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Observations of the wind of the old nova V 603 Aquilae with the HST-GHRS*

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Abstract. High resolution spectra of the old nova V 603 Aql (1918) were taken in the regions of the C IV, N V and Si IV resonance doublets, using the G160M grating of the GHRS on board the Hubble Space Telescope. No sign of sharp absorption components due to the envelope ejected in 1918 is present. If spherical symmetry is assumed, the estimated upper limits to the column densities indicate a maximum envelope mass near $6p \times 10^{-4} M_\odot$, where p=C^{+3}/C is on the order of 0.1.

Fairly wide emission and blue shifted absorption components were however visible. Si IV was in emission unlike in other low inclination high mass transfer rate cataclysmic systems, N V in pure absorption, while C IV showed both emission and absorption. The C IV absorption blue edge was at a velocity of about $-2500\,\mathrm{km\,s^{-1}}$, the value being only of about $-1500\,\mathrm{km\,s^{-1}}$ for N V. The observations suggest a model in which a substantial proportion of the Si IV and C IV emission arises from an optically thick chromosphere-corona-like region which surrounds the accretion disk and corotates with it, leading to the observed broad and nearly symmetric emission profiles. The absorption components of the C IV and N V lines are instead formed in a conical wind which flows out from near the centre of the disk and/or the boundary layer (if the latter exists) and whose axis is nearly aligned with the rotation axis of the accretion disk and the rotation axis of the system. The degree of ionization in the wind decreases outward and this suggests that the ionization source is energetic radiation (EUV-soft-X-ray) coming from a hot compact region near the white dwarf.

The emission and the absorption lines show significant variations on a time scale of the order of ten minutes, which are probably due to variations in the flux of the ionizing radiation. Variations of the UV continuum flux of about 10% to 30% are also seen, but apparently these are not correlated with the variations in the line profiles.

A wide Ly_α absorption strongly affects the observed continuum between 1218 and 1250 Å. We attribute most of this absorption to a stellar/circumstellar component, a minor component only being of interstellar origin.

Key words: stars: individual: V 603 Aql – cataclysmic variables – ultraviolet: stars – line profiles – stars: mass loss

1. Introduction

V 603 Aql had an outburst in 1918 in which the nova brightened by 13 magnitudes reaching magnitude −1.1 in the visual. Its outburst properties were summarized by Payne-Gaposchkin (1957). The development of V 603 Aql was that of a fast classical nova with a time to fade 3 magnitudes (t_3) of 8 days according to Duerbeck (1987a). Because of the nova's relative nearness (380 pc, Mc Laughlin 1960, 330 pc; Duerbeck 1987b) and its quite high ejection velocities (a velocity of the order of $-1800\,\mathrm{km\,s^{-1}}$ was seen for regions which probably contained most of the ejected mass about 80 days after optical maximum), the ejected nebula was already observed three and a half months after the outburst. The structure and kinematics of the nebula, studied in detail by Mustel & Boyarchuk (1970) and by Weaver (1974), suggest approximate axial symmetry and the presence of equatorial rings and polar caps. The axis is not far from the line of sight. Deceleration of the nebula supposedly due to interaction with the interstellar medium was suggested by Duerbeck (1987a), but a re-examination of the measurements by Anupama (Duerbeck 1994) indicated that this effect was not real.

The old nova is relatively well observed. Orbital elements reported in Ritter's catalogue (1990) indicate a period of 0.138 days, an orbital inclination of 17° to the line of sight and component masses of 0.66 and 0.29 $M_\odot$ for the white dwarf and the cool near main sequence companion, respectively. Warner (1976) gave 0.9 $M_\odot$ for the mass of the white dwarf and 15° for

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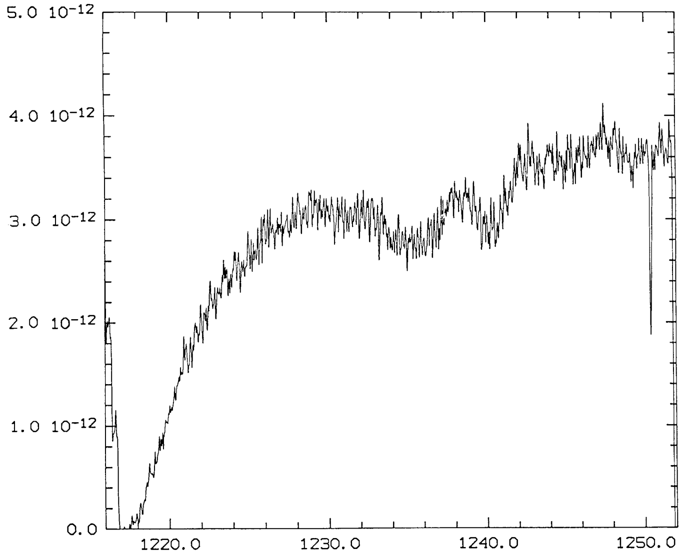

Fig. 1a. The merged spectrum of the N V 1240 Å doublet. The sharp feature near 1250.4 Å is the interstellar S II(1) 1250.58 Å line

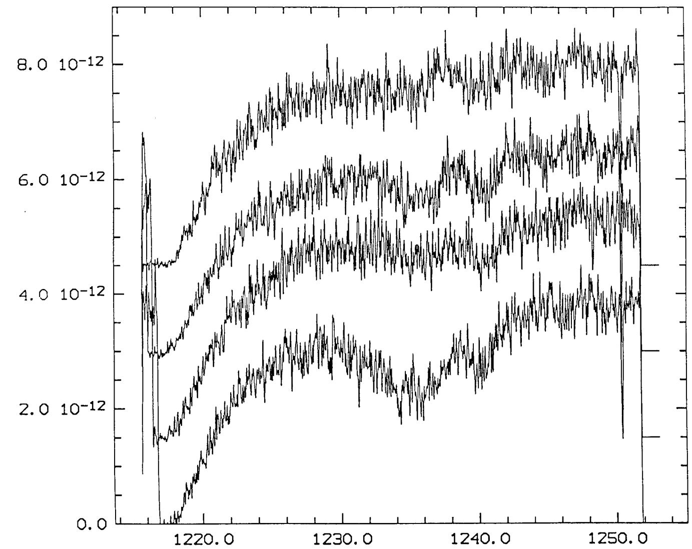

Fig. 1b. The individual subexposures of the N V 1240 Å doublet. For clarity, the spectra have been offset in the y-direction by 1.5×10^{-12} erg cm^{-2} s^{-1} Å^{-1} each

the system inclination. The low inclination of the system comes from the small value of $2K_1$, 75 km s^{-1} only, as found by Kraft (1964).

