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COORDINATED X-RAY, ULTRAVIOLET AND OPTICAL OBSERVATIONS OF AM HERCULIS, U GEMINORUM, AND SS CYGNI

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ABSTRACT

Simultaneous and quasi-simultaneous observations of AM Her, U Gem, and SS Cyg with the *Einstein* and *International Ultraviolet Explorer* (*IUE*) satellites are reported, with optical monitoring provided by the American Association of Variable Star Observers (AAVSO). AM Her appeared to be in a high state at the time of the observations, while SS Cyg and U Gem were in the optical low state. SS Cyg was also observed photometrically at the same time as the UV and X-ray observations. We detect hard (> 1 keV) X-rays from U Gem at minimum, but at much lower intensity than in AM Her and SS Cyg. The optical/UV/X-ray spectra of AM Her and SS Cyg are remarkably similar both in the continuum and in the UV emission lines. Although U Gem exhibits absorption lines on a continuous UV spectrum, it is similar to the other two systems in exhibiting a UV blackbody component with $kT > 10$ eV. The fluxes in these components are in excess of both the hard X-ray and optical fluxes. This is inconsistent with standard accretion disk and accretion column models. We suggest that nuclear burning at the surface of the white dwarf might be responsible for the excess UV flux. This assumes that the same basic mechanisms operate in these cataclysmic variables, but different detailed spectral distributions result from different balances between magnetic field intensity and accretion rates.

Subject headings: stars: individual — stars: dwarf novae — ultraviolet: spectra — X-rays: binaries

I. INTRODUCTION

AM Her, U Gem, and SS Cyg are believed to be binary systems consisting of a late type star of mass less than 1 $M_\odot$ and a more massive white dwarf. Optically they can be found in either a high emission state ($m_v \approx 12, 8, 8$ for AM Her, SS Cyg, and U Gem, respectively) or a low emission state ($m_v \approx 15, 12, 14$). SS Cyg and U Gem are optically quite similar, undergoing quasi-periodic outbursts lasting a few days. AM Her, on the other hand, is found typically in the high emission state. These systems have all been detected in the X-ray region (Tuohy *et al.* 1978; Heise *et al.* 1978; Fabbiano *et al.* 1978; Ricketts, King, and Raine 1979; Swank 1979; Córdova 1980*a*, *b*), and AM Her and SS Cyg have also been observed spectroscopically in the UV (Heap *et al.* 1978; Raymond *et al.* 1979*a*, *b*). The mechanism of X-ray emission is generally believed to be radial accretion on the white dwarf (Fabian, Pringle, and Rees 1976; Lamb and Masters 1979). The three systems chosen for this study represent different kinds of accreting white dwarfs. AM Her has an intense magnetic field ($B \approx 10^8$ gauss) (Tapia 1977) and no accretion disk. Because of this, it is believed to be powered by an accreting column at the magnetic pole of the white dwarf (Lamb and Masters 1979; King and Lasota 1979). Optical spectroscopy shows that both SS Cyg and U Gem are associated with accretion disks (see Robinson 1976 and references therein). The X-ray behavior of SS Cyg has led to an estimate of a magnetic field $B \approx 10^6$ gauss associated with the white dwarf (Ricketts, King, and Raine 1979). No estimate of B has so far been produced for U Gem. The fact that the hard X-ray luminosity of U Gem is at least one order of magnitude smaller than that of SS Cyg (Mason, Córdova, and Swank 1979) suggests different magnetic field intensities and/or accretion rates in the two systems. The comparative study of these three accreting degenerate dwarfs should then give us information that can put interesting constraints on the theory for different values of the parameters of the systems.

In this paper we report the results of coordinated observations in the optical/UV/X-ray of AM Her, U Gem, and SS Cyg, and we compare our findings with the existing theoretical predictions. The simultaneity or

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quasi-simultaneity of our observations in the different energy bands allows us a straightforward unambiguous comparison with the theory.

II. OBSERVATIONS

A description of the X-ray instruments on board the *Einstein* Observatory may be found in Giacconi *et al.* (1979); for a description of the *International Ultraviolet Explorer*, see Boggess *et al.* (1978*a*, *b*).

a) *AM Herculis*

AM Herculis was observed with the 500 lines mm^{-1} Objective Grating Spectrometer (OGS) in front of the High Resolution Imager (HRI) onboard the *Einstein* Observatory on 1979 March 17. The OGS allows us to obtain spectral information which is not otherwise provided by the HRI. The soft X-ray spectrum of AM Her obtained from the OGS observation does not show any line contribution (Seward 1979, private communication). It is consistent with a blackbody radiation with $kT \approx 30$–40 eV (Heise 1980, private communication).

Around the time of the HRI/OGS observation of AM Her, 13 low-dispersion short wavelength (1150–1950 Å) and three low-dispersion long wavelength (1900–3200 Å) spectra of the source were obtained with IUE. Exposure times were 10 minutes and 15 minutes for short and long wavelengths, respectively. To minimize time lost in camera preparation and readout, two spectra were obtained from each exposure by placing the star on alternate sides of the large aperture. Final spectra were obtained from the line-by-line files on the guest observer tape. The Intensity Transfer Function (ITF) error was corrected by interpolating old and new DN values (Holm 1979, private communication), and the results agree with the "three-agency fourth file correction" (Cassatella *et al.* 1980) to $\sim 3\%$. Only two of these spectra have simultaneous X-ray coverage owing to the Earth occultation gap in the *Einstein* satellite data and to the camera readout and preparation time needed by the *IUE* satellite. For the HRI/OGS observations we have calculated the incident undispersed X-ray flux from the number of counts in the zero-order dispersed spectrum, assuming the transmission of the spectrometer to be 18%, as deduced from the calibrations before launch. Table 1 summarizes the X-ray data; the UV and optical data are summarized in Table 2. The X-ray fluxes are background subtracted and corrected for the scattering of the telescope. The systematic uncertainty on the value of the grating transmission is of the order of 15%. The luminosities in Table 1 are calculated for a distance of 100 pc and a blackbody spectrum at 3×10^5 K with a low energy absorption corresponding to 3.75×10^{20} atoms cm^{-2} of neutral hydrogen on the line of sight (Tuohy *et al.* 1978).

While being viewed by the focal plane instrument, any target observed by the *Einstein* Observatory is also in the field of view of the Monitor Proportional Counter (MPC, energy band 1–20 keV). In Table 1 the MPC fluxes during the ON time of the AM Her observations are listed. Spectral analysis of such data using the eight pulse-height analyzer (PHA) channels of the detector yields a best fit for a power law spectrum with no significant low energy cutoff and spectral index $\alpha \approx 0.2$. Thermal bremsstrahlung fits show $kT > 30$ keV, consistent with the result of Swank *et al.* (1977). In both cases the 2–6 keV X-ray flux is $\sim 6.6 \times 10^{-11}$ ergs cm^{-2} s^{-1} (Table 1).

During the 1979 March HRI/OGS and *IUE* observations, optical monitoring of AM Her was also carried out by the AAVSO. An $m_v \approx 12.8$ was measured, showing that AM Her was in the optical high state. Figure 1*a* shows the soft X-ray (HRI/OGS) light curve of AM Her between days 1979 March 16 and 17. The units of the X-ray flux are HRI counts per second in a 125″ radius circle containing the zero-order dispersed image of the source (the background, only $\sim 6 \times 10^{-2}$ counts s^{-1} is not subtracted). The long gap in the middle of the X-ray data corresponds to the period when the source was Earth occulted. The gap covers the time of ingress into the X-ray eclipse. In the plot we can clearly see the last part of such eclipse and egress from it. A residual X-ray flux of $\sim 3\%$ of that observed during the ON time is still detectable during the eclipse, as already noticed by Tuohy *et al.* (1978). The X-ray emission of AM Her appears extremely variable during its ON time, with changes in flux up to a factor of ~ 2.5 in 3 minutes or less.

TABLE 1

X-RAY OBSERVATIONS

Object	Start and Stop Times (UT)	Instrument	Energy Band (keV)	Flux (ergs cm^{-2} s^{-1})	D (pc)	L_x (ergs s^{-1})
AM Her	1979, $76^d23^h23^m2^s$; $77^d1^h43^m40^s$	HRI/OGS(500)	0.1–4.5	$3.2 \times 10^{-10} \pm 15\%$ (ON time)	100	3.6×10^{32}
				$1.0 \times 10^{-11} \pm 15\%$ (eclipse)		1.1×10^{31}
		MPC	2–6	$(6.6 \pm 0.2) \times 10^{-11}$ (ON time)		7.5×10^{31}
				[a] (eclipse)		
U Gem	1979, $119^d1^h34^m16^s$; $2^h20^m41^s$	IPC	0.5–4.5	$(2.0 \pm 0.2) \times 10^{-12}$	76[b]	1.3×10^{30}
		MPC	2–6	$< 2.5 \times 10^{-11} (3\sigma)$		$< 1.6 \times 10^{31} (3\sigma)$
SS Cyg........	1979, $137^d7^h19^m53^s$; $17^h14^m29^s$	HRI/OGS(1000)	0.4–2	3.5×10^{-11} 20%	120[c]	5.7×10^{31}
		MPC	2–6	$(4.4–5.8) \times 10^{-11}$		8.3×10^{31}

[a] No eclipse date are available for MPC spectral analysis.
[b] Wade 1979.
[c] Kiplinger 1979.

