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АСТРОФИЗИКА

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SPECTROPHOTOMETRIC STUDIES OF NON STABLE STARS II. ON THE SPECTRUM OF RW AURIGAE IN THE REGION 3080—6100 A

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The results of a spectrophotometric study of RW Aur based onfive short dispersion spectra, covering the region 3080—6100 A are presented.

The strongest absorption and emission multiplets have been identified; the Balmer lines are present sometimes in emission, sometimes in absorption, Ca II (H and K in emission), Fe II (generally in emission), Ti II, Cr II (absorption); the results agree with those recently published by Gahm but they also cover the short wavelength region 3080—3250 A.

A rough determination of the continuum has been made; the spectrum taken at the time of the highest luminosity presents the strongest absorption features: the Balmer lines are visible in absorption except the first ones and a faint positive Balmer jump is present; the four other spectra correspond nearly to the same fainter luminosity (about one magnitude lower than the preceding at 4250 A): one of them is similar to the bright one but with less absorption, and the three others contain more intense emission lines, together with Balmer lines and Balmer continuum in emission.

The lower luminosity emission spectra present a strong ultraviolet excess compared to the higher luminosity absorption spectrum and this excess seems to be due, for the largest part, to the Balmer continuum.

Introduction. The RW Aur class objects, representing probably one of the earliest stages of stellar evolution are of significant interest to cosmogony [1—3]. Their observation may bring information on some apparently unusual phenomena which occur in the outer layers of their atmospheres.

An analysis of the observational data concerning the variations of the brightness and of the spectrum of the RW Aur class objects carried out by V. A. Ambartsumian [4] brought him to the conclusion that, in some cases, these variations seem difficult to explain only by thermal radiation mechanisms and that they are possibly connected with unknown sources of stellar energy.

It has been shown that the comparatively largest variations are observed in the short wave-length region of the spectrum of these stars. For that reason the observation of this region presents a special interest to collect information on the physical processes occuring in the extended chromospheres or shells. The advantages of the nearest ultraviolet region for astrophysical purposes have been recently summarized by J. P. Swings and P. Swings [5]. Unfortunately the spectra of the RW Aur class objects have not been sufficiently studied, particularly in this region.

Since 1966 we are observing some non stable stars in a large spectral region including the accessible ultraviolet: 3100—6100 A. Our principal aim is to obtain quantitative informations of the variations of their continuum. The present paper gives the first observational results concerning RW Aur.

The observations. The observations of RW Aur have been done with the reflectors of the Haute-Provence Observatory (France). During 1966—1969, several spectrograms of this star have been obtained, mainly with the Chalonge spectrograph [6] attached at the Cassegrain focus of the 80 or 193 *cm* reflector. Three of these spectrograms and their microphotometric tracings are reproduced in Fig. 1 and 2 (a, b, c).

The first observations showed that in the ultraviolet spectrum of RW Aur, below the Balmer limit, there are some characteristic emission and absorption features not yet described. Their identification appears possible, even with the small dispersion used. But, to verify these preliminary identifications of spectral multiplets, two spectrograms with a higher dispersion were used: one obtained with the Coudé spectrograph (Camera II) of the 193 *cm* reflector and the other with the Andrillat spectrograph*.

The data concerning all the spectral observations used in this paper are presented in Table 1. The last column gives the name of the comparison star used for the spectrophotometric work.

The line spectrum. The determination of the continuum will be easier after a preliminary identification of the emission and absorption lines. But it has been shown by A. Joy and G. van Biesbroeck [7] that RW Aur is a double star and it is necessary to examine if the spec-

* Grating spectrograph, attached at the Newton focus of the 120 *cm* reflector of the Haute-Provence Observatory.

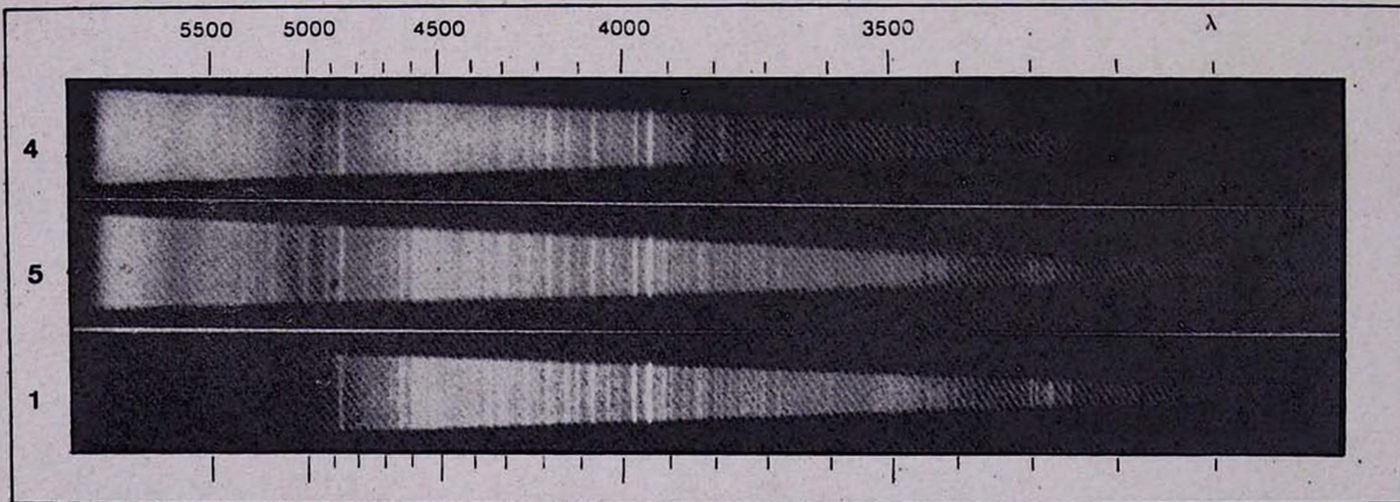

Fig. 1. Typical examples of the spectra of RW Aur. Their characteristics are given in Table 1. The shape of the spectra (5 times less broadened in the ultraviolet than in the red) shows the great advantage of the broadening by oscillation [6].

trum of RW Aur is not contaminated by the lines of its companion. The two components are separated only by 1.2 but the position angle of the companion is equal to 254° [8] and it must be kept in mind that the observations are generally done in the neighborhood of the meridian, and that the slit of the Chalonge spectrograph is always maintained in the vertical plane, the slit width being of the order of 0.7 (193 *cm* reflector) or 1.5 (80 *cm* reflector) it follows that during the observations the companion is mainly out of the slit of the spectrograph. In fact the presence of the molecular bands of the companion (which according to the General Catalogue of Variable Stars [8] is of the spectral class d M0e) has not been detected.