The orbital plane is probably close to the equatorial plane of the ejected nebula. It is not clear whether, as claimed, the observations really indicate that V 603 Aql contains a strongly magnetic white dwarf. A number of papers such as those of Haefner & Metz (1985), Gnedin et al. (1990), Udalski & Schwarzenberg-Czerny (1989) and Schwarzenberg-Czerny et al. (1992) proposed that V 603 Aql is an intermediate polar; in that case at least the inner parts of the accretion disk would be broken up by the magnetic field. However, this conclusion was challenged by Patterson & Richman (1991) and by Patterson et al. (1993), who considered it to be a superhumping cataclysmic binary like the members the SU Ursa Majoris class of dwarf novae. In any case, Einstein satellite observations showed V 603 Aql to be the one of the strongest X ray emitter among the old novae detected by it, after the probably magnetic systems CP Pup and GK Per (Becker 1989).

Ultraviolet observations of novae including V 603 Aql were summarized by Friedjung (1989). Though the energy distribution of the old nova can be interpreted in different ways, it appears to be close to that of a standard accretion disk, emitting as a sum of black bodies at different temperatures (see also Wade 1982). The estimated mass accretion rate from UV observations is $\dot{M} = 1.26 \times 10^{18}$ gr s^{-1} (Krautter et al. 1981) and/or 7.7×10^{17} gr s^{-1} (Wade 1982), while Patterson (1984) gave $\dot{M} = 3.3 \times 10^{17}$ gr s^{-1} from the optical luminosity.

A high resolution short wavelength IUE spectrum was obtained by Selvelli & Cassatella (1981); emission line half intensity widths indicating velocities of the order of 900 km s^{-1} were seen for the C IV and Si IV resonance doublets (value inclusive of the doublet separation). The He II 1640 Å emission line was also broad but no emission was seen in N V. In spite of the long exposure time (about seven hours) the signal in the high resolution mode of IUE was however too low to see the continuum and absorption lines such as those due to a wind. Low resolution IUE spectra did not show clear signs of lines with a P Cygni profile like that of the C IV profile observed for the old nova HR Del (1967). It was therefore difficult to clarify the nature of the line emission seen in the spectrum of V 603 Aql.

The Hubble Space Telescope Goddard High Resolution Spectrograph (HST-GHRS) observations reported in this paper, had two aims. One was to try to detect and investigate on any absorption components of resonance spectral lines which could be produced by the remnant of the ejected nebula. The other was to unambiguously detect possible wind signatures and to investigate the properties of the wind. This investigation could be carried out thanks to the the higher sensitivity of the HST-GHRS compared with IUE in the high resolution mode.

2. The observations

Blue shifted absorption components due to the ejected envelope or to a wind, if present at all, should be visible in resonance lines because of their very large absorption coefficients. Observations were therefore made in the regions of the C IV, N V and Si IV resonance doublets using the HST-GHRS G160M first-order grating (resolving power 2.5×10^4) covering each wavelength range with the 500 science diodes. All spectra were taken in the Accumulation Mode with the FP-SPLIT procedure (see Soderblom et al. 1995) in which each requested observation is broken into a number (default = 4) of separate and equal subexposures taken at a slightly different grating/carousel position in the dispersion direction along the 500 science diodes array. When, after a proper realignement in wavelength, the four separate subexposures are coadded into a single spectrum (in which the interstellar lines appear as single and sharp features), the

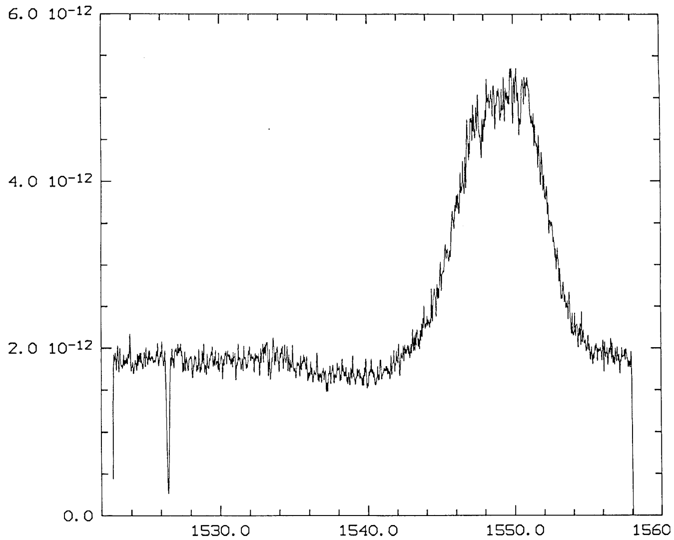

Fig. 2a. The merged spectrum of the C IV 1550 Å doublet. The sharp feature near 1526.5 Å is the interstellar Si II(2) 1526.70 Å line

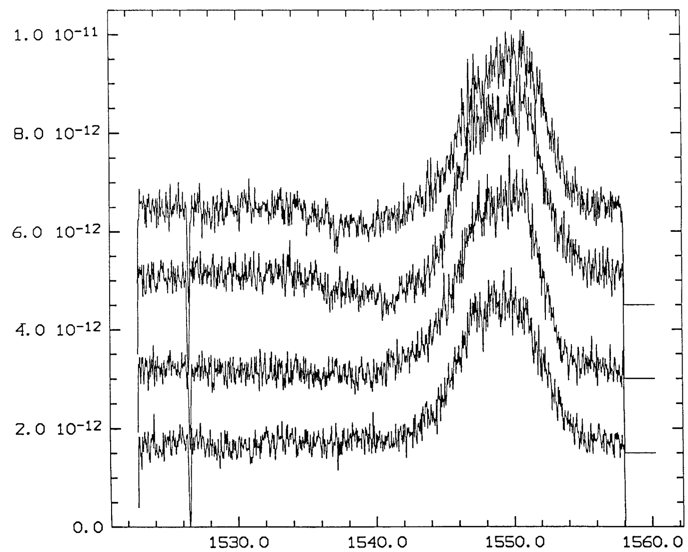

Fig. 2b. The individual subexposures of the C IV 1550 Å doublet. For clarity, the spectra have been offset in the y-direction by 1.5×10^{-12} erg cm^{-2} s^{-1} Å^{-1} each

Table 1. Log of the HST-GHRS observations (G160M grating, FP=4). Start time is in hours, minutes and seconds (U.T.); exposure time is in seconds

Spectrum	Subexposure	Date	Start time	Exposure time
C IV		19 Feb 94	23:33:46	2611.2
	1		23:33:46	652.8
	2		23:44:38.8	652.8
	3		23:55:31.6	652.8
	4		24:06:24.4	652.8
N V		20 Feb 94	01:12:11	2502.4
	1		01:12:11	625.6
	2		01:22:36.6	625.6
	3		01:33:02.2	626.6
	4		01:43:27.8	626.6
Si IV		20 Feb 94	02:48:34	1849.6
	1		02:48:34	462.4
	2		03:56:16.4	462.4
	3		03:03:58.8	462.4
	4		03:11:41.2	462.4

fixed pattern noise in the merged spectrum is significantly reduced. Anyway, a separate examination of the individual spectra allows a time resolved study of the spectral features at the price of a non optimum signal to noise ratio. The log of the HST observations is given in Table 1, which provides for each spectral range the date of the observations, the start time of the exposure (U.T. time) and the total exposure time in seconds. The exposure time of each individual subexposure is 1/4 of the total exposure time. As seen in Table 1, the separation between the start times of any two consecutive subexposures of the same spectral region ranges from about 7 min for Si IV to about 10 minutes for C IV and N V, so that it is possible to search for short timescale variations of the UV lines and continuum, as discussed in the following.