TABLE 2

UV AND OPTICAL CONTINUUM AVERAGE FLUXES (1979)

λ(Å)	E(keV)	F_E(10^{-8} ergs cm^{-2} s^{-1} keV^{-1})	F_E during Eclipse
		AM Herculis, March 17	
5500	2.2	8.8	
3100	4.0	7.05 ± 0.70	
2900	4.3	6.17 ± 0.62	
2700	4.6	6.11 ± 0.61	
2500	5.0	5.74 ± 0.57	
2300	5.4	5.16 ± 0.52	
2100	5.9	4.80 ± 0.48	
1896	6.4	4.36 ± 0.44	4.06 ± 0.41
1777	6.8	4.25 ± 0.42	3.74 ± 0.37
1658	7.3	3.98 ± 0.40	3.37 ± 0.34
1555	7.8	3.87 ± 0.39	3.21 ± 0.32
1407	8.6	3.73 ± 0.37	2.74 ± 0.27
1325	9.1	3.69 ± 0.37	2.70 ± 0.27
1263	9.6	3.83 ± 0.38	2.56 ± 0.26
1131	11.1	3.94 ± 0.79	
		U Geminorum, April 29	
5500	2.2	1.8	
1950	6.4	1.41 ± 0.06	
1850	6.7	1.68 ± 0.06	
1750	7.1	1.97 ± 0.05	
1650	7.5	1.76 ± 0.24	
1550	8.0	2.07 ± 0.24	
1450	8.6	2.37 ± 0.20	
1350	9.1	2.64 ± 0.12	
1250	9.9	2.80 ± 0.12	
1150	11.0	3.46 ± 0.6	
		SS Cygni, May 17	
5500[a]	2.2	16.	
4400[a]	2.8	9.3	
3600[a]	3.4	7.4	
1928	6.4	2.85 ± 0.14	
1739	7.1	2.66 ± 0.12	
1597	7.8	2.56 ± 0.19	
1496	8.3	2.78 ± 0.17	
1439	8.6	2.56 ± 0.10	
1363	9.1	2.83 ± 0.10	
1269	9.7	3.12 ± 0.17	
1162	10.8	3.87 ± 0.43	

[a] Szkody, private communication.

TABLE 3

UV EMISSION LINE SPECTRA

Line	λ(Å)	F_E(10^{-13} ergs cm^{-2} s^{-1}) AM Her (17 March 1979)	SS Cyg (17 May 1979)
C III	1176	29.6	4.2
N V	1240	52.2	6.9
O I, Si III	1300	9.1	12.1
C II	1335	13.4	10.6
O V	1371	0.7	...
Si IV	1400	53.6	32.2
C IV	1550	192.0	124.0
He II	1640	45.4	4.7
Al III	1860	20.3	10.7
Si III	1897	...	2.6

The UV spectra are similar to those reported by Raymond *et al.* (1979*a*). The average of the 13 short-wavelength spectra is shown in Figure 2. Strong emission lines of C III, Lα (which is contaminated by the geocoronal Lα), N V, O I + Si III, C II, Si IV, C IV, He II, and Al III are detected (Table 3). No Lα absorption line is apparent in the spectrum. The short wavelength spectra are spaced fairly uniformly over two orbital cycles. They confirm the suggestion of Raymond *et al.* (1979*a*) that the UV continuum is the sum of two power law components. The $F_\nu \propto \nu^{-1}$ component is always present whereas the $F_\nu \propto \nu^2$ component disappears in phase with the X-ray eclipse. The UV continuum (Table 2) may be separated into the two components as shown by Raymond *et al.* (1979*b*). The $F_\nu \propto \nu^2$ component may be interpreted as the Rayleigh-Jeans tail of the ~ 30 eV blackbody which

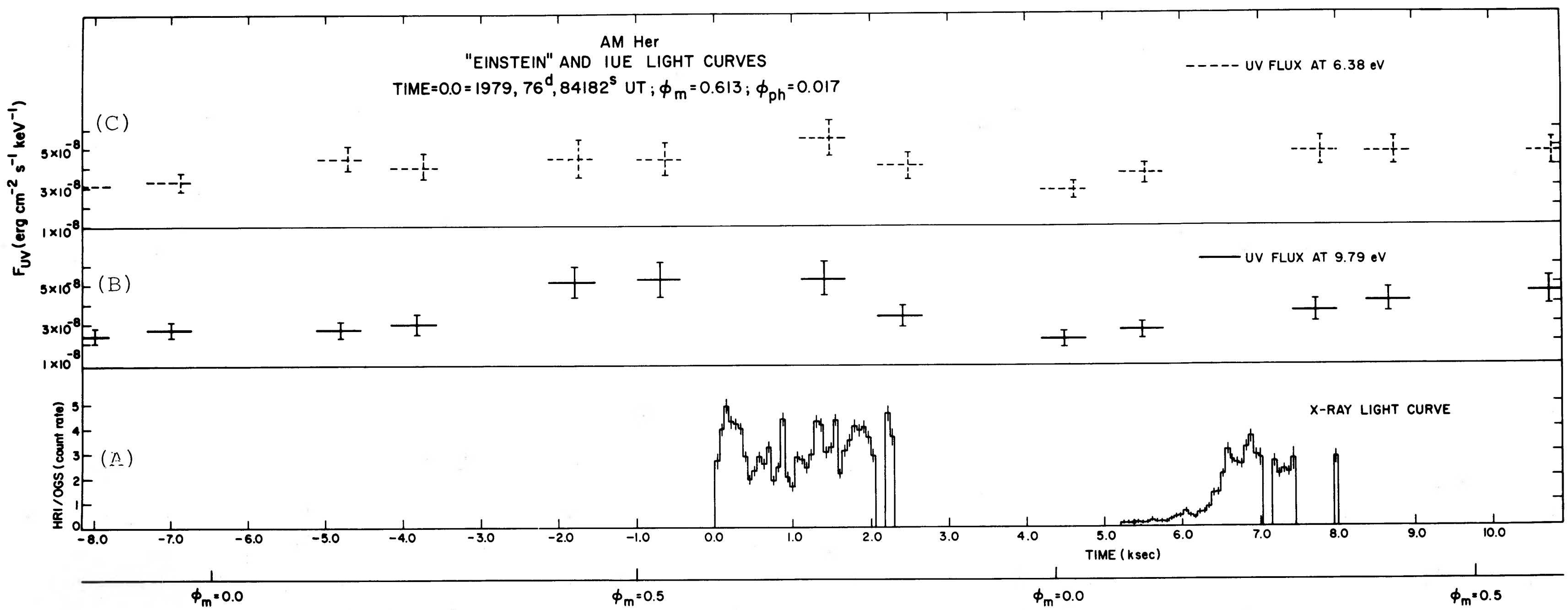

FIG. 1.—X-ray and UV light curve of AM Her. Notice the presence of the less energetic (6.38 eV) UV flux during the eclipse, in agreement with the observations of Raymond *et al.* (1979). The quantity ϕ_m is the magnetic phase and ϕ_{ph} the photometric phase (see Chiappetti, Tanzi, and Treves 1980 and references therein).

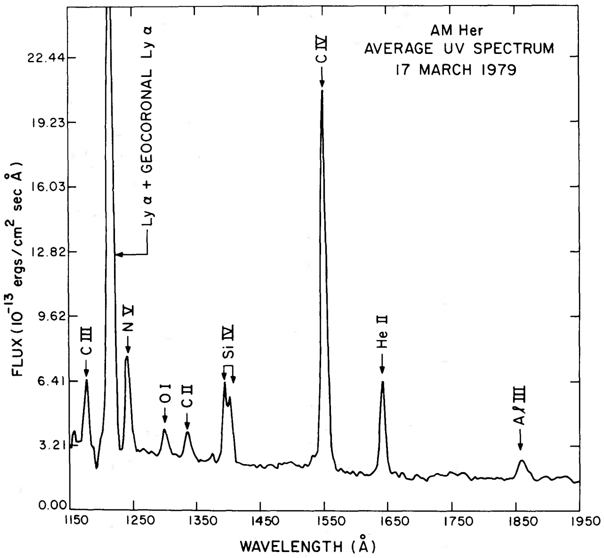

FIG. 2.—Average short-wavelength UV spectrum of AM Her during the 1979 March 17 observations

produces the soft X-ray emission (Bunner 1978; Tuohy *et al.* 1978). The light curves for the UV flux at energies of 9.76 and 6.38 eV reflecting the blackbody and power law components, respectively, are plotted in Figure 1*b* and 1*c*, respectively. The composite continuum spectrum of AM Her, from optical to X-rays, during the 1979 March 16–17 observation is shown in Figure 3. The X-ray and UV points are the averages of the *Einstein* and *IUE* observations.

b) U Geminorum

U Geminorum was observed on 1979 April 29 for 1170 s with the Imaging Proportional Counter (IPC) onboard the *Einstein* Observatory. This observation occurred 20 minutes after ~ 8 hours of observation with the *IUE* satellite, during which six spectra of the source were taken. Each one of the *IUE* spectra was exposed from 40 to 60 minutes. The *IUE* spectra do not show any presence of variability. U Gem was reported by the AAVSO to be in an optical low state at about $m_v = 14.2$ at the time of the X-ray and ultraviolet observations. The starting time of X-ray observation corresponds to binary $\phi = 0.00$.