Table 1

THE SPECTRAL OBSERVATIONS OF RW AUR

No.	Plate No.	Date	Exposure	Emulsion Kodak	Telescope (*cm*)	Spectro-graph	Spectral region (A)	Comp. star (HD)
1	6888	23.12.67	5h	103aO	80	Ch.	3100—4900	93521
2	6896	21. 1.68	2h 30mn	IaO	80	Ch.	3100—4900	93521
3	6911	21.11.68	3h	103aD	193	Ch.	3100—6100	73
4	6964—32	27.10.69	1h 45mn	103aD	193	Ch.	3100—6100	73
5	6964— 2	28.10.69	2h 30mn	103aD	193	Ch.	3100—6100	73
6	R 144	27.10.67	3h 45mn	IIaO	193	Coudé II	3700—4900	—
7	MTU 125	23. 1.68	3h	IIaO	120	Andrillat	3300—4700	—

Dispersion: Chalonge spectrograph (Ch.), quarts prisms: 470 A/*mm* at 6000 A; 220 A/*mm* at 4340A; 132 A/*mm* at 4700 A; 83 A/*mm* at 3200 A.
Coudé spectrograph (Camera II):39 A/*mm*.
Andrillat spectrograph: 78 A/*mm*.

A. Joy [9] has identified many lines in the visible spectrum of RW Aur and, among them, more than 100 emission lines. The strongest of these lines are well visible on our spectrograms; however owing to the large differences between the various spectra they can be divided into two groups:

Group A (spectra 3, 4, 6 of Table 1): the absorption lines are numerous and strong especially in the ultraviolet; the number and the intensity of the emission lines are lower than in the second group;

Group B (spectra 1, 2, 5, 7): numerous strong emission lines are present, the absorption lines being rare and relatively faint.

The spectra of Fig. 1 and the tracings of Fig. 2 (a, b, c), represent typical examples of both groups.

The differences in the line spectrum between these two groups are closely connected with the differences in the continuum which will be discussed in the next paragraph.

All the wave-lengths on our spectrograms have been measured with H_γ, 4340 A, as origin. The errors in the measurements are estimated to 1—2A near the ultraviolet limit and increase up to 7—8A near 5500 A. Thus, the low dispersion of the spectrograph does not permit the identification of isolated lines, but the identification of the strong multiplets is possible: they have been controlled for the visible and the near ultraviolet on the spectrograms of higher dispersion.

Our identifications are given in Table 2 (in the Appendix).

For every multiplet considered, the first column of Table 2 gives the laboratory wave-lengths of the components and the second the multiplet number; the following columns headed 1, 2, 3, 3, 5, 6 (below every one of the Figures 1, 2, 3, 4, 5, 6 is written the letter A or B representing the group to which belongs the spectrum) give respectively the wave-length measured on the various spectra of Table 1; the first two ciphers of the measured wave-length are omitted and the data relative to absorption lines are given in italics.

Most of the measured wave-lengths are printed on the microphotometer tracings of Fig. 2 (a, b, c) and the multiplets are also represented, those in emission above the tracing those in absorption below. The position of the Balmer lines are not given.

The shaded parts of Table 2 correspond to the regions where the spectrum does not exist (lack of transparency of the instrument, or lack of sensitivity of the plate).

The data presented in Table 2 are generally in good agreement with the results recently published by G. H. Gahm [10] for $\lambda > 3250$ A and new multiplets of Fe II, Ti II and Cr II have been found below 3250 A.

These results show that, in spite of their low resolution, the spectra taken with the Chalonge spectrograph are reliable and can be used for the qualitative study of spectral lines, especially in the short wave-length region where the dispersion is higher. Of course, this is true only for comparatively strong lines. The blends are so numerous that even in the spectrograms used by Gahm, for which the dispersion is much higher (16 A/*mm*) some emission features of RW Aur (near 4085, 4155, 4183 and may be 4410 A) could not be identified [10].

Many lines, strong on our spectrograms, remain unidentified; but, if one changes the position of the continuum drawn on the tracings (see following paragraph) several of the supposed emission lines can