Table 2. Profile characteristics of the N V, Si IV, and C IV lines

N V:	Only in absorption
	Absorption blue edge: −1500 to −2000 km/s
	Maximum absorption: −500 km/s
Si IV:	Only in emission
	Emission FWHM = 660±60 km/s
	Emission HWZI = 750 km/s
	Violet shift of emission peak: −100 km/s
C IV:	Emission - absorption profile
	a) absorption blue edge: −2500 km/s
	maximum absorption: −1400 to −2100 km/s
	b) emission FWHM: 750±45 km/s
	emission HWZI: 1000 km/s
	violet shift of emission peak: −50 km/s

The merged spectra as well as the individual subexposures in the N V, C IV and Si IV ranges are shown in Figs. 1, 2 and 3, respectively. The data have been smoothed with a running mean to improve further on the signal-to-noise ratio with a minimal effect on the spectral resolution. In the merged spectra, the nominal wavelength scale of the interstellar features (S II(1) 1250.58 Å and Si II(2) 1526.70 Å) is displaced by −0.20 Å with respect to the laboratory scale. Measurements of various parameters of the lines are given in Tables 2 and 3. As it appears from Figs. 1, 2, and 3, the N V doublet is seen in pure absorption, the C IV doublet is seen as a composite emission-absorption feature, and that of Si IV is seen only in emission.

3. Analysis

3.1. Search for absorption due to ejected envelope

In view of the probable non-deceleration of the nebula (Duerbeck 1994), we expect to observe the absorption due to the

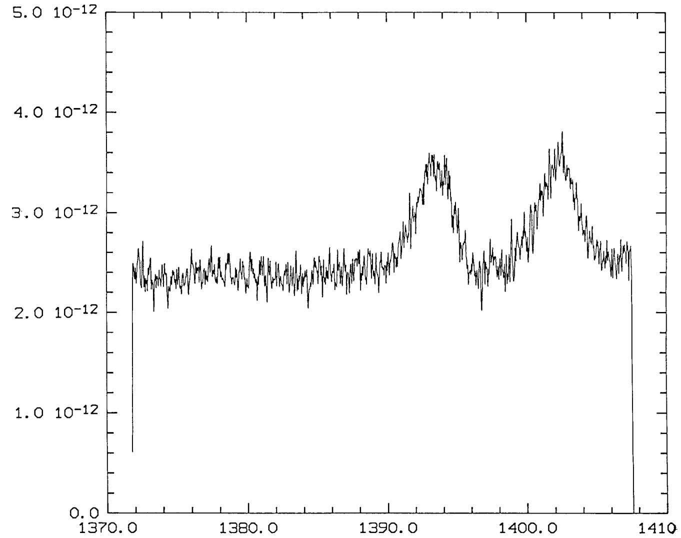

Fig. 3a. The merged spectrum of the Si IV 1400 Å doublet

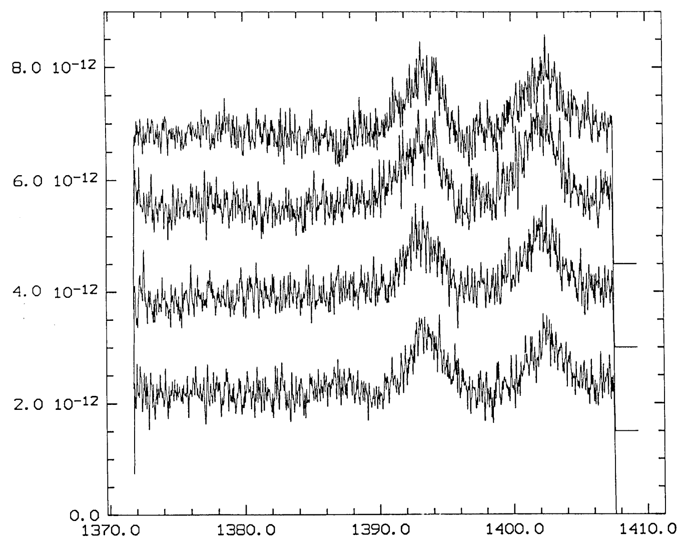

Fig. 3b. The individual subexposures of the Si IV 1400 Å doublet. For clarity, the spectra have been offset in the y-direction by 1.5×10^{-12} erg cm^{-2} s^{-1} Å^{-1} each

ejected envelope at a velocity close to that of the "principal absorption system" observed during outburst. This system seems to contain most of the ejected mass at the end of outburst development, because its velocity is of the order of that of the nebular expansion relative to the central nova remnant (McLaughlin 1960). As for most other novae, the velocity of the principal system of V 603 Aql showed a small systematic increase with time, the last velocity determination being around -1800 km s^{-1} (Payne-Gaposchkin 1957). It appears therefore justified to search for nebular absorption components at this or slightly higher velocities. It should also be emphasized that such lines should be fairly narrow with a full width at zero intensity of not more than 250 km s^{-1}, as profiles during outburst published by Sayer (1935) showed widths of this order in stages when the

Table 3. Emission lines measurements. Notes: o-c is the displacement of the observed wavelength of the emission peak with respect to the laboratory wavelength in km/s

Spectrum	Lambda Å	o-c km/s	FWHM km/s	Intens. (10^{-11})	Eq.wid. Å
C IV 1548.19 & 1550.77 (blend)					
Mean	1549.314	−32.5	748[a]	2.26	11.88
Subexp. 1	1548.999	−93.4	792[a]	2.10	12.38
Subexp. 2	1549.140	−66.1	777[a]	2.53	14.84
Subexp. 3	1549.408	−14.3	691[a]	2.31	10.59
Subexp. 4	1549.698	−42.0	753[a]	2.15	10.58
Si IV 1393.730					
Mean	1393.323	−87.5	669	0.35	1.467
Subexp. 1	1393.503	−48.8	639	0.33	1.534
Subexp. 2	1393.179	−118.5	603	0.29	1.185
Subexp. 3	1393.177	−118.9	709	0.38	1.456
Subexp. 4	1393.388	−84.3	722	0.40	1.759
Si IV 1402.730					
Mean	1402.228	−96.2	654	0.33	1.329
Subexp. 1	1402.626	−22.2	547	0.22	0.947
Subexp. 2	1402.100	−134.6	614	0.29	1.110
Subexp. 3	1402.045	−146.3	718	0.51	1.998
Subexp. 4	1402.227	−107.9	695	0.32	1.303

