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HUBBLE SPACE TELESCOPE FOS SPECTROSCOPY OF THE ULTRASHORT-PERIOD DWARF NOVA WZ SAGITTAE: THE UNDERLYING DEGENERATE[1]

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ABSTRACT

Two consecutive *Hubble Space Telescope* Faint Object Spectrograph (FOS) spectra of the exposed white dwarf in the ultrashort-period, high-amplitude, dwarf nova WZ Sge, reveal a rich absorption line spectrum of neutral carbon and ionized metals, the Stark-broadened Lyα absorption wing, the H_2 quasi-molecular Lyα "satellite" absorption line, and a double-peaked C IV emission line which is variable with orbital phase. A synthetic spectral analysis of the white dwarf yields $T_{\rm eff} = 14{,}900$ K $\pm$ 250 K, $\log g = 8.0$. In order to fit the strongest C I absorption lines and account for the weakness of the silicon absorption lines, the abundance of carbon in the photosphere must be ~0.5 solar, silicon abundance is 5×10^{-3} solar, with all other metal species appearing to be 0.1–0.001 times solar. The H_2 quasi-molecular absorption is fitted very successfully. The photospheric metals have diffusion timescales of fractions of a year, and thus they must have been accreted long after the 1978 December outburst. The source of the most abundant metal, carbon, is considered. If the time-averaged accretion rate during quiescence is low enough for diffusive equilibrium to prevail, then the equilibrium accretion rate of neutral carbon is 7×10^{-16} $M_\odot$ yr^{-1}. A convective dredge-up origin for the concentration of carbon is extremely unlikely, given that the white dwarf atmosphere is H-rich while in single degenerates showing carbon and hydrogen, the C and H are trace elements in a helium background. Additional implications are explored.

Subject headings: novae, cataclysmic variables — stars: individual (WZ Sagittae) — ultraviolet: stars — white dwarfs

1. INTRODUCTION

WZ Sge is a critically important cataclysmic binary because of its unique properties. It has one of the shortest orbital periods (81 minutes) of any known hydrogen-rich cataclysmic variable and undergoes eclipses every 81 minutes 38 s. Hence it was an early focus for studies of gravitational wave emission and its role in driving mass transfer (Kraft, Mathews, & Greenstein 1962; Paczyński 1967; Faulkner 1971). It was originally classified as a recurrent nova, but subsequently reclassified as a dwarf nova based upon its spectroscopic properties (Warner 1976). It has one of the largest outburst amplitudes (7 mag) and longest outburst recurrence time (33 years, with the last outburst having occurred on 1978 December 1–2) of any dwarf nova. During its quiescent interval, the underlying white dwarf accreter is exposed (Holm 1988; Szkody & Sion 1989) and dominates the far-ultraviolet while the Stark-broadened Balmer wings of the white dwarf are evident in the optical. Following the first comprehensive analysis of the system by Krzeminski & Kraft (1964), numerous authors have presented spectroscopic and photometric analyses of the system in outburst and in quiescence (cf. Krzeminski & Smak 1971; Robinson, Nather, & Patterson 1978; Gilliland & Kemper 1980; Sparks et al. 1980; Leibowitz & Mazeh 1981; Gilliland, Kemper, & Suntzeff 1986; Naylor 1989; Smak 1993).

Since the 1978 outburst, WZ Sge's ultraviolet flux (measured with *IUE*) continued to decline for 8 years, demonstrably due to the cooling of the white dwarf in response to the deposition of mass and energy at outburst (Holm 1988; Szkody & Sion 1989; La Dous 1990; Smak 1993). However, the *IUE* low-resolution SWP line spectra revealed a variety of puzzling features, difficult to identify because they occurred at wavelengths not associated with the obvious resonance lines normally seen in *IUE* spectra of white dwarfs and CVs or required large wavelength shifts to match up with the usual far-UV resonance absorbers. Sion, Leckenby, & Szkody (1990) established that many of the puzzling features in the *IUE* far-ultraviolet spectra were due mostly to resonance absorption lines of C I. Szkody & Sion (1989) verified Holm's (1988) suggestion that the broad absorption at 1400 Å, is a satellite line in the wing of Lyα due to quasi-molecular interactions with perturbers H and H^+, and proposed the use of this feature to determine an accurate gravity for the white dwarf. Despite the progress with identifying its unique line spectrum, the large mirror of *HST* was required to clarify the puzzling features seen in very noisy low-resolution *IUE* spectra of WZ Sge, confirming that they arise in the photosphere rather than from the accretion disk or circumstellar material and determine more accurate physical parameters and chemical abundances for the white dwarf. We report the results of our analysis of two consecutive FOS spectra of WZ Sagittae.

