Astron. Astrophys. 54, 219–225 (1977)

ASTRONOMY AND ASTROPHYSICS

The Complex Structure of the Ca II (H and K) Lines in the Spectrum of the A0ep Star with Infrared Excess HD 190073

III. Night to Night Variations during the Period 13—18 August 1975* and Interpretation of the Line Profiles via a Resonance Scattering Mechanism

J. Surdej and J. P. Swings

Institut d'Astrophysique, B-4200 Cointe-Ougrée, Belgium

Received May 31, 1976

Summary. Radial velocities, equivalent widths and profiles of the main components of the H- and K-lines in the spectrum of HD 190073 are analyzed on a 9-spectrum sample covering the period 13–18 August 1975. The characteristics of these components are correlated with the profiles of the Balmer lines, especially H_ε, as suggested in paper I (Surdej and Swings, 1976a). Dramatic variations occurring in the extended atmosphere of HD 190073 within that short period are further indicated by the disappearance during two nights of the undisplaced absorption component in the Ca II H-line. The mechanism described in paper II (Surdej and Swings, 1976b), i.e. radiative forces acting selectively via a resonance scattering mechanism of Ca^+ atoms is shown to be capable of explaining the evolution of the main features in the complex profile of H and K in the spectrum of HD 190073.

Key words: Ca II H and K — complex profiles — variable profiles — emission-line stars — infrared excess — radiative forces — resonance scattering

A. Introduction

The spectrum of the A0ep star HD 190073 is remarkable not only for the presence of emission lines, but mainly for that of a very complex structure for the Ca II H and K absorptions. During the last three decades the general aspect of the complex pattern of H and K has remained the following: one stationary component surrounded by two emission wings and at least two strong absorption components displaced towards the violet by 180 and 320 km s^{-1} (Surdej and Swings, 1976a, and references therein). Dramatic variations during the period 13–18 August 1975 are observed within that pattern: they are described, analyzed (in terms of radial velocities and equivalent widths of the components of the H and K lines) and shown to be strongly correlated with night to night variations in the complex P Cygni profiles of the Balmer lines; we then interpret these observations in terms of our model based on the selective effet of radiative forces.

Send offprint requests to: Dr. J. P. Swings

* Observations performed at the Haute Provence Observatory (C.N.R.S.)

B. The Ca II H- and K-lines in the Spectrum of HD 190073

Typical profiles of the H- and K-lines observed within the last three decades in the spectrum of HD 190073 have been illustrated in our previous papers (Surdej and Swings, 1976a, 1976b, hereafter referred to as papers I and II respectively). Figures 1 and 2 of the present paper readily show that although the general pattern of the complex profiles has remained the same, new phenomena have occurred lately such as the disappearance of the undisplaced component in H during a few days. A more detailed study further shows that the high radial velocity components (−360, −400 km s^{-1}) present during the last decades were no longer detected in 1975.

The H- and K-profile variations are studied in greater detail in the next section.

C. The H- and K-profiles during the Period 13—18 August 1975

An illustration of the variations in the H- and K-line profiles is given in Figure 1: the spectrograms were obtained by the authors at the coudé focus of the Haute Provence Observatory 152 cm telescope at a dispersion of 20 Å/mm.

1. Radial Velocities of the Components

We measured the radial velocities of the various components appearing in the H- and K-lines for 9 spectra obtained during the period 13–18 August 1975. The accuracy of the measurements is ± 7 km s^{-1} for all the plates. The intensity tracings reproduced in