[a] the reported value of FWHM represents the observed value minus the doublet separation of 2.575 Å

shell was probably well detached from the photosphere and spurious line widening due to the projection of material of different radial velocities in front of the photosphere was negligible. This value of the width was seen near the end of the Balmer series, where absorption component profile distortion due to the associated line emission was small. In addition, when the principal absorption system was last seen in optical spectra following the outburst, it was split into two narrower components with a separation of 120 km s^{-1} (Payne-Gaposchkin 1957). This suggests that the previously mentioned upper limit of 250 km s^{-1} is probably too large, and in the following calculations one of 150 km s^{-1} will be taken.

In view of these considerations we have used the merged spectra, obtained after adding together and realigning in the wavelength space each group of four independent subexposures, to search for narrow resonance line absorption components at wavelengths corresponding to velocities near -1800 km s^{-1}. No such lines were seen in the merged spectra for N V and C IV (see Figs. 1 and 2). Assuming half the local range of noise as an upper limit for the line central depth $(1 - r_\lambda)$ we derive upper limits to the optical thicknesses for the C IV 1548.20 Å and N V 1238.80 Å lines (the stronger line of each doublet) on the order of 0.06 and 0.05, respectively. Using these values we obtain upper limits in the range 1.1×10^{13}–1.5×10^{13} cm^{-2} for the column densities of both ions in the envelope ejected in 1918.

3.2. The line profiles and their variations

As already mentioned in Sect. 2, the N V, C IV and Si IV profiles are substantially different from each other: the N V doublet is seen in pure absorption, the C IV doublet is seen as a composite emission-absorption feature, while that of Si IV is seen only in emission. In the case of the N V 1240 Å doublet the merged spectrum shows a blue shifted absorption profile for each doublet component (see Fig. 1a and Table 2). The absorption maximum $V_{\rm max}^{\rm abs}$ (minimum of flux) occurs at approximately -500 km s^{-1} in each component and the edge velocity limit ($V_{\rm edge}^{\rm abs}$) of the shorter wavelength 1238.8 Å line is of the order of -1500 km s^{-1}. A separate examination of the 4 subexposures of N V shows however dramatic changes (see Fig. 1b). Subexposure 1 shows very strong absorption features with $V_{\rm max}^{\rm abs}$ at about -1000 km s^{-1} and $V_{\rm edge}^{\rm abs}$ at about -2000 km s^{-1}. Subexposure 2 shows a stronger continuum with much weaker absorptions, while subexposure 4 shows an almost featureless continuum with marginal evidence for very weak absorption features. These remarkable changes between successive subexposures, take place on a time-scale of about 10 min.

The merged spectrum of the C IV doublet (Fig. 2a and Table 2) shows a well developed P Cygni like profile, in which the strong wide emission blend is almost symmetrical around 1549.2 Å while the flat rather weak absorption blend has $V_{\rm edge}^{\rm abs}$ of about -2500 km s^{-1} with respect to the shorter wavelength component of the doublet. The average value of the full width at half maximum (FWHM) of the C IV emission profile in the four subexposures is 750 ± 45 km s^{-1} , while the half width at zero intensity (HWZI) is about 1000 km s^{-1} after subtraction of the 2.6 Å separation between the lines of the doublet.

Examination of the subexposures (see Fig. 2b and Table 3) shows dramatic variations also in the C IV doublet; in subexposures 1 and 2 the profile is in pure emission with a substantial increase in the intensity, while subexposures 3 and 4 show well developed absorption components. In subexposure 3 the absorption component has $V_{\rm max}^{\rm abs}$ at -1400 km s^{-1}, compared with $V_{\rm edge}^{\rm abs}$ at -2450 km s^{-1}, while in subexposure 4 the absorption component has significantly moved towards shorter wavelengths and a rather sharp absorption maximum is present at $V_{\rm max}^{\rm abs} = -2100$ km s^{-1}. The integrated effect of these changes on the merged spectrum produces the flat bottomed absorption profile shown in Fig. 2a. In spite of the above variations, the emission profile remains symmetric without evidence of the steep decrease in the blue wing generally observed in P Cygni profiles.

It is remarkable that, as seen in Fig. 2a, a narrow absorption component at 1550.8 Å, which looks like an interstellar/circumstellar feature, is clearly present on the top of the emission peak of the C IV doublet only in subexposures 3 and 4.

The merged spectrum of Si IV (see Fig. 3a and Table 2) shows two almost pure symmetric emissions having about the same intensity and the emission center violet shifted by about 100 km s^{-1} with respect to the nominal wavelength, ($V_{\rm centr}^{\rm emiss} \simeq -100$ km s^{-1}). The emission FWHM is 660 ± 60 km s^{-1} while the HWZI is about 750 km s^{-1}. An inspection of the subexposures (Fig. 3b and Table 3) reveals that the variations are less dramatic than for the N V and C IV lines, although subexposures 1 and 4 show some evidence of absorption components in the blue wing, and subexposure 3 shows a remarkable increase in the emission intensity. Subexposure 4 may show signs of a narrow absorption component at -1360 km s^{-1} for the stronger 1393.73 Å line of the doublet, the situation not being so clear for the weaker line.

Significant variations are seen also in the continuum flux of V 603 Aql. The continuum flux was measured around 1250 Å, 1374 Å and 1528 Å for the N V, C IV and Si IV regions, respectively. Taking the merged spectra as reference, the maximum amplitude of the variations seen in the individual subexposures was about 30% in the C IV region (a maximum flux of 2.2×10^{-12} erg cm^{-2} s^{-1} Å^{-1} being reached in subexposure 3, and minimum of 1.6×10^{-12} erg cm^{-2} s^{-1} Å^{-1} in subexposure 1) and about 12 % in both the N V and Si IV subexposures. Needless to say , these variations are much larger than the expected repeatability error of the GHRS observations which is less than 1% (Soderblom et al. 1995).

It is worth recalling that time-resolved spectrophotometry has shown optical variations of the same order of magnitude, with time scales of about 10 minutes, Panek (1979).