2. FAINT OBJECT SPECTROGRAPH DATA

Two 1500 s spectroscopic observations of WZ Sge were carried out with the *HST* FOS on 1992 October 8–9 using the

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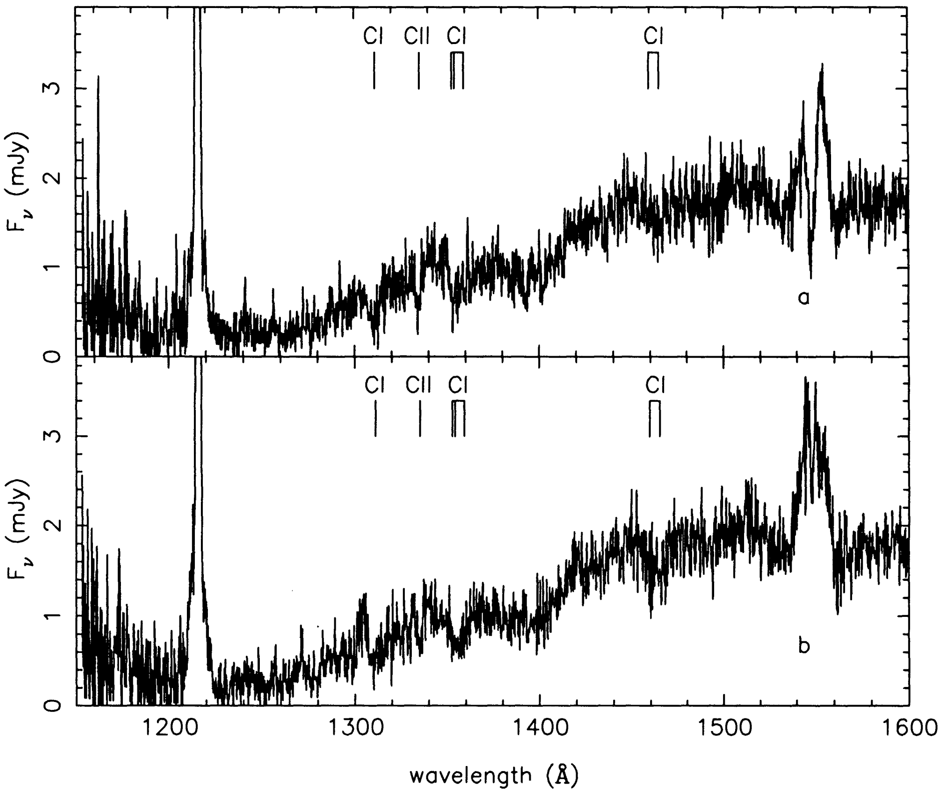

FIG. 1.—The FOS spectrum of WZ Sagittae showing flux F_ν (mJy) vs. wavelength (Å) for the first spectrum (*a*) and the second spectrum (*b*). Note the broad Lyα H_2 quasi-molecular absorption at 1400 Å, the rich absorption line spectrum with the strongest C I lines labeled, the emission at (1300 Å) in (*b*), the double-peaked emission feature at C IV (1550 Å) and its large variation in central absorption and the Stark-broadened Lyα longward absorption wing. The emission at Lyα is geocoronal in origin. See text for details.

