 1399

Bradstreet, D.H., DeWarf, L.E., Guinan, E.F., Maloney, F.P., & Maurone, P.A. (1995). Eclipsing Binaries in the Magellanic Clouds: Continuing Study of Stellar Structure, Evolution, and Distance, BAAS 27, 1344

Burns, J., Guinan, E.F., & Marshall, J. (1996). New Apsidal Motion Determination of the Eccentric Eclipsing Binary V1143 Cygni, IBVS No. 4363

DeWarf, L.E., Guinan, E.F., Wong, K., Dorren, J.D. (1996). Long-Term Photometric and Chromospheric Variations in V711 Tauri, BAAS 28, 942

Dukes, R., Nations, H., Buzasi, D., Guinan, E.F., & McCook, G.P. (1995). Photometry of 51 Pegasi. IAU Cir. No. 6261

Fabian, F., Nguyen, Q., Belle, B., Huang, M., & Sion, E. M. (1995). The Photospheric Properties of the Underlying Hot White Dwarf in The Nova-like Variable TT Arietis During Its 1983 Low State, BAAS, 27, 1399

Guinan, E.F., DeWarf, L.E., Messina, S., & McCook, G.P. (19950, Stellar Rubella: Starspots on F, G, and K Stars of Different Ages and Rotation Periods, BAAS, 27, 838

Guinan, E.F., Maley, J., & Marshall, J.J. (1996). V541 Cygni: An Eccentric Eclipsing Binary with a Smaller Than Expected Apsidal Motion. IBVS No. 4362

Guinan, E.F., & Messina, S. (1995). Alpha Centauri B, IAU Cir. No. 6259

Guinan, E. F., & Morgan, N.D. (1996). Proxima Centauri: Rotation, Chromospheric Activity, and Flares, BAAS 28, 942

Guinan, E.F., & Morgan, N. (1996). Alpha Centauri C., IAU Cir. No. 6338

Guinan, E.F., & Steelman, D. (1995). Betegeuse. IAU Cir. No. 6150

Maley, J.A., Guinan, E.F., Maloney, F.P., Marshall, J.J., McCook, G.P., & Bradstreet, D.H. (1996). Eclipsing Binaries as Tests of General Relativity: The Case of V541 Cygni, BAAS 28, 756

McDavid, D., Hirata, R., Guinan, E.F., Bjorkman, K.S., Babler, B.L. (1996). Variable Plarization of the Be Star Omega Orionis, BAAS 28, 913

Messina, S., & Guinan, E.F. (1996). Starspots on the Young Single K0V Star HD 82443, IBVS 4286

Nguyen, Q., Belle, K., Fabian, D., Huang, M., & Sion, E.M. (1995). A Photospheric Analysis of the Underlying White Dwarf in the High Accretion Rate Dwarf Nova RX Andromedae, BAAS, 27, 1398

Schaefer, K., Bond, H.E., Saffer, R.A., & Sion, E.M. (1995). HST Observations of the White Dwarf in V471 Tauri, BAAS, 27, 1358

Sofia, U.J., & Jenkins, E.B. (1996). The Abundance and Depletion of Interstellar Argon, BAAS, 28, 930

G. P. McCook & E. R. Jewell