3.3. The interstellar lines

Two sharp absorption lines identified as S II (UV 1) 1250.58 Å and SiII (UV 2) 1526.70 Å are evident near the N V 1240 Å and C IV 1550 Å resonance doublets, respectively. The SiII 1526.70 Å line (FWHM≈ 35 km s^{-1}) appears as shortward displaced by 40 km s^{-1} while the S II(1) 1250.58 Å line (FWHM≈ 30 km s^{-1}) is shortward displaced by 45 km s^{-1}. The sharpness of these features suggests an interstellar origin. This is supported by the absence of the SiII (2) 1533.44 Å line, which arises from the excited level with E.P. = 0.04 eV (not populated under interstellar conditions) of the same ground term $3p^2P^o$ as the 1526.70 Å line.

In the assumption that the lines are optically thin (linear part of the curve of growth) their observed equivalent widths (W=0.068 Å and W=0.162 Å, respectively) can be used to provide an estimate of the column densities of the respective ions. The relation (Spitzer 1978) $N_\lambda = 1.13 \times 10^{20} W f_{jk}^{-1} \lambda^{-2}$ provides column densities log N(SII) = 14.96 and log N(SiII) = 13.81 for the zero-eV population of the S II and SiII ions respectively. Since in an H I region silicon and sulphur are mostly in the ground level of the first ionization state, the above reported column densities provide a direct estimate ot the elemental column densities toward V 603 Aql.

An estimate of the column density of neutral hydrogen toward V 603 Aql can in principle be derived from the intensity of the wide absorption feature centered around 1215.6 Å assumed to be of interstellar origin. The procedure is that of the continuum reconstruction technique (Bohlin 1975), in which the portion of the stellar spectrum in proximity of Ly$_\alpha$ is multiplied by exp($+\tau$) where the optical depth τ is computed for a pure damping line profile: $\tau_\lambda = 4.26 \times 10^{-20} N(\mathrm{HI})(\lambda - 1215.7)^{-2}$, (in the hypothesis that the velocity dispersion of the gas is much less than the observed line width). The value of N(H I) is so

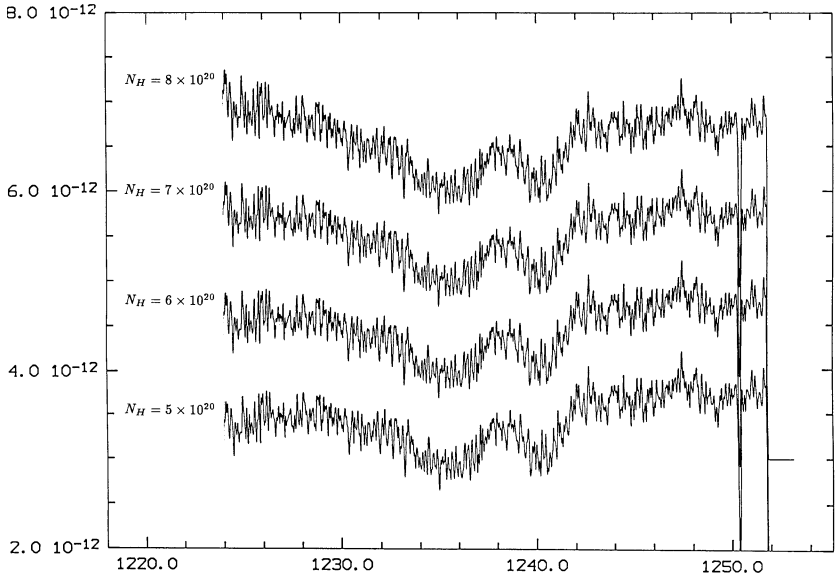

Fig. 4. The reconstructed continuum in the red wing of Ly$_\alpha$. The four theoretical fits correspond to hydrogen column densities equal to 5, 6, 7, and $8 \times 10^{20}\,\mathrm{cm}^{-2}$. For clarity the four reconstructed continua have been offset in the y-direction by $1.0 \times 10^{-12}\,\mathrm{erg\,cm^{-2}\,s^{-1}\,Å^{-1}}$ each

chosen as to remove from the spectrum the effects of the Ly$_\alpha$ absorption and to restore the expected continuum. This procedure provides a good fit for value of $\tau < 1$, and the errors in the derived columns, typically 0.1 dex, depend upon the acceptable range of restored continua for different values of N(H I). With this procedure we estimate that the neutral hydrogen column density toward V 603 Aql is log N(HI) = $20.90 \pm 0.05\,\mathrm{cm}^{-2}$. This value , where the errors reflect our judgement of acceptable limits, provides the expected slope in the reconstructed continuum longward of 1224 Å, that is in the region where $\tau < 1$, (see Fig. 4).

With this value of N(H I) the average relation between neutral hydrogen and dust $N(\mathrm{H})/E_{\mathrm{bump}} = 2.17 \times 10^{21}\mathrm{cm}^{-2}\mathrm{mag}^{-1}$ (Diplas & Savage 1994) gives E_{bump} = 0.37 , a value which is unconfortably high with respect to that derived from IUE data that show a rather faint 2200 Å interstellar dust feature with E_{bump} not greater than 0.07 mag (for an extensive literature see Friedjung 1989). In addition, the ratios of column densities $\log[N(\mathrm{SiII})/N(\mathrm{HI})] = -7$ and $\log[N(\mathrm{SII})/N(\mathrm{HI})] = -5.94$ provide elemental abundances that are low when compared with the solar ones (log Si/H = −4.45 and log S/H = −4.73, Anders & Grevesse 1989). Note that a substantial contribution by ionization states other than SiII and S II to the abundance of silicon and sulphur is unlikely because SiII and S II are the dominant ionization states in H I regions. While depletion can account for a large part of the silicon apparent underabundance, that of sulphur cannot be explained at all since sulphur is generally undepleted in low-density diffuse interstellar clouds (Spitzer & Fitzpatrick 1993).

The two above mentioned discrepancies can significantly be reduced in the hypothesis that the observed N(H I) column density is significantly affected by a stellar/circumstellar component (it is obvious that the method we have employed can be used for the determination of the interstellar H I column density only if the contribution by the intrinsic stellar Ly$_\alpha$ absorption is negligible). If we take $\log N(\mathrm{H}) \approx 20.1$ for the interstellar component of the hydrogen column density (this value provides $E_{\mathrm{bump}} \approx 0.05$, which is within the observational errors) we obtain $\log(\mathrm{S/H}) - \log(\mathrm{S/H})_\odot = -0.3$ and $\log(\mathrm{Si/H}) - \log(\mathrm{Si/H})_\odot = -1.65$. The remaining discrepancy in the abundance of sulphur can be accounted for by:

1) a small contribution by ionization states others than S II to the total sulphur abundance,
2) the fact that the use of Spitzer's (1978) relation to derive column densities is justified only under strict optically thin conditions ($\tau \ll 1$, residual intensity $r \gg 0$). Deviations from linearity in the the column density-W relation become larger than 10% and saturation starts, leading to an underestimate of N, when r_o is less than 0.70 (τ_o greater than 0.36). The observed residual intensity of the S II 1250.50 Å line is 0.50, and, therefore, saturation effects are not negligible.