1″0 aperture and the G130H disperser in the ACCUM operating mode for a wavelength coverage 1165 to 1605 Å and resolution of 1300. The start times of the first and second observations were 1992.282:23:02:37 and 1992.283:00:36:26, respectively. Each observation consisted of six groups with 2064 pixels per group. The estimation of the signal to noise for the FOS spectra is generally 8:1 with some variation evident between the two spectra. The data was processed through the standard STSDAS pipeline at STScI and equivalent widths of absorption-line features were measured with the IRAF task SPLOT. The two FOS spectra are displayed in Figures 1*a*–1*b*. Note the geocoronal emission at Lyα, the strong double-peaked emission line at C IV λ1550, the emission feature at 1300 Å, which is probably comprised in part of geocoronal O I $\lambda\lambda$1302–1306, and the numerous broad absorption troughs, the strongest of which is roughly centered at 1400 Å in both spectra. The strongest C I absorption lines are labeled in Figure 1. It is clear that the C IV emission feature underwent a significant change in structure with a much deeper central absorption in the first spectrum. In Table 1, the strongest absorption line features common to both spectra are listed together with identifications of neutral and ionized atomic species. The presence of a deep, broad absorption at 1400 Å in both FOS spectra of the WZ Sge white dwarf, confirms the *IUE* identification of the 1400 Å Lyα satellite line by Holm (1988) and Szkody & Sion (1989). This feature was observed to strengthen in a series of *IUE* low-resolution spectra, as the far-ultraviolet flux declined during quiescence, long after the 1978 outburst. The presence of substantial photospheric carbon in the form of C I absorption features, also confirms the earlier identifications by Sion, Leckenby, & Szkody (1990) from low-resolution *IUE* spectra.

The orbital phase of WZ Sge during the FOS exposure was obtained by using the still reliable (J. Patterson 1993, private communication) eclipse ephemeris of Robinson et al. (1978), viz., $T = \text{J.D. } 2{,}437{,}547.72845 + 0.0566878455E$. The orbital

TABLE 1

WZ SAGITTAE: TENTATIVE FOS LINE IDENTIFICATIONS AND MEASUREMENTS

Ion	Combined	EW	FWHM
C I	1189.9	6.4	8.3
C I	1195.0	0.8	8.3
C I	1252.0	3.2	5.6
Si II	1262.1	2.1	4.1
C I	1276.3	0.7	1.5
	1279.5	0.9	2.1
C I	1298.7	0.3	0.9
C I	1311.2	3.4	10.1
C I	1329.2	0.2	1.4
C II	1335.2	0.5	1.9
C I	1352.8	...	...
	1354.2	...	...
	1359.4	...	...
Lyα H_2	1400	...	...
Si I	1424.8	0.6	6.0
C I	1459.6	...	...
C I	1465.2	2.6	12.0
Fe II	1478.3	...	...
C I	1481.6	...	...
C I	1561.4	0.6	2.5
	1563.6	0.6	4.7

phases at the start of the two 1500 s exposures (including a heliocentric correction of 0.03 phase) were $\phi = 0.07$ (start of the first exposure) $\phi = 0.22$ (start of the second exposure). According to the system geometry of Robinson et al. (1978), the first FOS observation began just after the eclipse of the hot spot (impact shock front at the disk edge) by the low-mass secondary. Hence the velocity displacement of line features associated with the white dwarf would be at a minimum. The second FOS spectrum began near the quadrature phase 0.25 where the velocity displacement of white dwarf features would be maximal. However, within the resolution limit of 1.15 Å (or 246 km s^{-1}) and available S/N at 1400 Å, a comparison of the FOS spectra at the two phases reveals little evidence of convincing line displacements due to orbital motion. However, the expected orbital velocity amplitude, K, for the white dwarf is small (49 km s^{-1} and 77 km s^{-1}, derived by Gilliland et al. 1986 and Smak 1993, respectively).

3. CONTINUUM FLUX LEVEL OF WZ Sagittae

The far-ultraviolet flux level of WZ Sge measured with *IUE* spectra continually declined from the value 1×10^{10} ergs cm^{-2} s^{-1} $Å^{-1}$ at 1500 Å during the peak of the 1978 December outburst to 3×10^{-14} in 1989 August (Szkody & Sion 1989). The flux level remained reasonably steady between 2 to 3×10^{-14} since 1986, suggesting that, if it is due to the cooling of the white dwarf, then an equilibrium temperature has been reached. The flux level of the FOS spectra (see Fig. 1) reveals little difference with respect to the *IUE* spectrum obtained 4 years earlier, and the peak of the continuum energy distribution in the FOS remains at ~1500 Å. This flux level is in agreement with the continuum peak which has persisted since 1981 when it was observed to shift from 1300 Å during observations close to the 1978 outburst, to 1500 A since 1986. Our FOS spectra reveal no evidence of a significant ultraviolet continuum flux variation between the two FOS spectra obtained at the above-mentioned (limited orbital phase range.