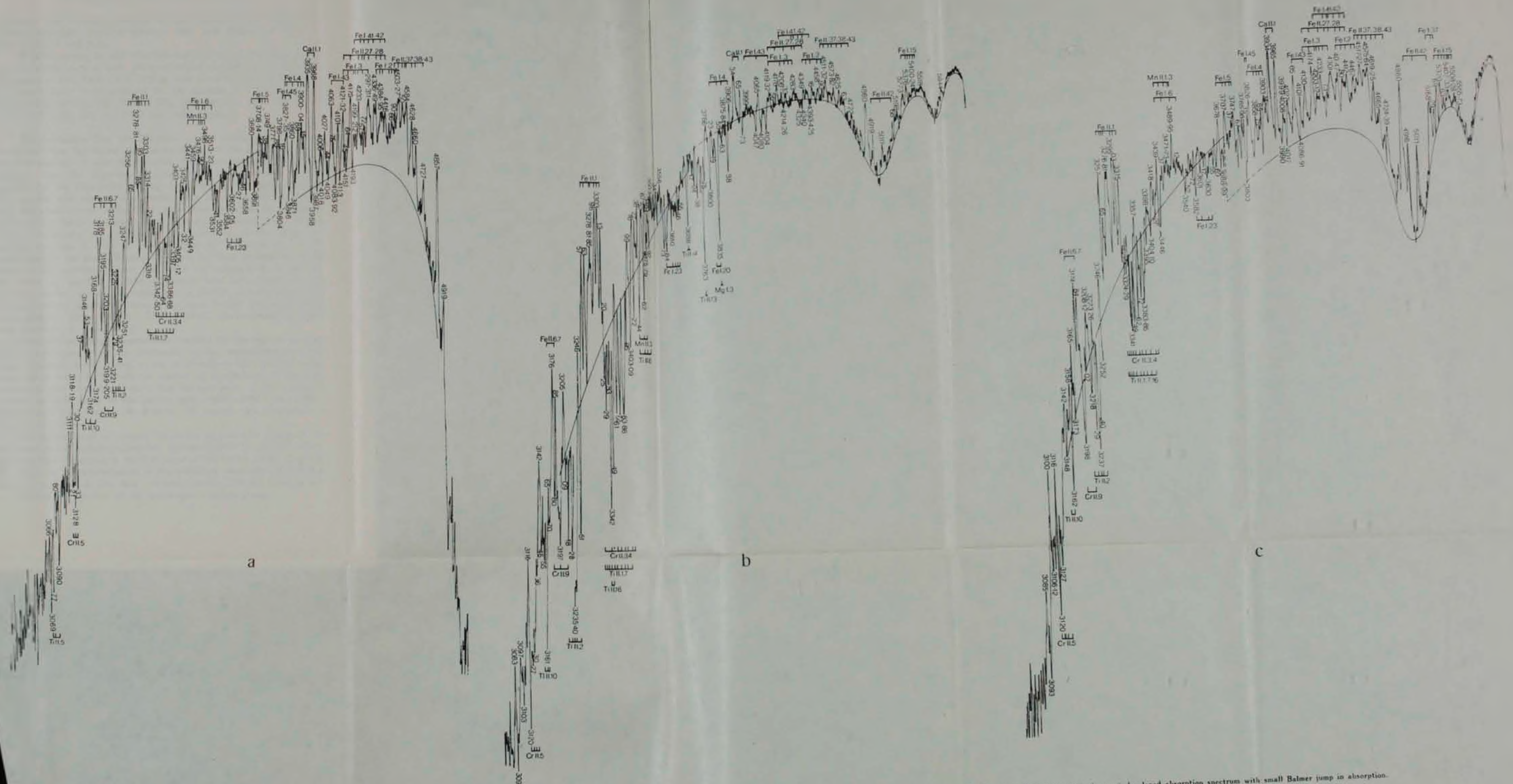

Fig. 2. Registrograms of spectra of RW Aur: a—Spectrum No. 1 (group B), the largest line and Balmer continuum in emission observed in the present work together with the less developed absorption spectrum. b—Spectrum No. 4 (group A), the most developed absorption spectrum with small Balmer jump in absorption. This spectrum corresponds to the brightest phase observed in the present work. c—Spectrum No. 5 (group B), similar to spectrum No. 1, but emission less developed. Spectrum obtained one day later than spectrum No. 4.

disappear and become „windows“ of the continuum (this could be the case for the lines situated between 3400 and 3550 A on the spectrum 4, Fig. 1 and 2b).

It is interesting to add that the line spectra of RW Aur and of the non stable stars of quite different classes present many similarities. Many lines of Fe I, Fe II, Cr II, Ti II as well as of H I and Ca II included in Table 2 have been observed in the spectra of VV Cep [11, 12], CH Cyg [5], BF Cyg [12], R And [13], BD—14° 1971 (Boss 1985) [14], α Her [15], η Car [16] and other non stable stars.

The continuum. The identification of the strongest emission and absorption lines facilitates the determination of the continuum on the different tracings: it must lie between these strong emission and absorption lines. An approximate location of the continuum is thus possible in the ultraviolet (strong emissions and absorptions) of the five spectra and also in the visible part of the group A spectra (Fig. 2b) where some unidentified absorption lines can be recognized between the many emission ones (these absorption lines appear very conspicuously on the tracing corresponding to the large dispersion spectrum 6, Fig. 3. very similar to spectrum 4). In the visible part of the group B spectra, where no large absorption can be detected, the continuum must lie below the tracing (Fig. 2a and 2c). The shape and position of the continuum have been chosen so that it keeps, on the various registrograms a similar position relative to the emission and absorption lines; it has been divided into three parts, 6100—4900 A, 4800—3900 A, 3700—3150 A, characterized by three mean gradients, Φ_r, Φ_b, Φ_{uv}.

Nevertheless, a large uncertainties remains for the precise location of the curve representing the continuum on the microphotometric tracings, especially in the cases where no absorption lines can be recognized and in order to limitate the number of possibilities, it has been assumed in this preliminary work that the two parts of the continuum situated on both sides of the Balmer jump (4800—3900 A and 3700—3150 A) have a blackbody distribution. Of course this assumption is open to criticism.

The method used to compare the curves supposed to represent the continuum to our spectrophotometric standards (HD 73 and HD 93521, [17]) has been described in the first paper of this series, on SS Cyg [18]. The results of the determination of the continuum parameters of RW Aur are given in Table 3. The data contained in the different columns are:

Column 1 — the No. of the spectrogram and its group;

Column 2—the monochromatic magnitude m_B of the continuum at 4250 A deduced from the energy distribution in the continuum[1] and from the values of m_B for the comparison star;

Columns 3 to 8—the spectrophotometric gradients Φ_r, Φ_b, Φ_{uv} and the corresponding colour temperatures T_r, T_b, T_{uv};

Column 9—the Balmer jump.