The same arguments apply also for silicon, with argument 2) being valid *a fortiori* since the residual intensity of the Si II 1526.70 Å line is 0.13 only. Then, depletion can account for the remaining silicon underabundance of about 1 dex.

The estimated "stellar" contribution to the Ly$_\alpha$ absorption profile is on the order of $7 \times 10^{20}\,\mathrm{cm}^{-2}$ and can be produced either in the optically thick accretion disk itself, as evident in model accretion disks reconstructed from model stellar atmospheres (see, for example, Wade 1988), or by the presence of a thick circumstellar shell or cloud of neutral hydrogen in front of the region where the UV continuum is emitted. This shell is not associated with the envelope ejected in 1918 which, at present, is extremely thin having a radius of about 0.1 pc.

In this context, we recall that X-ray observations of V 603 Aql have provided values for the hydrogen column density on the order of 8×10^{20} - $1 \times 10^{21}\,\mathrm{cm}^{-2}$ (Drechsel et al. 1983; Patterson & Raymond 1985; Heracleous et al. 1991), in perfect agreement with the value found here by the Ly$_\alpha$ method. In particular, the presence of a circumstellar shell of neutral hydrogen with N_{H} about $1.0 \times 10^{21}\,\mathrm{cm}^{-2}$ has been proposed by Jensen

(1984) to explain the lack of detection of EUV-soft-X-ray radiation in V 603 Aql and other CV's by the IPC detector on board the EINSTEIN Observatory since, for typical distances, the interstellar column densities are not large enough to produced the required amount of photoelectric absorption.

4. Discussion

4.1. The origin of the absorption and emission profiles

Despite a rather long record of high resolution observations of the resonance lines of C IV, N V and Si IV in cataclysmic variables, many uncertainties still exist concerning their behaviour and the theoretical interpretation. Previous observations have dealt with the brightest members of the novalike class and dwarf novae in their high states. Recent reviews are given by Drew (1990, 1991), La Dous (1993), Mauche (1994), Robinson et al. (1994) and by Drew & Kley (1994). Observations from IUE high resolution spectra were studied for a number of cataclysmic variables by Prinja & Rosen (1995). Systems with fairly high orbital inclination i show almost generally the presence of emission profiles (that are especially strong for the C IV lines), though rather weak absorptions of N V and Si IV can still be visible. Only the near edge-on system OY Car exhibits some Si IV emission (Prinja & Rosen 1995). Detailed studies of eclipsing systems (i near 90°) have shown that the emission lines of C IV suffer only a partial obscuration, this being an indication of formation in an extended region.

In low- and moderate-inclination high mass trasfer systems the UV resonance lines of C IV, Si IV, and N V exhibit strong blueshifted absorption components, the typical signature of outflow. The C IV doublet generally shows a P Cygni profile in which the emission peaks are typically red-shifted by 500–800 km s^{-}1 with a maximum redward edge at about 1000 km s^{-1} , while the N V and Si IV lines are in pure absorption only. Lower limits on the maximum velocities reached by these outflows can be derived from the observed $V_{\rm edge}^{\rm abs}$ in the resonance lines. These are of the order of 3000–5000 km s^{-1} for the C IV lines and rather lower for the Si IV and N V lines. This, together with the lack of emission, could suggest line formation in smaller volumes than for C IV. In any case, these velocities are about the escape velocity from the surface of the white dwarf and hence the origin of the outflow has been inferred to be at or near the accreting star (Cordova & Mason 1982). It is not yet clear whether the resonance lines have origin only in the wind, which seems to be preferentially accelerated perpendicularly to the plane of the orbit, or also contain a contribution from a more compact region such as a chromosphere-corona surrounding the accretion disk. A very recent paper by Mason et al. (1995) has reported HST-GHRS observations of the eclipsing novalike system UX UMa. Though the authors had difficulties in explaining all features of their observations, they were able to conclude that the C IV resonance doublet, like the He II 1640 Å line, was formed in a wind coming from the accretion disk.

In addition, it is still unclear what is the ionization structure in the wind and whether the velocity structure is that of a slowly accelerating outflow. Winds of cataclysmic variables seem to be preferentially accelerated perpendicularly to the plane of the orbit, that is to any accretion disk which is present. The most popular acceleration mechanism is by radiation pressure in spectral lines but, for instance, magnetic effects may also be important. The ionization state of the wind assuming only photo-ionization processes was calculated in detail by Hoare & Drew (1993); unfortunately they did not calculate spatial variations in ionization between different regions of the wind, and no reliable theoretical predictions exist concerning such variations.

Some effort has been expended to calculate theoretical wind line profiles in cataclysmic variables. Early work assuming spherical symmetry as for O star winds is not applicable in the present case, if ejection occurs from an accretion disk. Mass flows in cataclysmic variables seem to take place within a cone having its axis perpendicular to the disk, and the ejected material is expected have angular momentum due to the orbital velocity in the disk. This type of effect was taken into account by Shlossman & Vitello (1993) and by Vitello & Shlossman (1993). The approximations of the radiative transfer in the last two papers were criticised by Knigge et al. (1995), who used Monte-Carlo methods to make statistical simulations without the assumptions made by other authors and obtained what are probably the most reliable results up to now. These calculations are however limited to a few indicative cases in C IV, and more would be required for detailed comparisons.

The present HST-GHRS data can be used, together with the previous observational and theoretical considerations, to set some constraints on the structure of the line emitting and absorbing regions of V 603 Aql. We recall that the system inclination is about 17°, and that the calculated C IV line profiles due to winds from normal disks by Knigge et al. (1995) indicate a decreasing proportion of wind emission with respect to absorption, when the inclination becomes small. The emission is very small already at an inclination of 30° for which calculations were made, and it should be even less at 17°. Our observations instead show very strong emission from the C IV doublet. This strongly favours a non wind origin for most of the C IV emission. We therefore suggest that this emission mainly originates from an extended chromosphere-corona like region which surrounds the accretion disk and rotates with it. Rotation would lead to line broadening and to the observed nearly symmetric emission profiles.

In the framework of this interpretation we recall that the smallest radius of line formation R is unambiguously related to the rotational velocity line width $V_{\rm rot}$ by the expression $V_{\rm rot} \simeq 3600 M_{\rm wd}^{1/2} R_9^{-1/2}$, where $V_{\rm rot}$ is in km s^{-1}, $M_{\rm wd}$ is the white dwarf mass in solar units, and R_9 is in units of 10^9 cm.