4. DOUBLE-PEAKED EMISSION LINES

The FOS spectra reveal a very strong emission feature (other than the Lyα airglow emission) centered at 1550 Å, and double-peaked in both spectra with a central depression separating the two emission peaks. The C IV emission profiles were fitted with a Gaussian profile with emission centroid wavelength of 1548.027, an equivalent width of −5.5 Å and FWHM = 12.89 Å. The emission feature has a velocity width of 2500 km s^{-1}. This full velocity width is 63% of the full velocity width of the Balmer emission cores in the optical. For example the Hα emission line has a full width of 90 Å. Despite the narrower widths of the far-ultraviolet doubled C IV emission lines, they almost certainly share a common origin with the optical Balmer emission lines. The outer wings of the C IV emission presumably form in gas which is Keplerian motion close to the white dwarf while the emission peaks are formed in lower velocity gas farther out in the disk. A comparison of the top and bottom panels of Figure 1 reveals a large variation of the central absorption in the double-peaked emission profile, over one-fourth of the orbit. We defer discussion of the disk emission and its phase-dependent variations to a subsequent paper.

5. SYNTHETIC SPECTRAL FITS AND CHEMICAL ABUNDANCES

Given that the white dwarf reveals: (1) a rich metallic absorption line spectrum during quiescence; (2) the H_2 quasi-molecule; and (3) closely resembles DA white dwarf energy distributions at $T_{\rm eff} = 15{,}000$ K (Holm 1988), our synthetic spectral fitting utilized solar composition, high-gravity models including the satellite lines of Lyα due to quasi-molecular interactions of H atoms with H and H^+, seen in all DA stars between 9000 K and 19,000 K. Szkody & Sion (1989) proposed to use the gravity sensitivity of the satellite lines to determine a mass for the white dwarf. Recent improvements in the theory of the satellite features by Allard & Kielkopf (1991) and Allard & Koester (1992) incorporate realistic molecular potentials for the interactions, including the effect of multiperturber collisions. One of us (I. H.) has implemented the absorption coefficient in his code SYNSPEC, which we have used to generate the synthetic spectral fits described below.

In preparation for the synthetic spectral fitting, the two spectra were summed (the result of which is displayed as the dotted curve in Fig. 2). Note that the bottom of the very broad Lyα absorption profile is not at zero intensity. We cannot rule out that this residual flux is due to grating scatter since the FOS spectra are not corrected for grating scattered light as part of the pipeline process. Other possible sources could be the hot spot or the white dwarf. During the fitting procedure the summed spectrum was masked at the wavelength regions between 1200 and 1232 Å, 1297 and 1312 Å, 1537 and 1568 Å to avoid Lyα, O I, and C IV emission regions. We believe that the Lyα line is principally due to geocoronal emission; we simply assume the contribution to the continuum from any other source(s) is wavelength independent, and assume it as a free parameter in our synthetic spectral fitting. We used a grid of solar abundance models that have $\log g = 8$ and also includes the Lyα satellite absorption features. We find $T \sim 15{,}000$ K model yields the minimum χ^2, but silicon, carbon, and iron show deeper absorption than is observed. Therefore, the models with solar abundances do not provide satisfactory fits to the absorption-line spectrum. Nonetheless the precision of the continuum fits to the overall energy distribution for our solar composition model grid indicates the white dwarf surface temperature to be ~15,000 K.

To find improved chemical abundances for the white dwarf in WZ Sge, we first fixed the temperature T and the gravity g at 15,000 K and 10^8 cm s^{-2}, respectively, then generated a group of model spectra with elements lighter than carbon kept at solar abundance but all elements *heavier* than or equal to carbon uniformly having fractions of solar abundances, 1/2, 1/10, 1/100, 1/1000 solar, and so on. We found that the model with 1/100 solar abundance gave the smallest χ^2 value. But we also found that elements C (perhaps S and Fe) needed an abundance higher than 0.01 solar while Si had to be less than 0.01 solar. Therefore, we kept all of the *heavier* elements at 1/100 solar but allowed only one element to vary, and found the best abundance for this typical element from the minimum χ^2 value. Repeating the above procedure, we found the best-fitting abundances for the elements C, Fe, S, and Si to be, respectively, 0.5, 0.1, 0.1, and 0.005 solar. Comparing the minimum χ^2 value in each case with that for the 1/100 solar case, we found that the abundances C = 0.5 solar, Si = 0.005 solar are statistically significant above the 99% confidence level, but the abundances Fe and S are not (Lampton, Margon, & Bowyer 1976). Therefore, we prefer to say that the element C is the most abundant *heavier* element (0.5 solar) in the WZ Sge white dwarf, Si is less than 1/100 solar (0.005 solar), while the other metals appear to be at 1/100 solar. We are most confident of the carbon abundance being 0.5 while the other *heavier* elements are essentially subsolar because the χ^2 values drop significantly in the former when its abundance is allowed to vary and drops significantly