The results of these observations of U Gem are summarized in Tables 1 and 2 and in Figure 4.

From a comparison of the hardness ratios of U Gem and SS Cyg, we find that the X-ray spectrum of U Gem at minimum appears to be softer than that of SS Cyg ($kT \approx 20$ keV). We define the hardness ratio as the ratio of the counts in the (1–4) keV band to those in the < 1 keV band. The IPC hardness ratio of U Gem is less than 0.4 while that of SS Cyg is ~ 1.7. The hardness ratio of SS Cyg has been calculated using unpublished IPC data taken in 1978 December, during an optical low state.

Assuming a bremsstrahlung spectrum with a hydrogen absorption column density $N_{\rm H} \approx 1 \times 10^{20}$ cm^{-2} and $kT \sim 3$ keV, the (0.5–4) keV luminosity of U Gem is $(1.3 \pm 0.2) \times 10^{30}$ ergs s^{-1} for a distance of 76 pc (Wade 1979). If we allow for uncertainty in the determination of the spectrum, the systematic error in the luminosity would be ~ 30%. The X-ray observations (Fig. 5) show a clear presence of variability. The X-ray intensity appears to decrease during the length of the observation; a feature involving a decrease of the intensity in a smaller time scale is also present. A χ^2 test shows that the data are definably incompatible with the hypothesis of constant intensity for time scales greater than 2 minutes.

We find some evidence of a correlation between intensity and spectral behàviour in U Gem. If we divide our observations in three equal bins of ~ 480 s each, in fact, we have 0.17 ± 0.02, 0.09 ± 0.01, and 0.11 ± 0.01 counts s^{-1} average intensities in the first, second, and third bins, respectively, in the (0.1–4.2) keV energy range after subtracting the background. For each of them we calculated the hardness ratio as defined above, and we found 0.36 ± 0.09, 0.14 ± 0.08, and 0.17 ± 0.07, respectively. This suggests that the radiation becomes softer when the intensity of the source decreases. Figure 6 shows the results of this analysis.

The average of five short wavelength IUE spectra is shown in Figure 7. In contrast to AM Her and SS Cyg (see below), the spectrum exhibits only absorption lines on a strong continuous background. There are no emission lines (the Lα feature is very likely only geocoronal) while absorption lines of O I, C II, C IV, and He II are present. A broad Lα absorption line with a width $\Delta\lambda \sim 70$ Å is also present.

c) SS Cygni

SS Cygni was observed simultaneously with the *Einstein* Observatory and the *IUE* satellite on 1979 May 17. The X-ray observation was done with the HRI/OGS (1000 lines mm^{-1} grating) in the focal plane of the telescope and lasted 9.9 hr. The total observing time, because of Earth occultation and other data gaps, is 3.4 hr. Of this, about 2 hr is simultaneous with the observations in the ultraviolet. The *IUE* observations cover a total time of about 6 hr within the X-ray observing time. A total of nine low-dispersion long-wavelength spectra were taken, four of which are simultaneous to X-ray observations. SS Cygni was monitored by the AAVSO and appeared to be in an optical low state at the time of the *Einstein* and *IUE* observations, at a magnitude between 11.3 and 12.0. Szkody (1979, private communication) observed the source photometrically simultaneously with the *Einstein* and *IUE* observations.

The X-ray, UV, and optical observations are summarized in Tables 1, 2, and 3. As for AM Her, the incident undispersed X-ray flux is calculated from the number of counts in the zero-order dispersed spectrum, correcting for the transmission of the spectrometer. In this case, however, we integrated the dispersed spectrum only between 0.4 and 2.0 keV. This is in fact the only energy range where the grating efficiency for the 1000 lines mm^{-1} grating is reasonably well known (with an uncertainty of ~ 25%). Given the lower sensitivity of the 1000 lines mm^{-1} OGS, and the lower intensity of SS Cyg with

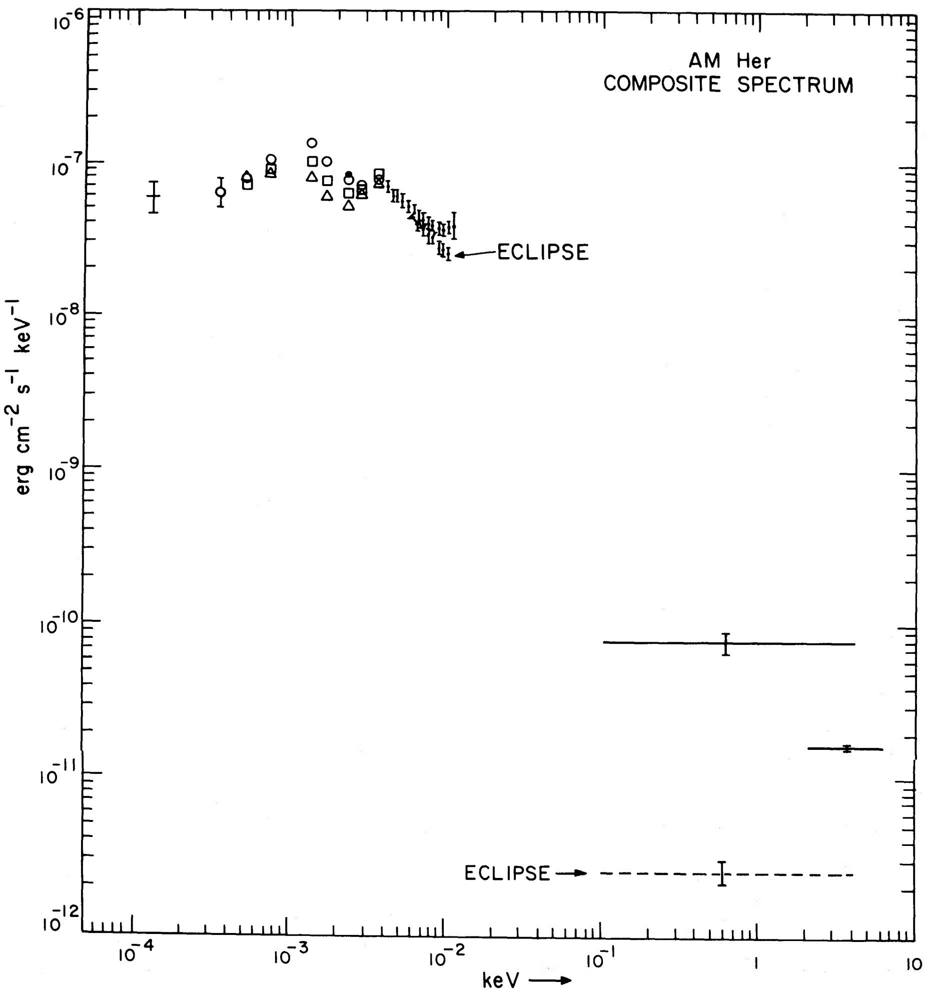

FIG. 3.—Composite spectrum of AM Her in high state. The UV and X-ray points were obtained during the 1979 March 17 simultaneous observations. The optical point (*dot*) has been given to us by the AAVSO and was obtained on 1979 March 17. The infrared and optical points are the measurements of Priedhorsky *et al.* (1978). The circles represent measurement obtained at maximum; the triangles refer to the primary minimum, and the squares to the secondary minimum. The secondary minimum coincides with the UV and X-ray eclipse.

respect to AM Her, this observation of SS Cyg cannot be used to obtain any short time scale variability information. No spectral features are detectable in the dispersed X-ray spectrum (Seward 1979, private communication). The MPC data are consistent with an exponential spectrum with $kT = 10$–30 keV and no significant low energy cutoff. The 2–6 keV intensity of SS Cyg is $(4.4$–$5.8) \times 10^{-11}$ ergs cm^{-2} s^{-1}.

The average *IUE* spectrum of SS Cyg is shown in Figure 8. The emission lines are the same as the ones observed in AM Her, but the line/continuum ratios appear to be smaller. The main difference with the spectrum of AM Her is in the presence of a broad Lα absorption line. We measure a width for this line of $\Delta\lambda = (45 \pm 5)$ Å.