In V 603 Aql, since the observed half widths at zero intensity for the C IV and Si IV lines are about 1000 and 750 km s^{-1}, respectively, and the system inclination to the line of sight is about 17°, it is straightforward to obtain values around 3200 and 2400 km s^{-1} for the maximum rotational velocities of the C IV and Si IV regions. With these velocities and $M_{\rm wd} \simeq 0.7 M_{\odot}$ for the accreting white dwarf, the previous expression gives 8.0×10^8 cm and 1.3×10^9 cm respectively for the inner radii of the C IV and Si IV emission formation, consistent with the inner edge for C IV formation being nearer to the disk center than for Si IV. Since the radius of a $0.7M_{\odot}$ white dwarf is about 7.0×10^8 cm the two regions of emission are very close to the white dwarf surface.

Ionization of the line emitting regions comes by radiation from a boundary layer or from other central regions, the geometry and conditions being suitable to give line emission source functions such that absorption of the underlying disk continuum is less important than the emission.

On the other hand, we interpret the absorption components of the C IV and N V lines as formed in a conical wind, flowing out from near the centre of the disk and the boundary layer (if the latter exists), whose axis is nearly aligned with the rotation axis of the accretion disk and the rotation axis of the system. The wind is photoionized by the EUV photons coming fom the hottest disk and boundary layer regions and its ionization decreases outwards. The wind slowly accelerates with height above the disk, N V being only present in the innermost lower velocity, higher density regions. The N V wind region is seen by the observer projected in front of the UV emitting inner disk part, so producing the shortwards displaced absorption components with $V^{\rm abs}_{\rm max} = -500\,{\rm km\,s^{-1}}$ and $V^{\rm abs}_{\rm edge} = -1500\,{\rm km\,s^{-1}}$. Within this framework of an accelerating conical wind, the C IV absorption would arise on average from regions further out in the wind, where the maximum velocity is higher. The absence of absorption components of Si IV might result from its lower ionization potential compared to the other ions so that it is almost fully ionized in the wind. Alternatively, if Si IV is formed in the outermost parts of the wind, its absence in absorption might simply result from a geometrical effect, because the Si IV region it is not projected in front of the UV emitting regions of the disk. A sketch of the kind of model we suggest is shown in Fig. 5.

The emission-absorption profile of C IV observed in V 603 Aql differs strongly from the typical P Cygni profiles observed in early type mass losing stars not only because its emission component is much stronger than the one in absorption (see the merged spectrum in Fig. 2a) but also and mainly because the emission component is substantially symmetrical and does not show the characteristic steep blue edge. Indeed, there is even evidence that the blue wing is occasionally stronger than the red one (see subexposure 2). This peculiar behaviour suggests that in V 603 Aql the emission and absorption components originate from two **separate** physical regions, i.e.

1) a chromosphere-corona which surrounds the disk and is optically thick (the flux ratio of the K to the H component of the Si IV and C IV emission doublets is on the order of unity, in contrast with the theoretical, optically thin, ratio 2:1).
2) the wind , whose temperature must be fairly low in order to limit the emissivity but not the opacity.

Therefore, we warn about associating the term "P Cygni profile" used for the C IV line in V 603 Aql with its common physical interpretation in terms of line scattering.

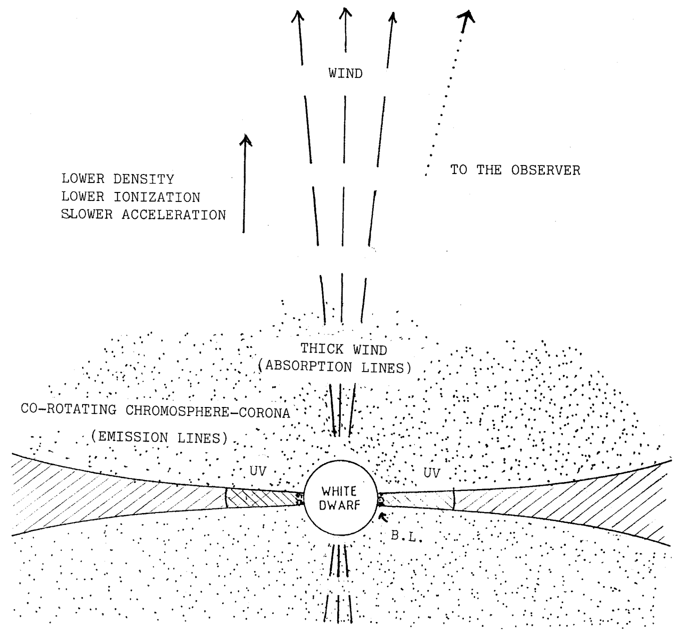

Fig. 5. A schematic two-components model for the origin of the absorption and emission features in the resonance lines of V 603 Aql

Incidentally, we point out that in high inclination and eclipsing objects the two distinct regions mentioned above (the wind and the chromosphere-corona) would each one give origin to a component for the (pure) emission spectrum observed in these objects both in and out of continuum eclipse.

As already mentioned, V 603 Aql has been suggested to be a magnetic system. One may then wonder whether there is an alternative interpretation in terms of a disk having a central hole as a result of the disruptive action of the magnetic field, with an accretion column going from the disk to the white dwarf and line emission from the receding part of the wind being visible through the hole. In that case it would be difficult to form N V wind absorption lines, because the N^{+4} region would probably not be projected in front of the disk. In addition, the accretion column(s) would lead to asymmetric emission line profiles. For these reasons we consider such a model unlikely.

Ferland et al. (1982), based on low resolution IUE and optical spectra, after a detailed analysis of the emission line fluxes suggested the the presence of a uniform "coronal" region with a radius comparable to the binary separation. Our observations indicate the presence of a co-rotating chromosphere-corona to be associated with the Si IV and C IV emissions, so confirming an aspect of the model by Ferland et al. (1982), but, in addition, we require the presence of another region with lower temperature (an optically thick wind) where the absorption lines of C IV and N V originate.

4.2. The rapid line profile variations

Fairly short timescale variations in the ultraviolet lines of some cataclysmic binaries are known since a long time. A very early paper on this subject by Drechsel et al. (1981) concerned the star of the present study V 603 Aql. The time variations of another old nova HR Del in low resolution IUE spectra were studied by Friedjung et al. (1982); except in the case of the C IV doublet the variations appeared to be related with the orbital phase. Recently Prinja et al. (1992) discussed low resolution IUE spectra of the novalike binary V795 Her, which appeared to show cyclic variations, whose origin is however unclear. This system can be understood as being permanently in what for dwarf novae corresponds to a superoutburst state, with superhumps as claimed by Patterson et al. (1993) for V 603 Aql. Prinja et al. (1992) report also on cyclic variability taking place in low inclination dwarf novae showing superoutbursts as well as ordinary outbursts. Quite dramatic variations of the line profiles of the dwarf nova YZ Cnc were fitted by Drew & Verbunt (1992) to the orbital phase.