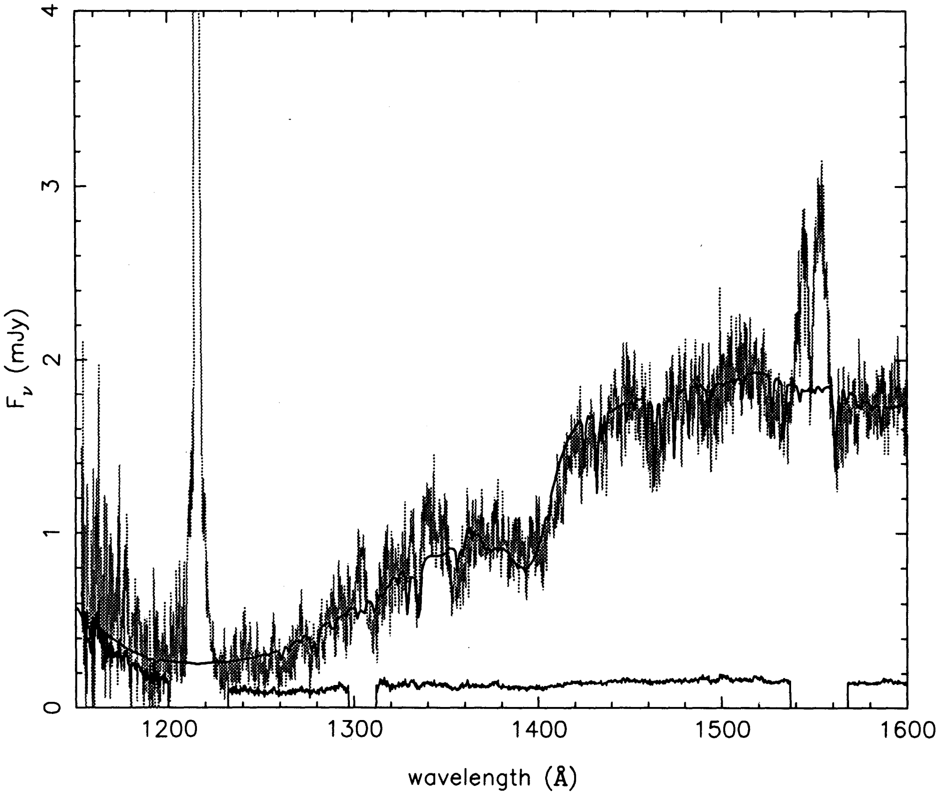

FIG. 2.—The best-fitting ($\chi^2 = 1.51$) synthetic spectrum to the summed data for the two spectra. The error bars of the summed data are shown at the bottom. The three gaps in the error bar curve indicate the wavelength regions masked in the spectral fitting. The physical parameters are $T_{\rm eff} = 14{,}900$ K, log $g = 8$, with carbon being the most abundant metal constituent in the hydrogen-rich atmosphere (see text for details).

in the latter when their abundances were varied from solar to 1/100 solar.