Table 3

PARAMETERS OF THE CONTINUUM OF RW AUR

No.	m_B	6100—4900		4900—3900		3700—3150		D
		Φ_r	T_r	Φ_b	T_b	Φ_{uv}	T_{uv}	
1B	11.6*	—	—	2.22	6500	2.45	5900	—0.22
2B	11.4	—	—	2.16	6700	2.42	5950	—0.17
3A	11.4	2.82	5150	2.25	6400	2.64	5450	+0.02
4A	10.6*	2.53	5750	2.21	6550	2.75	5250	+0.03
5B	11.6	2.92	4950	2.12	6850	2.58	5600	—0.16

* Weather conditions not very good, magnitudes somewhat uncertain (±0.3 mag.)

With the values of the parameters contained in Table 3 it is easy to determine the shape of the energy curve of the continuum for the five observed spectra.

The curves relative to the three spectra 1, 4, 5 are reproduced on Fig. 4. They represent log I + const. as a function of λ, the relative positions of the three curves being deduced from the values of m_B (Table 3).

The energy curve of the spectrum 2 is very similar to the curve (5) and the energy curve of the spectrum 3 similar to the curve (4) but with about one half intensity: these last two curves (2) and (3) are not represented on Fig. 4.

According to the shape of the curves of Fig. 4 the spectra of RW Aur may be divided into two groups:

1) the Balmer jump is small and positive (spectra 3, 4);

2) the Balmer jump is large and negative (Balmer continuum in emission, spectra 1, 2, 5).

[1] To compare the relative evolution of the continuum and of the spectral lines it is better to use as a parameter for the continuum the monochromatic magnitude m_B of the continuum instead of the monochromatic magnitude B of the star as a whole since B is sensitive to the variations of both the continuum and the lines. For example, according to W. Götz [19] the share of the influence of emission lines on the brightness of RW Aur can reach 0.2 mag., the importance of the emission lines on the total brightness of the star increasing with the decrease of its luminosity.

Column 2—the monochromatic magnitude m_B of the continuum at 4250 A deduced from the energy distribution in the continuum[1] and from the values of m_B for the comparison star;

Columns 3 to 8—the spectrophotometric gradients Φ_r, Φ_b, Φ_{uv} and the corresponding colour temperatures T_r, T_b, T_{uv};

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2B	11.4	—	—	2.16	6700	2.42	5950	—0.17
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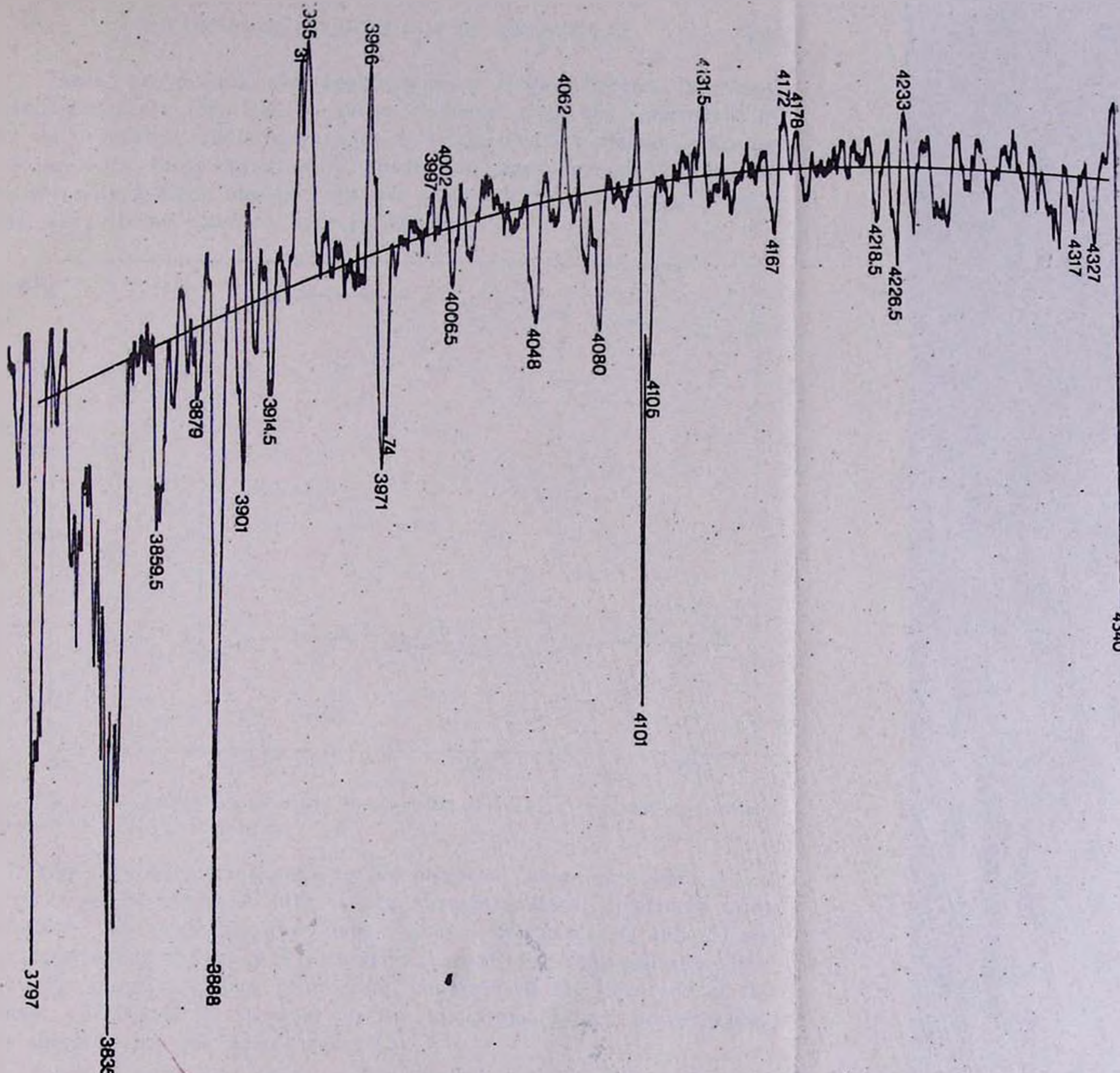

Fig. 3. A part of the registrogram of the large dispersion spectrum No. 6. This spectrum is very similar to spectrum No. 4 (Fig. 2b): the absorption-lines are the same but the very narrow part of the hydrogen lines visible on spectrum No. 6 cannot appear on the small dispersion spectrum No. 4.