The composite spectrum of SS Cyg during the May 17 observation is plotted in Figure 9. Here again, as in the case of AM Her, the UV data can be interpreted in terms of two components: a $\nu^{-1.3}$ power law that extends through the optical points and a ν^2 component that is predominant at the short wavelengths and could be representative of the Raleigh-Jeans end of a blackbody spectrum. The average flux of SS Cyg, both in the UV and in the X-rays, did not change significantly during our observations.

III. DISCUSSION

Despite previous work that indicates that AM Her, U Gem, and SS Cyg have substantially different accretion patterns, they possess one outstanding similarity. All of these cataclysmic variables have a UV short-wavelength component of their continuum spectrum which follows a $\sim \nu^2$ power law. This component had already been noticed in the spectrum of AM Her (Raymond *et al.* 1979*a*); our new observations show that it is also present in SS Cyg and in U Gem in quiescence. As discussed by Raymond *et al.* (1979*a*), if this feature represents the

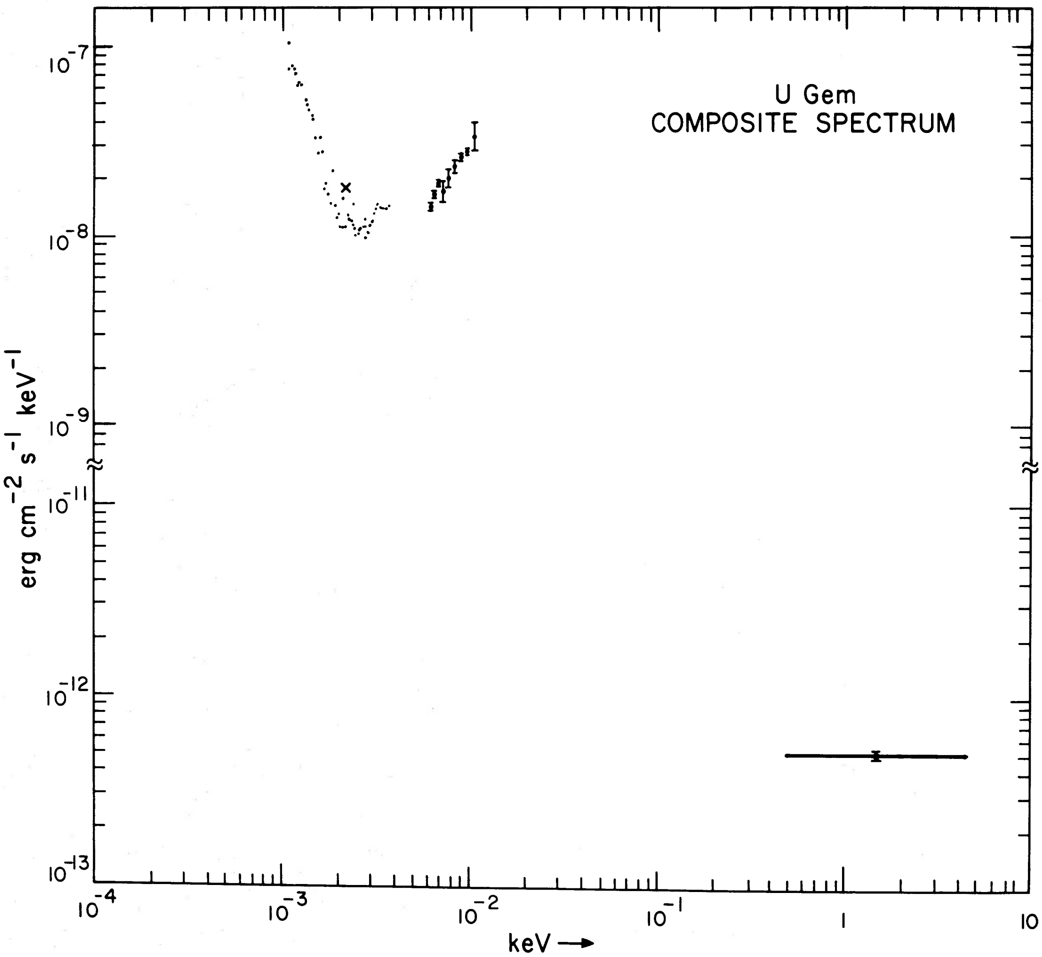

FIG. 4.—Composite spectrum of U Gem at minimum. The UV and X-ray points are relative to the quasi-simultaneous observations of 1979 April 29. The cross indicates the visual flux of U Gem at the time of the *IUE* and *Einstein* observations, as reported by the AAVSO. The dots cover the IR and optical observations of Wade (1979).

Rayleigh-Jeans end of a blackbody with temperatures of the order of 20–30 eV (see also Tuohy *et al.* 1978), the UV and soft X-ray luminosity of AM Her would be far greater than its hard X-ray luminosity. As is apparent from our data (Figs. 3, 4, and 9 and Table 4) and as discussed below in detail, the same is true in the case of SS Cyg and U Gem. This property disagrees with models of emission purely from gravitational accretion, both with and without magnetic fields (Lamb and Masters 1979; Kylafis and Lamb 1979). A possible resolution of this problem is the action of nuclear burning. Kippenhahn and Thomas (1978) have shown that it is possible to have localized burning in dwarf novae. They also have suggested that the different geometry could alter the condition for unstable burning which plays a crucial role in current nova theories (Giannone and Weigert 1967; Starrfield 1971). Moreover, the possibility of stable slow burning involving the *p-p* reaction instead of CNO burning is currently being investigated (Starrfield 1980, private communication). The results so far are very encouraging, although detailed dynamical calculations applied to the particular dwarf nova configuration have not yet been performed. The action of nuclear burning on the X-ray flux in a radially symmetric accreting white dwarf has been investigated by Katz (1977) and more recently by Weast *et al.* (1979).

In the following discussion, we present detailed analyses of this mechanism as applied to AM Her, SS Cyg, and U Gem. We also discuss our results in the light of the general behavior of these cataclysmic variables and find that we can reasonably explain different characteristics as the result of varying magnetic field strengths of the white dwarfs in the binary systems.

a) *AM Herculis*

AM Herculis has been widely studied (see, e.g., review of Chiappetti, Tanzi, and Treves 1980), and it is still an unsolved puzzle. Our simultaneous observations in the optical, UV, and X-ray are in agreement with earlier data (cf. Raymond *et al.* 1979*a*, *b*). This excludes the possibility

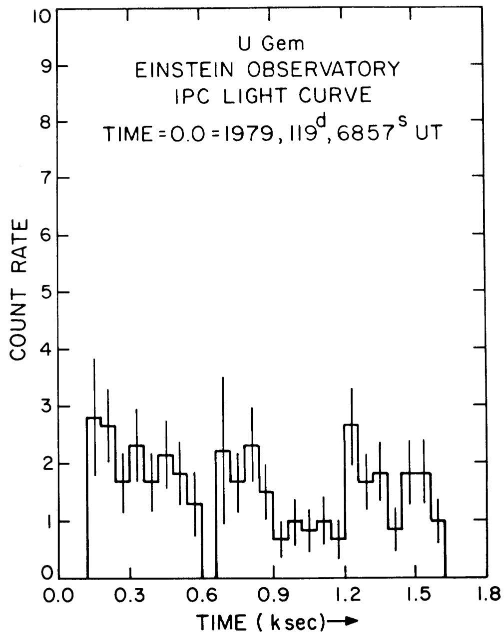

FIG. 5.—X-ray (0.1–4.2) keV light curve of U Gem in minimum. Notice that the light curve suggests variability.

that the discrepancy with theoretical predictions could be due to variability of the source, which could affect observations obtained at different epochs, and clearly demonstrates that the UV blackbody component is associated with the soft X-ray flux.