Having found an improved chemical composition, we varied the temperature and the surface gravity to construct a two-parameter (T and log g) grid of model spectra. For a fixed gravity we found the best-fit temperature and for a fixed temperature, we found the best fit gravity. In Table 2 we present the synthetic fitting results where it is seen that for a fixed gravity, log $g = 8.0$, we obtain a best-fit temperature of 14,000 K. In Figure 2 we display the best-fit model (solid curve) for $T = 14{,}900$ K, log $g = 8$, and the chemical abundances mentioned above. The 1400 Å satellite absorption feature is fitted perfectly, but in certain regions, such as 1340–1360 Å, 1500–1520 Å, the fit is not satisfactory. The probable reason, as mentioned earlier, is that we simply assume the non–white dwarf contribution is wavelength independent. A more detailed study including the contribution from an accretion disk with emission lines is in progress and will be reported in due time. The lack of a clear detection of a shortward wing of the 1600 Å satellite (near the limit of our FOS wavelength coverage is consistent with our derived $T_{\rm eff}$ of 14,900 K, since the 1600 Å satellite should be undetectable at 16,000 K and very weak and only marginally detectable at 14,900 K (cf. Koester & Allard 1993).

TABLE 2

SYNTHETIC FITTING RESULTS

A. FOR FIXED log g

Fixed log g	$\chi^2/1794$	Best-Fit T (K)	Scale Factor ($\times 10^{-2}$)
7.5......	1.541158	13,845	4.5315955
8.0......	1.516916	14,900	3.1344179
8.5......	1.554591	16,285	2.2397637

B. FOR FIXED T

Fixed T (K)	$\chi^2/1794$	Best-Fit log g	Scale Factor ($\times 10^{-2}$)
14,000......	1.537711	7.60	4.2169504
15,000......	1.517645	8.07	2.9902000
16,000......	1.542610	8.42	2.2281224

NOTE.—Final abundances: C: ~0.5 solar; Si: ~0.005 solar; others: ~0.01 solar.

Finally, from the best-fit model ($T_{\rm eff} = 14{,}900$ K, log $g = 8.0$), we have the scale factor $S = 3.1344 \times 10^{-2}$. Since the white surface gravity is $\sim 10^8$ cm^{-2} s^{-2}, we estimate the corresponding white dwarf radius $R_{\rm wd}$ in WZ Sge system to be 8.5×10^8 cm from the white dwarf mass–radius relation. Therefore, the distance d is given by

$$d = 10^3 \times (R_{\rm wd}/R_\odot)/S^{1/2} \text{ pc} , \quad (1)$$

from which we obtain a distance $d \sim 69.1$ pc.

6. PHYSICAL PROCESSES FOR THE SURFACE ABUNDANCE PATTERN

6.1. *Convective Dredge-up of Core Carbon?*

The most prominent UV metallic line features in WZ Sge are due to C I. Neutral carbon is seen in single, cool, non-DA

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(helium-dominated) white dwarfs with no H. The carbon abundances in these helium-rich objects is orders of magnitude below solar. Only two objects, both single stars, are known to have the simultaneous presence of C I and H, G35-26 (Liebert 1983; Thejll et al. 1990) and G227-5 (Wegner & Koester 1985). In both of these objects carbon and hydrogen are trace elements in a helium background plasma. The carbon abundance of 0.5 solar in WZ Sge, with all other heavy elements in much smaller concentrations, might at first glance suggest convective dredge-up of core carbon in WZ Sge. However, this possibility is extremely remote for a number of reasons. First, convective dredge-up of carbon is associated with the equilibrium diffusion tail of core carbon extending upward into a helium convection zone, the upper boundary of which is right at the helium-rich photosphere. However, the white dwarf in WZ Sge is definitely hydrogen-rich and accreting from a companion star. The dredge-up mechanism which operates in helium-rich single degenerates would not easily work in the H-rich atmosphere of WZ Sge. In any event the amount of C dredge-up depends also on ionization effects; the shallower H-rich convection zones and the fact that the local C concentration scales on the mass fraction, q, to an exponent determined by the charge and atomic mass, reduces the range that the diffusion tail of C in an H-rich plasma could cover. Thus it would be exceedingly difficult to bring carbon to the surface layers of an H-rich white dwarf like WZ Sge.