These two groups, corresponding to a large difference in energy distribution, are identical to those deduced from the comparison of the line spectra: the spectra with a small positive Balmer jump are the same as those with many absorption lines (group A) and the spectra with a large negative Balmer jump identical to those presenting many strong emission lines (group B).

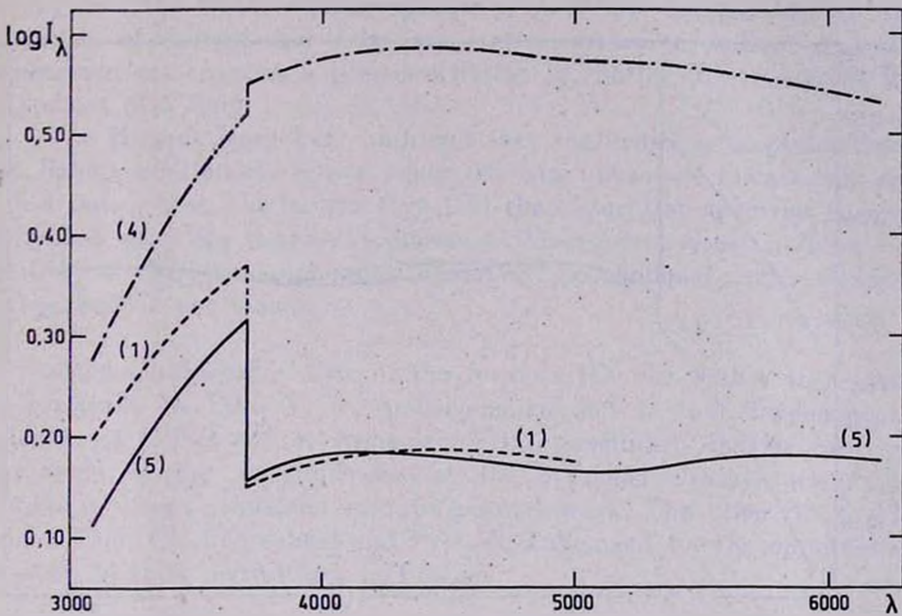

Fig. 4. The energy curves of the three spectra of Fig. 1: their relative positions correspond to the true intensities.

The curve (4) corresponds to the brightest stage observed; it is a spectrum of the group A with strong absorption lines, relatively faint emissions, and small positive Balmer jump. The curves (1) and (5) are two examples of the group B with faint absorption, strong emission lines and large negative Balmer jump; the emission of the lines and of the Balmer continuum is stronger for the spectrum (1) but, nevertheless, this spectram has the same m_B as (5).

Discussion and Conclusion. To permit the comparison between the shapes of the energy curves independently of the magnitudes, Fig. 5 shows the three curves of Fig. 4 translated vertically, as if, in the three cases, the star had always the same magnitude m_B, i. e. the same intensity of the continuum for 4250 A. The spectrum (2) and the spectrum (3), not represented, would lie respectively near (5) and near (4).

Thus appears the enormous difference between the proportion of ultraviolet radiation in the spectra of the two groups: there is a strong ultraviolet excess in the group B spectra compared to the group A.

As this ultraviolet excess appears in group B spectra for which the Balmer lines are in emission, it can be explained, at least partly, by the development of a Balmer continuum.

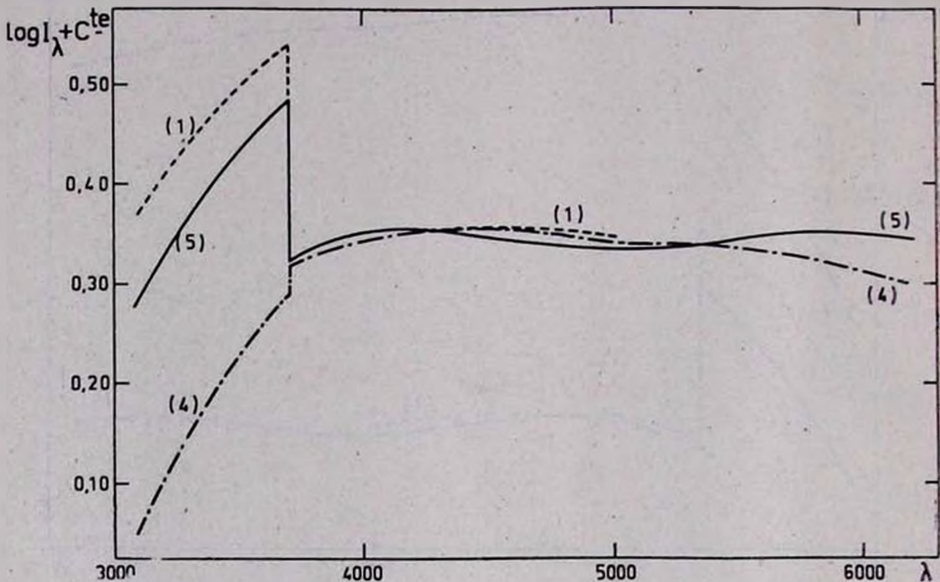

Fig. 5. The energy curves of the three spectra of Fig. 1,su pposed to have the same photographic magnitude m_B.