If the UV were due to cyclotron emission, as predicted by Lamb and Masters (1979) assuming a magnetic field $B \sim 10^8$ gauss, the UV luminosity would be higher than is observed by at least a factor of 20. This problem could be circumvented by assuming a lower magnetic field and

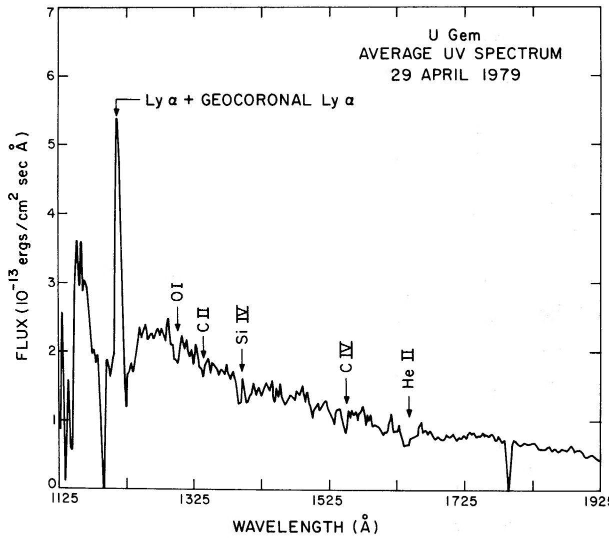

FIG. 7.—Average short-wavelength UV spectrum of U Gem during the 1979 April 29 observations

then shifting the bulk of the cyclotron emission toward the optical wavelengths. However, the discovery of the $\sim \nu^2$ component in the UV spectrum (Raymond *et al.* 1979*a*) poses a more serious problem. If the UV flux and soft X-ray flux (Tuohy *et al.* 1978) are due to the same blackbody with $kT \approx 28$ eV, the total blackbody luminosity $L_{BB} \gg L_{cyc} + L_{Brem}$ (the optical and X-ray luminosity), in sharp disagreement with the theory, as remarked by Raymond *et al.* (1979*a*). An alternative steady nuclear burning to produce the soft blackbody component has been explored by Weast *et al.* (1979). In their $M_* = 1\ M_\odot$, $\dot{M} = 5 \times 10^{-3}\ \dot{M}_E$ model (where $\dot{M}_E$ is the

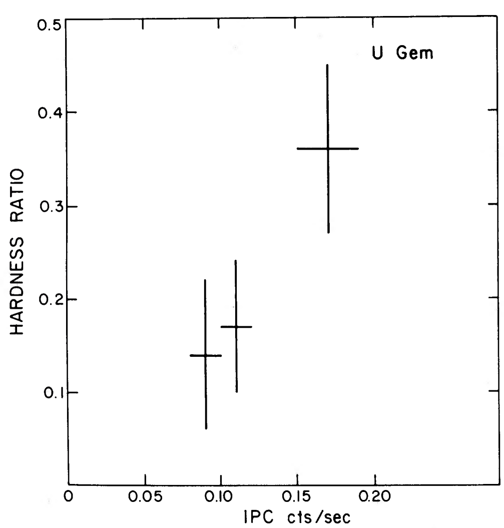

FIG. 6.—The X-ray hardness ratios of U Gem (see text) are plotted as a function of the IPC count rate

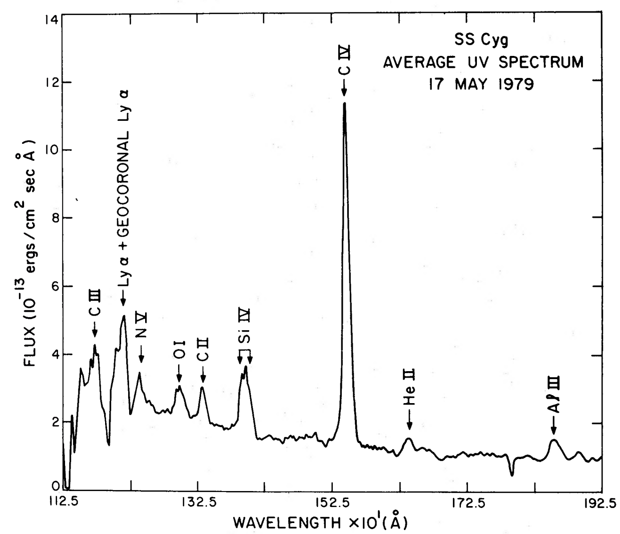

FIG. 8.—Average short-wavelength UV spectrum of SS Cyg during the 1979 May 17 observations. SS Cyg was in quiescence at the time of the observations. Notice the similarity with the UV spectrum of AM Her (Fig. 2).

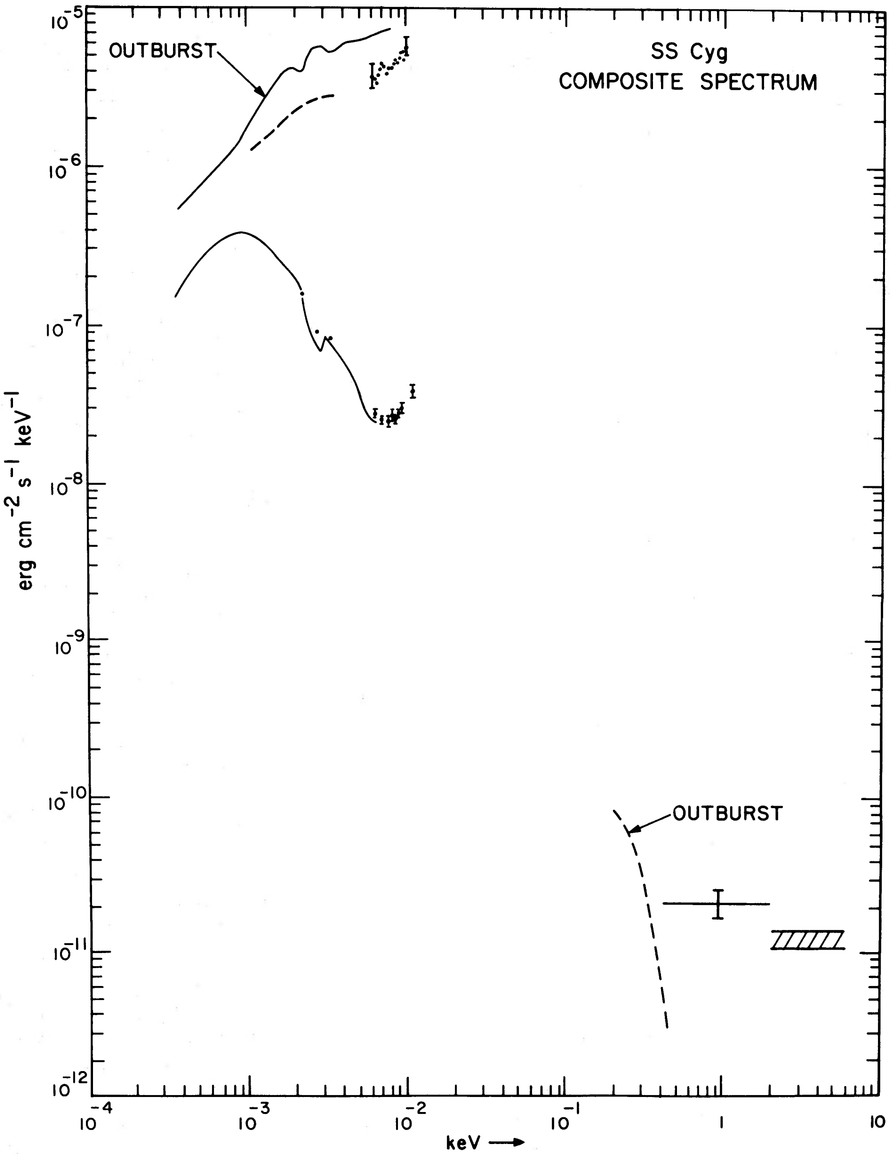

FIG. 9.—Composite spectrum of SS Cyg both in quiescence and in outburst. The *U*, *B*, *V* points (*dots*) in the spectrum in quiescence are the photometric measurements of Szkody (1980, private communication) simultaneous to the *IUE* (dots with error bars) and *Einstein* (lines) measurements of 1979 May 17. The lower energy X-ray measurement is the HRI/OGS observation; the higher energy measurement represents the MPC data. The double line represents the range of variability of SS Cyg during the MPC observations. The continuous line that covers the IR through optical range is from the spectrophotometric measurements of Kiplinger (1979). In the spectrum during outburst, the continuous line is again from Kiplinger (1979) and the dotted line underneath it represents the Szkody (1976) photometric measurements. Both these lines have been normalized to the UV data (Heap *et al.* 1978). During the UV observation the visual magnitude of the source was 9.5, one magnitude fainter than at maximum. The X-ray data are from Córdova *et al.* (1980*a*, *b*).

Eddington limit accretion rate), they find a blackbody luminosity of ~ 200 times the hard X-ray luminosity. This model assumes no strong magnetic field and radial accretion. AM Her clearly has a strong magnetic field; the field must dominate the accretion process. Since a scaling of the Weast *et al.* model would imply a surface area only $\sim 10^{-4}$ of the white dwarf's surface, the model appears to be consistent with strong magnetic confinement. The model predicts a softening of the hard X-ray flux from 25 keV to ~ 12 keV in the case of complete burning; given the fact that a spherical geometry is assumed, this softening is an upper limit to what would be taking place in an accretion column.

If the temperature of the soft X-ray emitting region is larger than 30 eV, as might be suggested by the OGS data (Heise 1980, private communication), the energy balance discussed in the previous paragraph does not necessarily apply. In this case, either the UV/soft X-ray emission region is not optically thick or we have a multitemperature region. The UV emission with $kT \approx 10$–30 eV could still be due to nuclear burning, while the soft X-ray flux could be due to a hotter blackbody, originating from the reprocessing of the hard X-ray flux. The integrated flux of a ~ 40 eV blackbody would be of the same order of magnitude as the hard X-ray flux $L_x(2$–$60 \text{ keV}) \approx 7.4 \times 10^{-9}$ ergs cm^{-2} s^{-1} (Swank *et al.* 1977).

