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THE EMISSION LINES IN THE ULTRAVIOLET REGION 3140–3500Å OF CH CYGNI[1], AND RELATED PROBLEMS

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The M6 semi-regular variable CH Cygni had an outburst in June 1967. The emission lines of the ultraviolet region $\lambda < 3500$ Å are described. General considerations on the importance of this region are outlined.

The region $\lambda < 3500$ Å may reveal important information on the physical phenomena occurring in the shells of bright line stars, including symbiotic or nova-like objects of low or average excitation. It has been studied by Chalonge and his co-workers, for spectrophotometric purposes and, recently, also for the detection of faint bright lines. Struve and his collaborators at the McDonald Observatory have occasionally covered the region in the case of peculiar bright-line objects. This region is however usually neglected for simple practical reasons: with ordinary spectrographs (i.e. not of the Chalonge type) lines around $\lambda = 3200$ require strong exposures, which often produce over-exposures in the ordinary blue–violet region. On the other hand a higher resolution than is attainable with Chalonge's instrument is often desired. The advantages of the region $\lambda < 3500$ may be summarized as follows:

(1) No blending difficulty is encountered with late-type features, such as are very often found in peculiar stars. A striking example is the discovery by Herzberg (1948) of Fe II-emission lines in the supergiant stars α Herculis and α Scorpii (multiplets 1, 6 and 7). In many cases the continuum is very weak and the absorption features are rare.

(2) In the photographic region all the strong Fe II-emission lines arise from excited levels between 5.3 and 5.6 volts, their lower levels lying between 2.6 and 2.9 volts. The photographic region is, therefore, not suitable for the discussion of the behaviour of bright lines arising from widely separated levels. On the contrary the region $\lambda < 3500$ contains Fe II-lines which may have similar laboratory intensities, yet arise from excited levels ranging from 4.8 volts (z^6 D°) to 8.6 volts (y^2 F°). The effect of the excitation potential appears clearly in the ultraviolet. A line of laboratory intensity 10 gives a stellar emission at least five times stronger if its excitation potential is around 5 volts than when it is around 8 or 9 volts (Swings and Struve 1941).

(3) The forbidden lines of Fe II require a fairly high excitation, not much lower (hardly one volt) than certain permitted lines. The relative intensities of Fe II and [Fe II] differ greatly in different stars, and even vary in the course of the evolution of a specific star.

(4) The ultraviolet region often reveals strong [Ni II] lines, while the ultraviolet [Fe II] lines are very weak or absent. Yet the excitation potentials of the [Ni II] lines are practically the same as those of the ultraviolet [Fe II] lines. The lower abundance of nickel relative to iron may, in adequate circumstances, be more than compensated by the higher transition probabilities of [Ni II] and possibly by more favourable collisional cross sections.

(5) The general aspect of the region varies greatly in different stars or in the course of the evolution of a star, even when the excitation is about the same. Such variations have been described recently in the B2IVe star HD45677 (Burnichon *et al.* 1967). In particular the behaviour of the Mn II-lines (multiplets 1 and 3) varies considerably: while Mn II appears in emission in HD45677, VV Cephei, CH Cygni, etc...., it is present in absorption in Boss 1985 from 1947 to 1950 (Bosman-Crespin and Swensson 1956). Mn II and Cr II are much stronger in emission in VV Cep than in B 1985.

(6) Struve (1944) called attention to a strong absorption feature in VV Cep near $\lambda = 3384$, probably due to Ti II, but not exclusively of interstellar origin.

[1] CH Cygni = HD 182917 = BD 49° 2999; α (1950) = 19 h 23 min 14 sec, δ (1950) = 50° 08′ 31″.