Fig. 5 seems to show that this ultraviolet excess appears just at the Balmer limit but this may be due to the arbitrary drawing of the continuum on the microphotometric tracings. The comparison of the tracings reproduced Fig. 2b (spectrum 4) and Fig. 2a and 2c (spectra 1 and 5) shows that if the position of the visible continuum is rather well determined for the spectrum 4 (group A) it is much more arbitraty for 1 and 5 (group B): if the assumption that the continuum must be similar to a black body is abandoned the curve by which it is supposed to be represented on Fig. 2 (a, b, c) may be quite different and the sharp limit (limit of the Balmer series) separating the two regions of each spectrum on Fig. 5 would then disappear; it would simply remain that the short wave-length part of the spectrum is relatively more intense in the spectra of the group B than in the group A, result probably due for the greatest part to the variations of intensity of the Balmer continuum; but other causes may also play a role.

The variations of RW Aur observed between October 27-th (spectrum 4) and October 28-th (spectrum 5) may be explained by the effective contraction of an envelope (situated inside the observed low-pressure shell) which had been ejected during a preceding, non observed flare. Thus these two observations would concern the evolution of the star on the decreasing branch of the light curve of a flare. But it is not possible to say how the three isolated spectra 1, 2, 3 are located during the evolution of a flare. So, it is now very necessary to collect a *series of observations* covering a pre-flare period or, better, the complete development of a flare.

The present work has confirmed that the emission spectrum (lines and Balmer continuum) grows when the star becomes fainter [20] and it has shown that, like for SS Cyg [18] the absorption spectrum is more developed when the luminosity increases. Moreover, a great part (or the totality) of the ultraviolet excess observed near minimum can be ascribed to the Balmer continuum.

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СПЕКТРОФОТОМЕТРИЧЕСКОЕ ИЗУЧЕНИЕ НЕСТАЦИОНАРНЫХ ЗВЕЗД
II. О СПЕКТРЕ RW ВОЗНИЧЕГО В ОБЛАСТИ 3080—6100 А

Д. ШАЛОНЖ, Л. ДИВАН, Л. В. МИРЗОЯН

Приводятся результаты спектрофотометрического исследования RW Возничего, основанного на пяти спектрах низкой дисперсии, покрывающих спектральную область 3080—6100 А.

Отождествлены наиболее интенсивные абсорбционные и эмиссионные мультиплеты. В спектре наблюдаются линии бальмеровской серии (либо в эмиссии, либо в поглощении), H и K CaII (в эмиссии), Fe II (большей частью в эмиссии), Ti II, Cr II (в поглощении). Эти резуль-

таты находятся в согласии с данными, недавно опубликованными Гаамом, однако они охватывают дополнительно коротковолновую область 3080—3250 A.

Грубо определено распределение энергии в континууме. Спектр, полученный при наибольшей яркости, содержит наиболее сильные абсорбционные особенности: бальмеровские линии, кроме первых, находятся в поглощении, а бальмеровский скачок положительный и небольшой. Остальные четыре спектра соответствуют периодам примерно одинаковой яркости (около одной звездной величины слабее у 4250 A, чем предыдущий). Один из них похож на описанный выше спектр, однако поглощение слабее. Три остальных спектра содержат более интенсивные эмиссионные линии, включая бальмеровские, а бальмеровский континуум — эмиссионный.

В эмиссионных спектрах, соответствующих меньшей яркости звезды, наблюдается сильный ультрафиолетовый избыток по сравнению с абсорбционным спектром, при этом, вероятно, этот избыток большей частью обусловлен бальмеровским континуумом.

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Appendix

Table 2

EMISSION AND ABSORPTION LINES OBSERVED IN THE SPECTRUM OF RW AUR

λ_{lab}	Multiplet	1 B	2 B	3 A	4 A	5 B	6 A
			H				
4861.33	H_β	57	61	62	60	60	63.5
4340.47	H_γ	40	36	40	40	40	37
4101.74	H_δ	01	00	03	04	01	99.5
3970.07	H_ϵ	68	68	—	—	65	71
3889.05	H_8	88	88	89	88	85	87.5
3835.39	H_9	35	30	38	35	—	35
3797.90	H_{10}	98	00	00	00	98	97
3770.63	H_{11}	71	70	74	75	—	70
3750.15	H_{12}	49	50	50	54	47	49
3734.37	H_{13}	38		35	34	37	33.5
3721.94	H_{14}	23		23	29	20	21
3711.97	H_{15}	08		14	17	—	15
			Mg I				
3838.29							39.5
3832.30							31.5
3829.35	3			38	35		28.5
3838.29							37.0
3832.30							31.5
			Ca II				
3933.66	1	35	34	34	34	34	31—35
3968.47		68	68	66	65	65	74
			Ti II				
3349.40		50	51	48	49	49	
3361.21		64	63	61	61	62	
3372.80		74	74	71	72	72	
3383.76	1				83	83	
3380.28		86	87	84			
3387.83					86	86	
3394.57		97	91	94	95	95	
3234.52		35	37	35	35	37	
3236.57							
3239.04		41	40	—	40	40	
3242.00							
3254.25	2						
3252.91		51	53	51	51	52	
3251.91							
3217.06		21	20	17	18	18	
3222.84			23	23			
3229.19		29	30	27	28	29	

Table 2 (cont.)

λ_{lab}	Multiplet	1 B	2 B	3 A	4 A	5 B	6 A
			Ti II (cont).				
3088.63	5	*90*	*88*				
3078.65		77	*75*				
3075.23							
3072.97			*72*				
3072.11							
3066.22		69	*68*				
3066.35							
3444.31	6			*43*	*44*		
3461.50				*62*	*62*		
3477.18				*77*	*79*		
3491.65				*93*	*92*		
3489.70							
3322.94	7	*18*	*23*	*23*	*25*	*24*	
3329.46		—	*30*	*29*	*29*	*29*	
3335.19		—	*37*		*33*	*35*	
3440.34		*42*	*44*	*41*	*42*	*41*	
3343.77							
3346.72				*48*	*49*	*49*	
3348.84		*50*	*51*				
3308.81			—		—		
3318.02		*18*	—		—		
3326.76		—	*23*	*23*	*25*	*24*	
3168.52	10	*72*	—	*70*	*70*	*70*	
3162.57							
3161.76		*62*	*64*	*62*	*61*	*61*	
3161.21							
3155.67							
3152.25		*51*	—	*54*	*55*	*55*	
3154.20							
3759.29	13			*63*	*63*		*58.0*
3761.32							*60.0*
3685.19	14			*87*	*88*		*84.5*
3349.04	16	*50*		*48*	*49*	*49*	
3341.88		*42*		*41*	*42*	*41*	
4395.03	19						*96.0*
4443.80							*42.5*

Table 2 (cont.)