Assuming a distance of ~ 100 pc for AM Her, and $kT \approx 30$ eV for the UV blackbody, we can calculate the area of the blackbody emitting region by dividing the luminosity of the source at 10 eV by the flux (at 10 eV) of a 30 eV blackbody. Since the blackbody flux at 10 eV is roughly one-half of the total flux, the emitting area is $A = 8 \times 10^{16}$ cm^2, $\sim 5\%$ of the projected area if the radius of the white dwarf is $R_* \approx 5 \times 10^8$ cm. This is considerably larger than what is expected from the model on the basis of the hard X-ray luminosity. If nuclear burning is really taking place on the white dwarf, this might indicate a tendency of the accreting material to diffuse somewhat on the surface.

Since AM Her has a strong magnetic field, an accretion disk is not likely to account for the optical flat component, which is similar to that of HZ Her, where an X-ray–heated stellar photosphere accounts for this radiation (Dupree *et al.* 1978). While there is no universally agreed upon interpretation of the AM Her light curve, one possibility (e.g., Priedhorsky, Krzeminski, and Tapia 1978) is that the optical light consists of a highly polarized red component whose absence accounts for primary and secondary minima and an unpolarized blue component which is relatively constant. We identify the latter with the heated face of the secondary. Priedhorsky and Krzeminski (1978) estimate that up to 3% of the X-ray emission can be intercepted and reprocessed by the cool star. While 3% of the hard X-ray luminosity cannot account for the luminosity in the $F_\nu \propto \nu^{-1}$ component, 3% of the blackbody luminosity is quite adequate.

The He II λ1640 line provides a check on this hypothesis. We assume, as is the case with the Sun (Raymond, Noyes, and Stopa 1979), that EUV photons with $55 < h\nu < 120$ eV are absorbed by He II, and the helium then recombines. Using the case B rates of Osterbrock (1974) and assuming that the $F_\nu \propto \nu^{-1}$ component extends from 1000 Å to 10,000 Å, we predict equivalent widths of 10.0 Å, 8.0 Å, and 6.4 Å, respectively, for a photosphere heated by a 20 eV, 30 eV, or 40 eV blackbody. If we identify the narrow component of the λ1640 line with the heated photosphere (Greenstein *et al.* 1977; Raymond *et al.* 1979*a*), this is about one-third of the total λ1640 line flux. In the spectra which show little contribution from the $F_\nu \propto \nu^2$ component, the equivalent width of the narrow part of the λ1640 line is ~ 12 Å. This is within the uncertainties, so it appears very likely that heating of the cool star by the 30 eV blackbody accounts for the $F_\nu \propto \nu^{-1}$ continuum and for the narrow components of the emission lines.

b) *SS Cygni*

i) *Optical minimum*

From Figure 8 we can distinguish at least three different components of the continuum composite spectrum of SS Cyg at minimum: (1) IR and optical, which follows a power law $\nu^{-1.3}$; (2) UV, where a change of slope from $\nu^{-1.3}$ to ν^2 is evident at the high frequency end of the spectrum; (3) X-rays, compatible with a bremsstrahlung spectrum with $kT \approx 10$–20 keV. From a previous *Einstein* observation of SS Cyg at minimum with the IPC, we can put an upper limit of $T < 12$ eV to the eventual blackbody component of the soft X-ray spectrum. From the IPC data, we calculate a (0.2–0.5) keV flux of $\sim 8 \times 10^{-12}$ ergs cm^{-2} s^{-1} keV^{-1}, which is if anything lower than the flux at higher energies. The UV spectrum at the higher frequencies indicates that the UV flux is due to a blackbody with $kT \gtrsim 9$ eV. Assuming that the flux for $\lambda > 5000$ Å is mainly due to the companion star, we can calculate the luminosities listed in Table 4 using a distance of 120 pc (Kiplinger 1979).

From the presence of hard X-ray flux at minimum and from the anticorrelation of the optical and X-ray emission in SS Cyg, Ricketts, King, and Raine (1979) proposed the presence of a magnetized white dwarf. The presence of a magnetic field is confirmed by our observations. In fact, the combined optical-UV spectrum at minimum is not compatible with a viscous disk model. Such a model (Lynden-Bell and Pringle 1974) predicts a spectrum with a $\sim \nu^{1/3}$ rise at the longer wavelengths and a $\sim \nu^{-3.3}$ decay at the shorter wavelengths, while our observations show a $\nu^{-1.3}$ power law in the optical and near-ultraviolet. Even if more recent disk models are being developed (Bath 1980, Austin Workshop on Cataclysmic Variables) that do not follow the $\nu^{1/3}$ spectrum, they are still unable to reproduce the trend shown by our data. This is in agreement with the conclusions of Kiplinger (1979), who was unable to match the continuum optical spectrum of SS Cyg at minimum with a disk model. Moreover, in the UV both the continuum and line spectra of SS Cyg are similar to those of AM Her, which has a strong magnetic field (Tapia 1977). Ricketts, King, and

TABLE 4

Object	$L_{\rm opt}$[a]	$L_{\rm BB}$[a]	$L_{\rm HX}$[a]	$T_{\rm BB}$(eV)	$T_{\rm HX}$(keV)
AM Her	6×10^{32}	$\sim 2.3 \times 10^{34}$	7.5×10^{31}	~ 28	>30
SS Cyg	$\sim 1 \times 10^{33}$	$\geq 3.0 \times 10^{33}$	2.1×10^{32}	10–12	10–30
U Gem	$\sim 9 \times 10^{30}$	$\geq 2.3 \times 10^{33}$	1.3×10^{30}	≥ 10	...

[a] In units of ergs s^{-1}; distance determinations are discussed in the text. The $L_{\rm HX}$ refer to the total hard X-ray emission.

Raine (1979), applying the basic theory of accretion on a magnetized compact star (as developed by Pringle and Rees 1972; Lamb, Pethick, and Pines 1973; Bath, Evans, and Pringle 1974; Fabian, Pringle, and Rees 1976), show that the X-ray behavior of SS Cyg is compatible with a magnetic field of the order of 10^6 gauss. An upper limit to the magnetic field can be set using the results of Walker and Chincarini (1968), who measured widths of the optical emission lines at minimum consistent with Keplerian velocities at a radius $R \approx 1.5 \times 10^{10}$ cm. Ghosh and Lamb (1977, 1979*a*, *b*) gave a detailed quantitative treatment of the magnetohydrodynamic of an accretion disk. We use their (1979*b*) equation (30) to calculate the innermost radius of the disk:

$$r_0 = 0.52\mu^{4/7}(2GM)^{-1/7}\dot{M}^{-2/7}$$
$$= 1.2 \times 10^9 B_6{}^{4/7}\frac{R_*{}^{12/7}}{10^9}$$
$$\times (M_*/M_\odot)^{-1/7}\dot{M}_{20}{}^{-2/7}\ \mathrm{cm}\ , \qquad (1)$$

assuming $\mu = BR_*{}^3$. $\dot{M}_{20}$ is the accretion rate in units of 10^{20} g s^{-1}, M_* is the mass of the white dwarf, R_* is the radius of the white dwarf, and B_6 is the magnetic field in units of 10^6 gauss. For $M_* \approx 1\ M_\odot$, $R_* \approx 5.0 \times 10^8$ cm, $r_0 \leq 1.5 \times 10^{10}$ cm, and an accretion rate

$$\dot{M} \approx 8 \times 10^{14}\ \mathrm{g\ \ s^{-1}}\ ,$$

which can be inferred from the X-ray luminosity at minimum we have

$$B \leq 1.9 \times 10^6\ \mathrm{gauss}\ . \qquad (2)$$

That an appreciable magnetic field is present seems clear from the absence of a disk extending down to the surface of the white dwarf and the necessity that the emission originate on a small fraction of the stellar surface. If the UV emission is due to a blackbody with $kT \approx 10$ eV, at a distance of 120 pc, the emitting area will be $\sim 5\%$ of the area of the white dwarf, consistent with the emission originating from the polar caps, for $B \approx 10^6$ gauss. Using the expression $d = R_*(2R_*/r_0)^{1/2}$ to calculate the radius of the accreting column, we find that the fraction of the area of the white dwarf affected by the accretion column is $\sim 4\%$ for $B \sim 10^6$ gauss.

From the luminosities of SS Cyg at minimum in different energy ranges (Table 4), we have

$$L_x < L_{\mathrm{opt}} < L_{\mathrm{UV}}\ , \qquad (3)$$

where L_x is the hard X-ray luminosity, L_{opt} is the optical luminosity, and L_{UV} is the UV/soft X-ray luminosity.

This is inconsistent with a simple magnetic accretion picture. In such a picture the X-rays would originate in a polar accretion column due to dissipation of strong shock waves. Approximately half of these X-rays would escape from the star. The other half would heat the stellar surface, which would emit as a blackbody in the ultraviolet and soft X-rays (Lamb and Masters 1979). The optical flux would mainly originate from the inner disk in a region near the Alfvén radius, where the magnetic field would disrupt the disk. Since the Alfvén radius for a 10^6 gauss magnetic field and a white dwarf of mass $M_* \approx 1\ M_\odot$ is a factor of ~ 30 times larger than the star radius, we would expect that the L_{opt}, which mainly originates from accretion at the Alfvén radius, would be $\sim (\frac{1}{30})L_x$, while $L_{\mathrm{UV}} \sim L_x$.