TABLE I

Spectrum of CH Cygni and related stars in the region λ=3130–3490 Å

λ meas.	Int.	n	Identification				VV Cep[a]	VV Cep[b]	B 1985[c]	B 1985[d]	BF Cyg[a]	η Car[e]
3139.3	0.5	1										
3162.3	2	3	Fe II	7	63.09	(5)	8				1	2.5
3168.3	2	3	Fe II	66	67.85	(11)						2.5
3180.0	1	1	Fe II	157	79.50	(8)					1–0	
			Fe II	157	80.16	(7)						
			Cr II	9	80.73	(75)						
3183.0	3	3	Fe II	7	83.11	(8)	3		1		2	3
			Cr II	82	83.33	(40)						
3186.3	2	3	Fe II	6	86.74	(11)	5				1–0	4N
3192.8	4	4	Fe II	6	92.92	(9)	8		1	1	3	3
			Fe II	6	93.81	(11)						
3196.2	4	4	Fe II	7	96.07	(10)	10		4	1	4	4
			Cr II	9	97.12	(75)						
3210.4	3	4	Fe II	6	10.45	(10)	5		2	2	3	7N
			Cr II	9	09.21	(50)						
3213.2	4	4	Fe II	6	13.31	(13)	10		5	2	4	8N
3216.7	2.5	1	Cr II	82	16.55	(20)	2		3	0	0	1.5
			Cr II	9	17.44	(50)						
3227.9	5	4	Fe II	6	27.73	(13)	10		10	3	4	9N
3233.0	1	1	?Fe II	119	32.79	(7)	2		1		1	2N
3248.3	1	2	?Ti II	66	48.60	(50)					0	
3255.7	5	4	Fe II	1	55.88	(8)	9		3	2	4	8
3259.0	2	2	Fe II	81	58.77	(10)	2			2	1	4N
			Fe II	81	59.05	(10)						
3271.8	2	1	?Ti II	66	71.65	(25)	0			0		1
			?Ti II	66	72.08	(25)						
3277.3	5	4	Fe II	1	77.35	(9)	15	3	6	3	10	12
3281.3	4.5	4	Fe II	1	81.29	(7)	10	1	1	2	3	10
3295.8	3	4	Fe II	1	95.81	(6)	7			0–1	1	9
3303.6	2.5	4	Fe II	1	02.86	(4)	3	0		1	1	8N
			Fe II	1	03.47	(4)						
3322.7	2	2	Fe III	5F	22.54		3			A		
			?Ti II	7	22.94	(75)						
			Fe II	92	23.07	(8)						
3340.0	2	1	Cr II	4	39.80	(50)	1	0		A		
3359.6	1	1	Cr II	21	60.29	(100)	3			2		3
3368.1	1	1	Ti II	1	61.21	(125)		3		A		3n
			Cr II	21	61.77	(30)						
3361.8	1	1	Cr II	4	68.05	(150)		3		A		1.5
3379.8	1	1	Cr II	21	79.37	(30)		1		0		
			Cr II	21	79.82	(60)						
			Ti II	1	80.28	(30)						
3382.8	1	1	Cr II	3	82.68	(60)		3		A		
			Ti II	1	83.76	(125)						
3387.7	1	1	Ti II	1	87.83	(50)		1		1		
3393.6	1	2	Cr II	21	93.00	(35)		1		0		1n
			Cr II	21	93.86	(30)						
			Cr II	21	94.32	(35)						
			Ti II	1	94.57	(40)						
3421.4	1	2	Cr II	3	21.20	(75)						
			Cr II	3	22.74	(125)		2		0		2.5
3438.9	1	1	Ni II	5F	38.92			5	6	10		6
			Mn II	1	38.98	(20)						
3441.5	2	2	Mn II	3	41.28	(100)		4		A		5
3460.3	1.5	2	Mn II	3	60.31	(75)		3		A	0	5
3474.3	0.5	1	Mn II	3	74.04	(50)		2		A	0	3
			Mn II	3	74.12	(40)						
3482.4	0.5	1	Mn II	3	82.90	(40)		4		A	2	3

Notations:
Column 1: measured wavelength
Column 2: estimated intensity
Column 3: number of spectrograms on which the line was measured
Column 4: element; number of multiplet in R.M.T.; laboratory wavelength; laboratory estimated intensity
Column 5, 6, 7, 8, 9 and 10: estimated intensities in related stars

References:
[a] Swings and Struve, 1945.
[b] Struve, 1944.
[c] Swings, 1950.
[d] Bosman-Crespin and Swensson, 1956.
[e] Thackeray, 1967.

CH Cygni[1] which is normally an M6 semi-regular variable suffered outbursts in 1963 and 1967, in the course of which a hot blue continuum was superposed over the late-type features (Deutsch 1964, 1967). The nova-like behaviour of CH Cyg in the usual spectral region will presumably be described by various observers. We used the opportunity to examine the region $\lambda < 3500$ which is rich in fairly sharp emission lines. The four spectrograms analyzed in this investigation were obtained by Mrs Y. Andrillat at the 120 cm reflector of the Haute Provence Observatory, using the Montpellier fast spectrograph with a dispersion of 67.8 Å/mm. The measures cover the region $3140 < \lambda < 3500$. Only one absorption feature is observed; it is located close to that found by Struve in VV Cep. The ultraviolet metallic emission of CH Cyg is not unlike that of B 1985, BF Cyg and other peculiar bright line stars; there are also individual differences. We do not observe the He I-line at $\lambda = 3187.74$.

Our measures and the identification and comparison data are compiled in Table I. Future discussions, for example of the Fe II-lines, may be facilitated by tabulating separately the multiplets 1, 6 and 7 as they appear in emission in various objects (Swings and Struve 1943) and in absorption in α Cygni (Rush 1942). The strong Fe II-multiplets 1, 6 and 7 arise from excitation potentials from 4.75 to 5.59 volts; although this energy range is rather narrow it leads to different relative intensities in specific stars. More conspicuous is the behaviour of the Fe II-lines which are as strong on laboratory spectra—such as $\lambda\lambda = 3289.35$, 3297.89, 3259.05, 3167.85 and 3177.53—but are absent or much weaker than the lines of multiplets 1, 6 and 7: this is simply due to their higher excitation potentials (from 7.5 to 7.8 volts, instead of 4.75 to 5.59). [Ni II] and [Fe II] are very weak or absent. Multiplets 1 and 3 of Mn II are present in emission, while they appear in absorption in B 1985 in 1947–1950. There is no clear evidence in favour of [Fe III]-lines (multiplets 5 and 6) which appear very weakly in long exposures on BF Cygni.

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