Drechsel et al. (1981) studied the variations in the ultraviolet emission line spectrum of V 603 Aql (C IV, Si IV and He II) as well as in the continuum and suggested an orbital origin for them, although only two orbital periods were covered and it is not known whether the variations repeat on longer time scales. However, the continuum variations reported by Drechsel et al. (1981), do not appear orbital. On the other hand, Schwarzenberg-Czerny et al. (1992), through a longer term monitoring with IUE, found variations with a period of 63 minutes in a continuum band 180 Å wide centered around 1475 Å. Variations with the same period in the X-ray (Eracleous et al. 1991) and optical domains (Udalski & Schwarzenberg-Czerny 1989) were interpreted by the authors as due to the spin period of a magnetized white dwarf.

The amplitude of the flux variations in the present GHRS-HST observations is of the order of 10% to 30% (maximum to minimum) for both the continuum and the emission lines. These variations take place on a time scale of the order of 10 minutes (i.e. the separation between the mid-times of two successive subexposures). More dramatic changes occur in the absorption components of N V and C IV (see Figs. 1b and 2b). Given the short time scale for these variations, it seems unlikely that they are associated with the orbital motion (e.g. an asymmetry of the wind with respect to the disk's rotation axis) or with a possible superhump period (which is generally of the same order of the orbital period). On the basis of our limited sample of continuum measurements we cannot rule out the presence of a modulation with the 63 minutes X-ray period mentioned above. Unfortunately, GHRS-HST observations in different spectral lines are not simultaneous like for IUE and this prevents a study of the possible correlations in the observed variations.

As for the changes in the absorption profiles, which are prominent for N V (Fig. 1b), we note that, to the first order, these affect the entire profile rather than a limited part of it. Such a simultaneous effect is most easily explainable by changes in the flux of the ionizing radiation rather than by inhomogeneities in the mass outflow, although for C IV there is some evidence for an inhomogeneous wind structure (compare subexposure 3 and 4 in Fig. 2b). It is not clear whether the ionizing flux should be considered as intrinsically time dependent, or whether the variations are due to cyclic changes in the geometry of the ionizing source with respect to the observer. The ionizing source could be, for instance, a hot spot near or on the white dwarf and rotating with it.

In any case, it is clear that no reliable mass loss rate can be derived until a satisfactory model for the wind ionization structure is available.

4.3. The absence of absorption due to the ejected envelope

The most recent and consistent abundance determinations for classical novae in the nebular stage by Andreä et al. (1994), obtained from UV and optical observations, suggest that the abundance ratio of both C and N to hydrogen (by number) is usually above 10^{-2} in non neon novae. The weakness or absence of [NeIII] in fairly early stages of the development of V 603 Aql reported by Payne-Gaposhkin (1957) indicates that it was not a (O,Ne,Mg) nova. Andreä et al. (1994) have also found that the fraction (C^{+3}/C) in the envelope of rather recent novae is generally above 0.1, with an average value of 0.16. The ionization state in the envelope of the few novae as old as V 603 Aql is however poorly known because of the faintness in their nebular emission. In view of these uncertainties, if p is the fraction of carbon which is triply ionized we adopt (C^{+3}/H) $\approx p \times 10^{-2}$ for V 603 Aql. Using the C^{+3} column density (1.1×10^{13} cm^{-2}) derived in Sect. 3.1 and with the further assumptions that the hydrogen mass fraction in the ejected envelope was just above 0.4 (this value is suggested by the numbers of Andreä et al. (1994)) and that the envelope was spherically symmetric, we obtain an upper limit of $6p \times 10^{-4} M_\odot$ for its mass. There is evidence however that the ejected material was not spherically symmetric (Weaver 1974), and that the line of sight to the earth passed through or near a polar cap where the density is expected to be high (Mustel & Boyarchuck 1970). In this case, the lack of detection of narrow and blue shifted absorption lines in the resonance lines of N V, C IV and Si IV would lead to a lower upper limit for the mass of the nebular remnant.

We cannot rule out, however, the possibility that the lack of absorption is caused by the break up of the ejected envelope into small clumps, with none being intercepted by the line of sight. Evidences for a clumpy structure in the ejecta of some novae have been recently reported by Williams (1994), Shara (1994), and by Slavin et al. (1995).

5. Conclusions

Benefiting from the high sensitivity of the HST-GHRS it has been possible to obtain high-resolution time-resolved spectra for the resonance lines of the ex-nova V 603 Aql. Unlike in other low-inclination-high-mass-tranfer rate systems strong symmetric emission features are present both in the C IV and Si IV doublets. This challenges a theoretical interpretation since the current models of wind formed resonance lines fail to reproduce these features in objects seen at low inclination angles. Significant variations with timescales of minutes are present in the profiles of the N V, Si IV, and C IV resonance lines, both in emission and in absorption.

These observations have been used to set some constraints on the physical nature and geometrical structure of the line forming region of the old nova V 603 Aql. We interpret the observed profiles in terms of two components:

i) an optically thick chromosphere-corona associated to the accretion disk (seen nearly face-on) and corotating with it, which is responsible for most or all the flux in the symmetric and rotationally broadened emission lines of C IV and Si IV, and
ii) a separate conical-shaped wind region, where matter flows out from the innermost parts of the accretion disk in a direction nearly perpendicular to the disk itself, which gives rise to the N V and C IV absorption lines. The wind is accelerating outward and is photoionized by the energetic radiation coming from a compact region near the white dwarf.

The main shortcoming of these observations resides in the fact that the spectral variations in the various resonance lines cannot be compared with each other because each spectral region was observed separately. Since simultaneous observations of different spectral regions are not feasible with the HST-GHRS, a longer monitoring in a single spectral region would be extremely important and would allow a more detailed study of items like the origin of the conspicuous variability observed in the absorption profiles of N V and C IV, here tentatively ascribed to variations in the EUV-soft-X-ray ionizing flux.

The lack of detection of the absorption lines due to the envelope ejected in the outburst of 1918 sets an upper limit of about 1.5×10^{13} cm^{-2} for the column densities of N^{+4} and C^{+3} ions. With this value and some conservative assumptions we have obtained an upper limit of $6p \times 10^{-4} M_\odot$ for the mass of the ejected envelope, where p is the fraction of carbon which is triply ionized. Obviously, these estimates are critically affected by the intrinsic uncertainty in several assumptions and, therefore,the upper limit to the mass of the envelope does not represent a very strong constraint. Higher signal-to-noise observations of this nova are required, or, alternatively, observations of other old novae much sooner after they outburst. If such observations would still show absence of absorptions due to the ejected envelope, the conclusion would be that the envelope has been disrupted into small clouds.

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