6.2. *Accretion-Diffusion during Dwarf Nova Quiescence*

From the diffusion timescales tabulated for metals by Paquette et al. (1986), it is clear that for a hydrogen-rich white dwarf with $T_{\rm eff} = 15{,}000$ K, $M = 1.0\ M_\odot$, a pristine H-rich atmosphere should result within a small fraction of a year following the deposition of accreted mass from a dwarf nova outburst. Hence the mere presence of photospheric metals in the white dwarf in WZ Sge 15 years after the 1978 December outburst implies that it is experiencing some ongoing accretion. This picture is supported by the strong double-peaked C IV disk emission line feature in the FOS spectrum and by the changing strength of this line in the *IUE* spectra obtained since 1988. In addition, radiative forces are negligible in a white dwarf with $T_{\rm eff} = 15{,}000$ K thus requiring accretion as the most plausible source of the metals. Moreover, Gilliland et al. (1986) have presented ground-based spectroscopic evidence that there is material infalling into the WZ Sge system at a velocity of 270 km s^{-1}. This is based upon the presence of sharp Si II features which are stationary with respect to the binary and reshifted to $+270$ km s^{-1}

The metal abundances determined by the model atmosphere fitting described in § 2 provides a means of estimating the approximate mean ongoing accretion rate (although the accretion may occur episodically as bursts or blobs) such that metals are provided at the same rate as they diffuse. Unfortunately, since the diffusion timescales of metals do not depend in any simple way on the masses of the diffusing ions in white dwarfs (Paquette et al. 1986), it is meaningless to examine line strengths of given ions as an indication of a decrease in diffusion time with increasing atomic mass. Factors other than simple diffusion probably affect the overall abundance pattern seen in our single epoch spectrum. Since carbon appears to be the most abundant trace metal, we shall use our carbon abundance of 0.5 times solar in the estimate that follows.

If an equilibrium between diffusion and accretion is assumed, then we have

$$4\pi R_{\rm wd}^2\, \rho v_d({\rm C/H})_{\rm wz} + \dot{M}({\rm C/H})_{\rm wz} = \dot{M}({\rm C/H})_{\rm M2}\ , \qquad (2)$$

where ρ is the photospheric density, v_d is the diffusion velocity, $\dot{M}$ is the accretion rate, $({\rm C/H})_{\rm wz}$ is the carbon abundance in the photosphere of the white dwarf (C/H = 0.5 solar) and $({\rm C/H})_{\rm M2}$ is the carbon abundance in the matter flowing from the secondary. The diffusion velocity may be estimated by knowing the pressure scale height, H_p and the diffusion timescales for C based upon the most accurate diffusion coefficients (cf. Paquette et al. 1986). The diffusion timescales for C in 0.6 $M_\odot$ and 1.0 $M_\odot$ H-rich white dwarfs with $T_{\rm eff} = 15{,}000$ K are, respectively, $1 \times 10^{-2.13}$ and $1 \times 10^{-2.72}$ yr (Paquette et al. 1986). We have

$$v_d = P/\rho g \tau_d\ . \qquad (3)$$

The pressure is simply that of an ideal gas since the material in the atmosphere is nondegenerate. For a 1 $M_\odot$ white dwarf model (cf. Fontaine & Van Horn 1976), the density near optical depth of unity is 5×10^{-7} g cm^{-3} and the resulting gas pressure is $\log P = 5.50$. Thus the diffusion velocity is $\sim 2.4 \times 10^{-2}$ cm^{-2} s^{-1}. The equilibrium accretion rate of neutral carbon is

$$\begin{aligned}\dot{M} &= 4\pi R_{\rm wd}^2\, \rho v_d({\rm C/H})_{\rm wz}/[({\rm C/H})_{\rm M2} - ({\rm C/H})_{\rm wz}] \qquad (4)\\ &= 7 \times 10^{-16}\ M_\odot\ {\rm yr}^{-1}\ .\end{aligned}$$

Thus the total accretion rate needed for a state of accretion-diffusion equilibrium is $\sim 2 \times 10^{-12}\ M_\odot$ yr^{-1}. For our Si abundance of 5×10^{-3} solar and a diffusion timescale for Si at 15,000 K of $10^{-2.54}$ yr, a similar calculation yields $\dot{M}({\rm Si}) = 2.5 \times 10^{-17}\ M_\odot$ yr^{-1} and a total $\dot{M} = 7.5 \times 10^{-13}\ M_\odot$ yr^{-1}. This rate computed from the Si abundance is, remarkably, within less than an order of magnitude of the accretion rate derived from C.