The optical flux cannot be due to reprocessing by the stellar surface of the UV/soft X-ray flux in the simple accretion picture because in this case we would expect that $L_{\mathrm{opt}} + L_{\mathrm{UV}} \sim L_x$, contrary to the observations that show that the total optical and ultraviolet flux is ~ 20 times larger than the X-ray flux if the UV is due to a blackbody with $kT > 9$ eV. A possible solution of this puzzle is the hypothesis of nuclear burning at the surface of the white dwarf. In this case, in fact, L_{UV} can be larger than L_x; part of the ultraviolet flux could heat up the matter filling the Alfvén surface, and consequently the disk, and give the observed optical fluxes. Assuming that the accreting matter, mainly hydrogen, burns to helium, the $L_{\mathrm{UV}} \approx 3.8 \times 10^{33}$ ergs s^{-1} (for a 9 eV blackbody) would imply an accretion rate of burned hydrogen $\dot{M}_{\mathrm{H}} \approx 6 \times 10^{14}$ g s^{-1}. This is compatible with the accretion rates on the white dwarf derived from the X-ray observations.

Since the optical and UV spectra of SS Cyg are so similar to those of AM Her, and since the continuum does not agree with that predicted for an accretion disk (Kiplinger 1979), we can ask whether reprocessing of the EUV blackbody emission can account for the $F_\nu \propto \nu^{-1.3}$ component. The equivalent width of He II λ1640 predicted as in the previous section for heating by a 10–12 eV blackbody is 2.4–6.0 Å, which compares well with the observed value of 4.0 Å. The luminosity of the $\nu^{-1.3}$ component is such a large fraction of the blackbody luminosity that reprocessing in the accretion flow is more likely than heating of the face of the cool companion.

Comparing the line spectra of AM Her and SS Cyg, we found a good correlation between the ratio of the observed fluxes in a given line and the predicted ratio of ionizing photons for the same line (Fig. 10). The ratios for the H and He I lines are calculated using the optical spectra of Stockman *et al.* (1977) and Kiplinger (1979). We assume that the ionizing photons have blackbody spectra with $kT \approx 10$ eV and 30 eV for SS Cyg and AM Her, respectively.

From the observed correlation we conclude that the ratio between the assumed temperatures is reasonable and the blackbody approximation for the ionizing spectra gives the correct number of ionizing photons. The slope between the He lines (He I λ4471 and He II λ1640/4686) is nearly 1, consistent with the fact that these two lines are probably recombination lines. On the other hand, C IV and N V lines, which are expected to be produced by collisional excitation and/or photoexcitation, do not match the correlation. The He lines seen in the UV or the optical (He I λ4471 and He II λ4686) may thus be used as temperature indicators for the ultraviolet component in this kind of system. The He lines as a temperature indicator had been used by Kraft (1959) in the case of DQ Her. Kraft concluded that a high tempera-

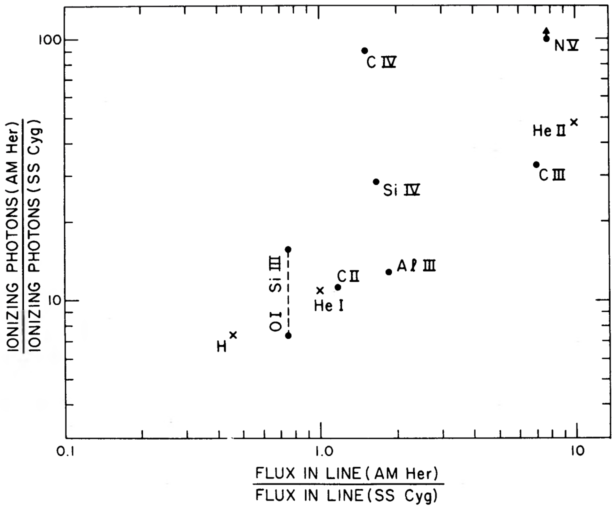

FIG. 10.—The expected ratios of emission line intensities for AM Her and SS Cyg in quiescence, on the hypothesis that the lines are due to photoionization only (see text), are plotted versus the observed ratios. The crosses indicate lines that are seen in the optical range. The He II point was calculated from the UV spectra, but agrees with the ratio from the optical lines.

ture component ($kT \approx 10$ eV) was present in DQ Her, a conclusion in agreement with our findings of AM Her and SS Cyg.

ii) *Optical maximum*

The composite spectrum of SS Cyg at maximum is shown in Figure 9. The UV points are obtained from Heap *et al.* (1978), correcting for the ITF error and normalizing the flux according to the photometric data of Holm and Gallagher (1974). These fluxes were obtained when SS Cyg was in outburst at a $m_v = 9.5$, 1 mag fainter than the maximum magnitude of 8.5. The optical and IR points are obtained from the photometric data of Szkody (1976) and the spectrophotometric data of Kiplinger (1979) of SS Cyg in outburst. We have normalized the fluxes published by Szkody and Kiplinger to $m_v = 9.5$. The X-ray data are from Córdova *et al.* (1980*b*). No hard X-rays are typically seen from SS Cyg at maximum, except for a short flare at the beginning of the outburst (Swank 1979). Emission lines are not present in the UV spectrum at maximum (Heap *et al.* 1978), and a broad Lα absorption line is present, suggesting that the UV emission originates in an optically thick region (Fig. 11). The same is true for the optical spectrum (Kiplinger 1979).

From Figure 9 the integrated flux from the infrared to the ultraviolet is:

$$f(\mathrm{IR + Opt + UV}) \gtrsim 1 \times 10^{-7} \text{ ergs cm}^{-2} \text{ s}^{-1} \quad (4)$$

which, for a distance of 120 pc, corresponds to a luminosity:

$$L(\mathrm{IR + Opt + UV}) \gtrsim 1.6 \times 10^{35} \text{ ergs s}^{-1} . \quad (5)$$

The lack of UV emission lines is similar to what is observed in U Gem at minimum (see below). The IR, optical, and UV continuum spectra are compatible with a $\nu^{1/3}$ slope, as predicted by a viscous disk model (Lynden-Bell and Pringle 1974). Spectrophotometric observations of the optical emissions of SS Cyg in outburst (Kiplinger 1979) are consistent with a disk model for an accretion rate $\dot{M} = 5 \times 10^{18}$ g s^{-1}. For such an accretion rate, there would be no magnetic effect on the accretion flow only if $B < 10^5$ gauss. For $10^5 < B < 10^6$ gauss, from 100% to $\sim 30\%$ of the white dwarf area will be accreted upon. The optical data are explainable simply in terms of an accretion disk (Kiplinger 1979). On the basis of all the information we have about SS Cyg at maximum, we are unable to discriminate between different magnetic regimes. Given the high accretion rates, in fact, the hard X-ray flux would be degraded to lower energies (Ricketts, King, and Raine 1979). In both cases, we would expect the accretion disk to be predominant in the optical range.

If all of the SS Cyg emission at maximum is due to a viscous accretion disk, assuming that the disk spectrum does not extend much past 10 eV, an X-ray flux of the same order as the IR to UV flux should be expected from the innermost parts of the disk. We would obtain such a flux if the Córdova *et al.* (1980*b*) X-ray data are due to the high energy end of a ~ 20 eV blackbody. We can calculate the X-ray emitting area, equating the observed flux at 0.4 keV to the flux of a 20 eV blackbody at the distance of SS Cyg. The X-ray emitting area is $\sim 80\%$ of the white dwarf area, consistent with the picture of magnetic accretion. We notice that Córdova *et al.* (1980*a*), fitting the soft X-ray spectrum of SS Cyg in outburst with a 30 eV blackbody, find that the emitting area is less than 0.1% of the area of the white dwarf. Their data, however, are also compatible with a cooler (~ 20 eV) blackbody, and such a blackbody would have an integrated luminosity of $\sim 10^{35}$ ergs s^{-1} to fit their observations, implying larger emitting areas.

