MASS FLOW ANALYSIS OF THE ULTRAVIOLET SPECTRUM OF UW CANIS MAJORIS

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ABSTRACT

The ultraviolet spectrum of the close binary UW CMa (= HD 57060; 07f Ia + O-B), obtained with the COPERNICUS (OAO-3) and IUE satellites, is analyzed in terms of a comparison between observed P Cygni resonance line profiles and theoretical calculations in an expanding model atmosphere.

The line fit suggests an electron temperature of the circum-stellar gas of $T_e = 2.2 \times 10^5$ K, and a mass loss rate from the 07f component of $dM/dt = 2.3 \times 10^{-6}\ M_\odot \cdot yr^{-1}$.

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The far ultraviolet spectrum of UW CMa was scanned with the U2 spectrometer of the Princeton University Telescope aboard OAO-3 in the wavelength region from 1010 to 1510 Å on 1975 January 29 through 31, with a resolution corresponding to 0.2 Å (McCluskey and Kondo, 1976). The IUE observations were obtained on 1978 June 4 between 1200 and 3000 Å with the short and long wavelength cameras, at resolutions of 0.1 and 0.2 Å, respectively.

The dominant features are P Cygni lines of S IV, P V, Fe III, C III, C IV, and N V. A wealth of interstellar lines, and a few photospheric absorption lines of N III and He II originating from the more luminous O7f binary component are also present. Tables 1 and 2 give the identified stellar lines, laboratory wavelengths, and line strengths in terms of peak height for emission (E) or central depth for absorption (A) components, normalized to the local stellar continuum.

Compared with the large terminal velocities of about -1000 km s^{-1}, which by far exceeds the escape velocity of the system, the observed variations of the P Cygni line center wavelengths with time are an order of magnitude lower, with a theoretical maximum value of 220 km s^{-1}, defined by the projected orbital velocity component of the primary. No definite phase correlation of the line shifts with the 4.4 day binary period of UW CMa was found. Application of accretion theory suggests that only a negligible amount of mass lost by the O7f supergiant (~2%) is transferred to the secondary, and thus we are dealing with a continuous stellar wind from UW CMa which is nearly completely lost by the binary system.

The resonance doublets of S IV (1063, 1073 Å) and of Si IV (1394, 1403 Å), the doublet component of P V (1128 Å), and the unresolved multiplet of C III (1176 Å) are used for an investigation of the mass loss process. The observed P Cygni line profiles are compared with theoretically predicted profiles formed by isotropic and coherent scattering in a spherically symmetric expanding circumstellar envelope applying Lucy's (1971) solution of the equation of transfer in a frame comoving with the gas. For the calculation of grids of P Cygni profiles, analytical parametrized expressions for the velocity law and the variation of the ionization fractions with distance from the stellar surface are used for the computation of the optical depth of the envelope. The mass flow is treated in a fully trans-sonic way, i. e. the thermal random motions of the scattering ions are neglected compared to the mass flow velocity (Sobolev approximation). Grids of computed line profiles and description of the free parameters can be found elsewhere (Drechsel et al., 1979).

Regrettably, there is no space for an additional illustration. For comparison of the theoretically computed profile and the actual stellar spectrum observed with Copernicus, the reader is referred to the article by Drechsel et al. (1979).

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Table 1: COPERNICUS (OAO-3) UV SPECTRUM OF UW CMa

Ion	λ_{lab} (Å)	I_o/I_{con} *)	Remarks
N III	1006.015	~0.5 A	Photospheric line
S IV	1062.672	0.50 A 1.15 E	P Cygni profile
S IV	1073.045	0.58 A 1.42 E	P Cygni profile
He II	1084.942	0.66 A	Photopsheric line
P V	1117.979	0.45 A 1.24 E	P Cygni profile
Fe III	1122.5	0.80 A 1.22 E	P Cygni profile
P V	1128.006	0.78 A 1.21 E	P Cygni profile
C III	1175.66+)	0.52 A 1.23 E	P Cygni profile
N III	1183.030	0.68 A	Photospheric line
N III	1184.544	0.68 A	Photospheric line
N V	1238.821	~0.0 A	P Cygni profile
N V	1242.804	~0.0 A 1.80 E	P Cygni profile
Si IV	1393.755	~0.2 A ~1.7 E	P Cygni profile with uncertain background
Si IV	1402.770	~0.1 A ~1.8 E	P Cygni profile with uncertain background

Employing electron temperature dependent theoretical ionization fractions, the line fit procedure for the C III, S IV, Si IV, and P V features yields the following values for the mass loss rate dM/dt of UW CMa, and for the electron temperature T_e of the circumstellar gas:

$$dM/dt = 2.3\ (\pm 0.8) \times 10^{-6}\ M_\odot \cdot yr^{-1} \text{ and}$$

$$T_e = 2.2\ (\pm 0.4) \times 10^{5}\ K.$$

The electron temperature $T_e = 2.2 \times 10^5$ K of the envelope is an order of magnitude higher than the stellar effective temperature, and consistent with the observation of nearly saturated P Cygni lines of N V (1238, 1242 Å) which are produced by collisional ionization. This result is in accordance with the warm coronal model first postulated by Lucy and Solomon (1970) who also suggested a non-radiative heating mechanism driving the expanding atmospheres of hot luminous stars.

The deduced mass loss rate $dM/dt = 2.3 \times 10^{-6}\ M_\odot \cdot yr^{-1}$ can be compared with a rough estimate of McCluskey, Kondo, and Morton (1975), who found a value of about $3 \times 10^{-6}\ M_\odot \cdot yr^{-1}$ from an investigation

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Table 2: IUE UV SPECTRUM OF UW CMa

Ion	λ_{lab} (Å)	I_o/I_{con} *)	Remarks
C III	1175.66+)	0.17 A 1.16 E	P Cygni profile
N III	1183.030	0.50 A	Photospheric line
N III	1184.544	0.69 A	Photospheric line
Si III	1206.533	0.43 A	Uncertain feature
N V	1238.821	~0.0 A	P Cygni profile, blended with emission feature
N V	1242.804	2.20 E	P Cygni profile, blended with absorption feature
Si IV	1393.755	~0.0 A 1.33 E	P Cygni profile
Si IV	1402.770	0.06 A 1.69 E	P Cygni profile
C IV	1548.188	~0.0 A	P Cygni profile, weak emission
C IV	1550.762	1.25 E	Uncertain feature
N IV	1718.551	0.48 A	Probably no emission component
N III	1747.848	0.80 A	Photospheric line
N III	1751.437	0.80 A	Photospheric line
N III	1885.136	0.80 A	Photospheric line
Mg II	2795.528	A	Mainly interstellar absorption;
Mg II	2802.693	A	slightly asymmetric line profile

*) A = absorption; E = emission;

+) mean wavelength of unresolved multiplet.

of UV absorption line strengths. Clearly the evolution of Of-type stars will be influenced by mass loss rates of the order of 5×10^{-6} $M_\odot \cdot yr^{-1}$; about 1/4 up to 1/3 of the initial ZAMS mass is lost during the main sequence hydrogen burning phase.

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