λ_{lab}	Multiplet	1 B	2 B	3 A	4 A	5 B	6 A
			Cr II				
3643.22	1						*41.5*
3644.70							*44.0*
3647.40							*47.0*
3651.68							*51.0*
3408.77	3	*05*	*08*	*10*	*09*	*10*	
3422.74		—	—	*22*	*22*	*22*	
3433.30		*32*	*33*	*33*	*33*	*31*	
3382.68		*86*	*87*	*84*	*83*	*83*	
3403.32		*05*	—	*04*	*03*	*04*	
3421.20		—	—	*22*	*22*	*22*	
3363.71		*64*	*63*	*61*	*61*	*62*	
3391.43		88	91	94	95	—	
3353.12	4	}*50*	}*51*	—	—	—	
3349.34				—	—	*49*	
3324.06		—	}*23*	*23*	*25*	*24*	
3328.35		—		*29*	*29*	*29*	
3374.95		*74*	*74*	*71*	72	72	
3342.51		}*42*	}*44*	}*41*	}*42*	}*41*	
3339.80							
3336.33		—	—	—	—	*35*	
3368.05		—	—	*71*	*67*	*69*	
3358.50		—	—	*61*	*61*	—	
3347.84		—	—	*48*	*49*	*49*	
3132.06	5	*33*	*33*	*32*	*33*	*34*	
3124.98							
3120.87		}*21*	}*20*	}*19*	}*20*	}*20*	
3118.65							
3147.23		—	—	*48*	*48*	*48*	
3136.68		—	—	*36*	*36*	*34*	
3128.70		*28*	*28*	*27*	*27*	*30*	
3180.73	9	—	—	*80*	*80*	—	
3197.12		—	—	*97*	*97*	*98*	
3209.21		—	—	*09*	*09*	—	
3217.44		*21*	20	*17*	*18*	*19*	
3181.43		—	—	*80*	*80*	—	
3196.96		—	—	*97*	*97*	*98*	
3208.62		—	—	*09*	*09*	—	

Table 2 (cont.)

λ_{lab}	Multiplet	1 B	2 B	3 A	4 A	5 A	6 B
			Mn II				
3441.98		41	40	*43*	*44*	39	
3460.31		59	60	*62*	*62*	57	
3474.12		}76	}72	}*75*	}*75*	}73	
3474.04							
3482.91	3	86	81	*79*	*79*	80	
3488.68		90	87	—	—	89	
3496.81		}98	}00	—	—		
3497.54				—	—	95	
3495.83				—	—		
			Fe I				
4375.93		74	69	75	71	80	75
4427.31		16	22	23	30	39	26
4461.65		66	62	60	58	62	61
4482.17		}90	}88	}87	}90	}86	}81
4489.74							
4347.24	2	49	50	50	49	47	89
4445.48		44	42	45	50	39	—
4471.68		66	78	70	79	62	—
4389.24		84	82	86	86	80	—
4435.15		34	42	45	30	39	—
4466.57		66	62	60	58	62	—
4216.19		}12	14	18	—	}12	—
4206.70			03	06	06		07
4199.97		99		98	99	03	97
4134.34	3	32	29	29	32	30	—
4149.96		48	46	53	56	64	—
4191.47		97	92	90	83	92	—
4258.12		57	60	60	62	57	59
4232.72		33	34	34	33	33	32
3859.91		60	62	57	55	58	60
3886.28		88	88	—	—	85	—
3899.71		00	00	98	—	}03	00
3906.48		04	04	07	06		08
3824.44	4	27	20	24	23	26	—
3856.37		54	52	57	55	58	57
3878.58		80	75	75	75	75	79
3930.30		35	34	34	34	34	—
3920.26				18			

Table 2 (cont.)

λ_{lab}	Multiplet	1 B	2 B	3 A	4 A	5 B	6 A
			Fe I (cont.)				
3719.94		23	15	18	*17*	20	*21*
3737.13		38	43	32	*38*	37	*36*
3745.56							*44.5*
3748.26		}49	}50	}48		}47	*49*
3745.90			43				*44.5*
3679.91	5	80	82	80		78	*80*
3705.57		08	08	07		07	*05*
3722.56		23	}26	—		20	*22.5*
3733.32		31		32		37	*33.5*
3683.05		80	82	80		78	
3707.83		08	08	07		07	
3440.61							
3440.99		}41	}40	}*43*	}*44*	}39	
3443.88							
3490.58		90	91	—	—	89	
3475.45	6	76	76	—	—	73	
3465.86		69	68	*62*	*62*	67	
3526.04		23	22			22	
3497.84		98	00			95	
3476.70		76	76			73	
5269.54				67	73	69	
5328.04				20	26	20	
5371.49				—	66	63	
5405.78				03	00	00	
5434.53	15			33	—	33	
5397.13				03	00	00	
5429.70				33	24	33	
5446.92				}52	—	48	
5455.61					58	52	
3581.20		*84*	*85*	*83*	*84*	*82*	79.5
3647.84		*46*	*45*	*45*	*46*	*43*	47
3631.46	23	*27*	*34*	*34*	*34*	*30*	29.5
3618.77		*19*	—	*20*	*17*	*17*	17.5
3608.86		*05*	*05*	*11*	*10*	—	*08*
5167.49						68	
5227.19	37					29	
5270.36						69	
4383.55		84	82	86	86	80	84
4415.13	41	16	14	14	10	12	15.5
4294.13		97	97	97	83	92	94.5
4337.05		36	36	34	32	40	37

Table 2 (cont.)