If nuclear burning is present at maximum light with high efficiency, the resulting blackbody must have fairly high temperatures. In fact, given the area of the white

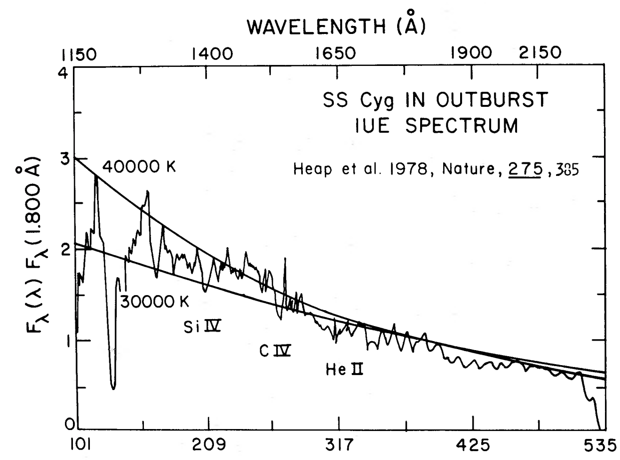

FIG. 11.—UV spectrum of SS Cyg in outburst

dwarf, such a blackbody would have $kT \approx 75$ eV and $L_{BB} \approx 3 \times 10^{37}$ for accretion rates of $\sim 5 \times 10^{18}$ g s^{-1} as inferred from the disk luminosity (Kiplinger 1979), if the nuclear burning is ~ 30 times more efficient than the gravitational energy release. If there is nuclear burning at maximum, we would expect that some of the resulting UV flux would be effective in heating up the disk. In this case the observed IR and optical fluxes would not be a direct measure of the accretion rate. Since we do not see hard X-rays, the accretion rate cannot be much lower than $\sim 10^{17}$ g s^{-1} (Ricketts, King, and Raine 1979), otherwise the accreting column would be optically thin. For this accretion rate the luminosity of the blackbody generated at the star surface by nuclear burning could be $L_{BB} \approx 6 \times 10^{35}$ ergs s^{-1} and $kT \approx 30$ eV. The flux from this blackbody would greatly exceed the measured flux at 0.4 keV, unless it is reprocessed by the large amount of matter surrounding the white dwarf and reradiated from a much larger surface. This is in fairly good agreement with what we expect the physical conditions to be in proximity to the white dwarf at maximum.

c) *U Geminorum*

In Figure 4 we have plotted the optical and IR points of Wade's (1979) observation of U Gem at minimum, together with our UV and X-ray observations. The optical measurement of the AAVSO of U Gem at the time of the joint *Einstein/IUE* observations is compatible with Wade's (1979) points. Moreover, all the UV spectra are compatible with the same average continuum, showing no obvious phase dependence. On this basis, we feel comfortable in comparing our results with the optical data.

Interpreting the rising flux in the IR as due to the cool companion star, Wade (1979) was able to derive a spectroscopic parallax for U Gem. In the following discussion, we will adopt a distance for the system of ~ 76 pc, consistent with Wade's (1979) measurement. The flat optical component is consistent with accretion disk models (Lynden-Bell and Pringle 1974). For this component, the flux (3000–6000 Å) is $f_{op} \approx 1.3 \times 10^{-11}$ ergs cm^{-2} s^{-1}. The UV spectrum is well fitted with a power law $F(\nu) \sim \nu^{1.5}$. Assuming that what we see is the Raleigh-Jeans end of a blackbody spectrum, we can set a lower limit of ~ 10 eV on the temperature of such a blackbody. The ultraviolet flux will then be $f_{UV} \geq 3.5 \times 10^{-9}$ ergs cm^{-2} s^{-1}. At a distance of 76 pc, these fluxes correspond to the luminosities listed in Table 4.

From the assumption that the UV flux is due to a blackbody with $kT \geq 10$ eV we can calculate the area of the UV emitting region at a distance of 76 pc. We find that the emitting area is

$$A = \frac{L_{UV}\ (10\ \text{eV})}{f_{BB}\ (10\ \text{eV})} < 2.3 \times 10^{17}\ \text{cm}^2\ , \qquad (6)$$

where L_{UV} (10 eV) is the luminosity of the source at 10 eV and f_{BB} (10 eV) is the emitted blackbody flux at the source at 10 eV. If the mass of the white dwarf is $M_* \approx 1\ M_\odot$ and its radius $R_* \approx 5 \times 10^8$ cm, then $A/A_* \lesssim 7\%$. For the same white dwarf parameters, using the extreme minimum and maximum estimates of the distance of 52 pc and 112 pc (Wade 1979), we obtain $3\% \lesssim A/A_* \lesssim 15\%$. Only if $M_* > 1\ M_\odot$ and the distance is near the maximum estimate does A/A_* reach 100%. But in that case the white dwarf would considerably heat up the disk, causing it to have a bright atmosphere with emission lines, contrary to the observations. The spectrum also indicates that the UV emitting region is not a hot spot radiating in a diffuse medium. In this case, in fact, we would expect to see emission lines. We cannot be very precise without detailed calculations of line formation. Nevertheless, it seems qualitatively reasonable that the presence of lines in U Gem similar to those in AM Her and SS Cyg, such as C IV, Si IV, but in *absorption* rather than *emission*, suggests that the gaseous region of the line formation is seen against an extended, bright continuous background which is not much smaller in projection. This would be the case if the accretion disk extends down to the surface of the white dwarf. The fact that the width of the Lα absorption line is wider in U Gem than in SS Cyg, and that it is absent in AM Her, could be interpreted as supportive evidence of this scenario. With this assumption we can get an estimate of the magnetic field. Letting $r_0 \approx R_*$ yields an order-of-magnitude upper limit to $B \lesssim 10^3$ gauss.

Further evidence of disk accretion is given by the low temperature of the hard X-ray emission, which suggests that strong shocks, as expected in the case of magnetic radial accretion, are not present and by the hardness ratio versus intensity relation that suggests Comptonization (Fig. 6). The latter is similar to what is seen in Cyg X-2 (Branduardi *et al.* 1980) and could be indicative of a high electron density in the X-ray emitting region, such as could be found in the boundary layer of an accretion disk.

We observe $L_{opt} \gtrsim L_x$ and $L_{UV} \gtrsim 200\,(L_{opt} + L_x)$. Since we do not know how far the spectrum of the accretion disk (the main component in the optical range) extends in the UV range, we can estimate a blackbody luminosity for the UV excess $L_{BB} \approx (100\text{–}200)\,(L_{DISK} + L_X)$. This seems to suggest that if nuclear burning is taking place in U Gem (and if the same is true for AM Her and SS Cyg), the efficiency of the nuclear burning in U Gem is higher than in the two other systems. Paczyński and Schwarzenberg-Czerny (1979) show that the standard disk accretion models yield optical fluxes that are too bright if accretion is proceeding steadily. This leads them to confirm Smak's (1971) idea that the outbursts arise from instability of the nonaccreting material building up in the disk until it reaches some critical value. Our detection of X-ray and UV flux from U Gem strongly indicates that, between outbursts, there still is some accretion onto the white dwarf, implying the presence of some viscosity in the disk.

IV. CONCLUSION

We have shown in this paper the results of simultaneous optical/UV/X-ray observations of three accreting degenerate dwarfs. The fact of covering such a wide span of energy ranges at once enables us to draw interesting conclusions about the nature of these objects. In particular:

1. We have discovered the presence of a strong excess UV radiation in SS Cyg and U Gem.. For U Gem we show that this radiation, for most likely parameters for the system (Wade 1979), is likely to originate from the boundary layer of the accretion disk. The luminosity of the UV component is ~ 200 times larger than the combined optical and X-ray emissions. This is inconsistent with the traditional picture of gravitational accretion. We suggest that such a large UV flux might originate from nuclear burning (Kippenhahn and Thomas 1978; West *et al.* 1979; Sparks 1980, private communication) at the surface of the white dwarf in the vicinity of the disk boundary layer. A possible blackbody component of the UV flux similar to the one in U Gem is seen also in AM Her (confirming previous observations by Raymond *et al.* 1979*a*) and in SS Cyg. Although the UV excess in these two systems is not as high as the one seen in U Gem, it is not possible to explain it in terms of the current theoretical framework (Lamb and Masters 1979; King and Lasota 1979). In both cases the UV emitting area is of the same order as the X-ray emitting area, and in AM Her in particular the blackbody UV flux is eclipsed in phase with the X-ray flux. We suggest that nuclear burning of the accreted material might also happen in SS Cyg and AM Her and be responsible for the excess. We would expect this to be quite a common feature in other similar systems.

2. If nuclear burning is responsible for the UV blackbody excess, we find that AM Her, SS Cyg, and U Gem can be explained within a scenario of accretion in different magnetic regimes. A strong magnetic field ($\sim 10^8$ gauss) in AM Her would be responsible for polar radial accretion, as suggested by many authors (see review of Chiappetti, Tanzi, and Treves 1980 and references therein). A reexamination of the data collected on SS Cyg both at maximum and at minimum, together with our new observations, shows the presence of a magnetic field $\sim 10^5 - 10^6$ G, as suggested by Ricketts, King, and Raine (1979). SS Cyg at minimum looks remarkably similar to AM Her, consistent with a picture of polar magnetic accretion. But the magnetic field is not so intense as to inhibit completely the formation of a disk, as shown by the observation of Walker and Chincarini (1968). The increased accretion at maximum causes the magnetosphere to move closer to the white dwarf, with the consequent building up of a disk. In U Gem instead, the magnetic field is so low as to make polar accretion impossible even at a minimum, as shown by the lack of emission lines in the UV and the possible presence of Comptonization in the X-radiation.

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