Hence replenishment of the diffusing material requires only a small amount of accretion, which is at the low end of estimated quiescent accretion rates for H-rich CVs. Curiously, Gilliland et al. (1986) presented ground-based spectroscopic evidence that WZ Sge is accreting material from outside the binary (an external disk or ring?) or even possibly from the interstellar medium. The relatively low rate of accretion we have determined is not inconsistent with just such a scenario. Perhaps the accreting material is part of a shell(s) ejected during the 1978 or earlier outbursts (cf. Liebowitz & Mazeh 1981) or possibly the interstellar medium, or capture of wind outflow from the secondary or an exceedingly low rate of steady mass transfer via Roche-lobe overflow during the long quiescence of WZ Sagittae. A series of FOS spectra extending over a baseline of 2–3 yr could help resolve this question of ongoing accretion.

7. DISCUSSION AND CONCLUSIONS

We have presented a synthetic spectral analysis of a cataclysmic variable white dwarf which underwent an intense accretion episode in 1978 December followed by cooling to an equilibrium temperature, while undergoing accretion at a considerably reduced level. The white dwarf in WZ Sge has a surface temperature of 14,900 K, a surface gravity $\log g = 8.0$, reveals the H_2 quasi-molecular absorption trough at 1400 Å and has photospheric chemical abundances of trace metals, in a DA (hydrogen-dominated) atmosphere, in the proportion one-half solar for C, Si at 5×10^{-3} solar and all other trace elements 1×10^{-2} times solar. These elemental abundances cannot be due to deposition of matter from the original accretion event at outburst 15 years ago, or from convective dredge-up at that time, because the diffusion timescales in the DA star are fractions of a year for all metals. Since radiative acceleration is negligible, these metals must have originated from subsequent accretion at a substantially lower rate, then probably diluted from their original accreted proportions by a superficial H-convection zone expected to be present at the white dwarf's derived $T_{\rm eff}$. If the accretion rate is low enough during quiescence to build up an accreted layer in equilibrium with the diffusion timescale of accreted carbon, then the total accretion rate can be as low as $2 \times 10^{-12}\ M_\odot\ {\rm yr}^{-1}$. However, it is also possible that the time-averaged accretion rate during quiescence is too high for there to be an equilibrium between accretion and diffusion.

This is only the third CV white dwarf with detailed *HST* spectroscopic study during quiescence, the others being OY Car (Horne et al. 1993) and U Gem (Long et al. 1994; Sion et al. 1994). Unlike the white dwarf spectrum in OY Car where virtually all of the absorption features in the white dwarf spectrum are due to a veil of Fe-peak absorbers (representing cool absorbing material above the disk plane) and thus not photospheric, we have found that a cool absorbing curtain of Fe-peak metal absorbers interposed on the white dwarf model fits to WZ Sge, does not match the absorption-line spectrum nor improve the χ^2 fits. Nor is there current evidence of any such absorbing curtain masking the U Gem white dwarf spectrum. The likely reason for the lack of such an absorbing curtain may be that both WZ Sge and U Gem have significantly lower orbital inclinations.

Finally, Robinson et al. (1978) detected very stable, rapid, coherent oscillations in WZ Sge with periods of 27.8682 and 28.9596 s, whose simultaneous presence on one occasion ruled against the oscillations being due to rotation of a spotted white dwarf. Instead, the length of the periods for reasonable mass values for the white dwarf and their close spacing, while eliminating radial pulsation modes, suggested the periods were nonradial g-mode oscillations. Since we have shown that the WZ Sge white dwarf is a trace metal-enriched DAQZ star with $T_{\rm eff} < 16{,}000$ K, our derived $T_{\rm eff}$ for the white dwarf places it within 1000 K of the blue edge of the ZZ Ceti instability strip. However, the possibility that the coherent oscillations are related to the ZZ Ceti pulsational instability is extremely remote because (1) no theoretical pulsation models give a blue edge as hot as 15,000 K, and (2) the periods are ultrashort, being a factor of 3–4 shorter than those of the shortest period ZZ Ceti pulsators.

A single *HST* spectrum with the Faint Object Spectrograph has greatly increased our knowledge of the nature and physical properties of an underlying white dwarf in an astrophysically critical cataclysmic binary, providing us with a tantalizing glimpse of the effect of the accretion process and envelope physics on the chemistry of the white dwarf atmosphere. It is clear that it would be enormously beneficial to probe this area further with additional *HST* FOS and GHRS spectra.

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