λ_{lab}	Multiplet	1 B	2 B	3 A	4 A	5 B	6 A
				Fe I (cont.)			
4271.76	42	72	72	80	83	73	70
4307.91		11	11	03	08	01	07
4202.03		99	03	06	06	03	02
4250.79		48	42	45	—	—	52
4045.82	43	44	49	44	—	—	—
4063.60		63	63	63	65	65	62
4071.74		75	77	—	—	73	—
3969.26		68	68	66	—	65	66
4005.25		06	08	11	99	08	—
4143.87		45	46	—	—	—	41
4132.06		32	29	29	32	30	31.5
3815.44	45	16	16			15	
3827.82		17	30			26	
3841.05		39	44			—	
				Fe II			
3277.35	1	78	77	77	78	76	
3302.86		03	05	04	03	03	
3312.71		}14	}15	}13	}13	}15	
3314.00							
3255.88		56	58	57	57	57	
3281.29		81	85	82	81	81	
3295.81		95	97	95	96	92	
3303,47		03	05	04	03	03	
3264.76		65	65	65	63	65	
3285.43		85	85	82	85	81	
3227.73	6	25	25	—	—	26	
3213.31		}13	}13	—	—	}12	
3210.45				09	—		
3192.92		95	—	—	—	89	
3186.74		85	85	84	85	84	
3193.81		95	—	—	—	—	
3166.67		}68	66	65	65	65	
3170.34			72	—	—	—	
3196.07	7	95	—	—	—	—	
3183.11		}85	—	}84	}85	}84	
3185.32			85				
3163.09		—	—	—	—	—	
3161.95		—	—	—	—	—	

Table 2 (cont.)

λ_{lab}	Mult.	1 B	2 B	3 A	4 A	5 B	6 A
			Fe II (cont.)				
4233.17	27	33	34	34	33	33	32
4351.76		49	50	50	49	47	50
4416.82		16	14	14	16	12	15.5
4173.45		75	76	76	78	74	72
4303.17		97	97	03	08	01	01
4385.38		84	82	86	86	80	84
4128.73		32	29	29	32	30	—
4273.32		72	72	70	75	73	—
4178.86	28	75	76	76	78	74	78
4296.57		97	97	97	83	92	94.5
4369.40		74	69	69	71	69	—
4122.64		21	29	21	19	21	20.5
4258.16		57	60	60	62	57	59
4629.34	37	28	27	27	25	25	28
4555.89		50	54	54	56	52	56
4515.34		21	15	15	11	17	15
4491.40		90	88	87	90	86	89
4520.22		21	15	25	11	17	20.5
4489.18		90	88	87	90	86	89
4472.92		66	78	72	—	—	—
4666.75		60	—	63	63	65	65
4582.83		84	80	80	82	84	81.5
4534.17		27	—	25	32	27	—
4583.83	38	84	80	80	82	84	81.5
4549.47		50	54	48	48	46	47
4522.63		27	}15	}15	}11	}17	—
4508.28		03					08
4620.51		28	23	19	25	19	—
4576.33		73	80	73	73	75	—
4541.52		50	54	54	48	46	40
5169.03	42			70	68	68	
5018.43				11	11	11	
4923.92				19	19	16	
			Sr II				
4077.71	1			*75*	*80*		*80*
4215.52				*23*	*14*		*18.5*

REMARKS

H — The many blends make the identification of the last Balmer lines very difficult on the small dispersion spectra. On the spectrum 6 (large dispersion, Fig. 3) the Balmer lines appear as very sharp absorption lines (shell) superimposed on wide profiles (underlying star).

Ti II — All the lines of Ti II are observed here as absorption lines. None of these observed in emission by Joy [7] in the visible could be recognised on our spectra.
(5): identification impossible in the spectra 3, 4, 5, the shortest wave-lengths being underexposed.
(6), (13), (14): visible only on the group A spectra (No. 3, 4),
(19): visible on spectrum No. 6 (large dispersion) as absorption lines: Gahm gives them as emission lines.

Cr II — (1): the feature visible neer 3645 A in the group A spectra (No. 3, 4) may correspond to the group of 4 lines of the multiplet blended with a line of Fe I (23).
(3), (4), (5), (9): in the group B spectra (No. 1, 2, 5) some lines of the four multiplets disappear, probably blended with unidentified emission lines.

Mn II — (3): this multiplet seems in emission in the three spectra of group B (No. 1, 2, 5) and in absorption in the two others: Gahm observed only absorption.

Fe I — (2): on the low dispersion spectra the identification is difficult: the large dispersion spectrum No. 6 confirms the existence of the strongest lines only.
(3): faint lines on spectrum No. 6.
(4): line 3886,28 A, blend with H_8, disappears in group A.
(5): emission in group B spectra; faint emission in spectrum No. 3; the strongest lines in absorption in spectrum No. 4; absorption in spectrum No. 6.
(6): emission in group B, absorption in group A.
(37): in absorption in the unique spectrum of group B extending in the region considered.
(43): the emission lines 4063 A and 4132 A are, as expected in a RW Aur type star, more intense than the other lines of the multiplet.
(45): emission in group B; not observable in group A.

Fe II — (1): the emission feature at 3278—81 A is more intense in spectrum No. 1 than in the others (No. 6, 7): the two emission features 3195 A and 3213 A (each of which is the superposition of some emission lines of both multiplets) are more or less in coincidence with some absorption lines of Cr II (9) and Ti II (2), For that reason, 3195 A and 3213 A appear more intense in spectrum No. 1 where the absorption lines have almost disappeared and they are faint or absent in the other spectra.

Sr II — (1): identification uncertain.