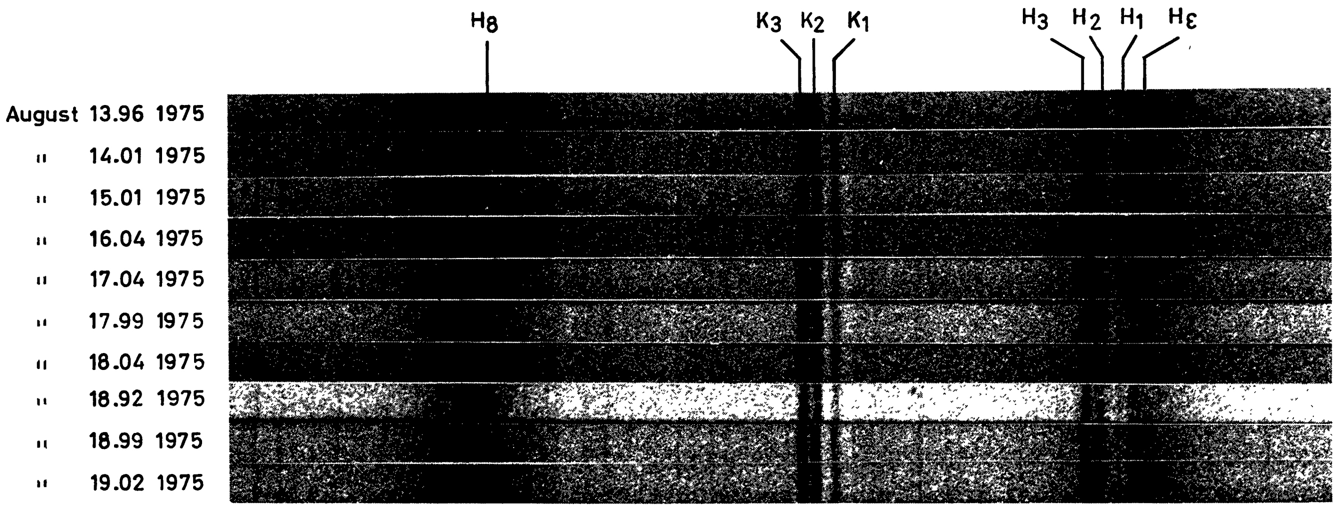


Fig. 1. The Ca II H and K lines in the spectrum of HD 190073 during the period August 13–18, 1975, observed by the authors at the coudé focus of the 152 cm telescope at the Observatoire de Haute Provence (original dispersion 20 Å/mm)

Figure 2 show typical examples of the complex profiles in which the radial velocities were determined for the individual components. The format of Table 1 of paper I in which the data (in km s^{-1}) for the various components of H and K during the period 1943–1974 were collected is used here to group the measurements for August 1975 (see Table 1). It is to be recalled that E^+, A and E^- refer respectively to the red emission wing, the central absorption and the violet emission wing of the "undisplaced" H- and K-lines. Under the headings ranging from -110 to -400 km s^{-1} are grouped the velocities of the other absorption components. The date at which the spectrogram was obtained is given in Column 1.

As established in paper I a short examination of Table 1 and of Figures 1 and 2 reveals that three distinct groups and subgroups of absorption components exist for the H- and K-lines, i.e., H_1, K_1 (with the emission wings E^+, E^- and the central absorption a_1); H_2, K_2 (central absorption a_2 and inflexion in violet wing c_2); and H_3, K_3 (central absorption a_3). The subgroups for which there exists a common radial velocity are collected in Table 2 in which the different columns indicate the mean radial velocity (in km s^{-1}), and standard deviation determined from Table 1; the last two columns give the number of spectra on which each subgroup is present and the number of spectra for which the radial velocity was measured.

As indicated in paper I one can readily see from the data included in Table 2 (average values of the measurements performed on the spectra where the a_1 component is present in the H line) that the separation between the emission wings in the K line is greater than that in the H line, i.e. $\simeq 170$ km s^{-1} compared to $\simeq 90$ km s^{-1}. This is due to the fact that the underlying profile of the Balmer line H_ε perturbs the H line of Ca II. As written in paper I: "an emission in H_ε acts dramatically on H in filling in the undisplaced H_1 component, therefore reducing the separation between the emission wings". The occurrence of such a fact is well illustrated by some of the intensity tracings given in Figure 2 where H_ε may completely fill in the a_1 component of the H line (August 16 and 17, 1975). Similar emission components appear in H_γ, H_δ, and H 8.

Merrill (1951) reported that the absorption components of the H- and K-lines were distinctly grouped into a lower-velocity (-150, -200 km s^{-1}) and a higher velocity (-300, -400 km s^{-1}) system. On the basis of a 12 spectrum sample he noted the fact that the velocities in the higher-velocity system are within the measurements uncertainties, precisely twice those in the lower velocity system. From the examination of Tables 1 and 2 we conclude, as in paper I, that the 2:1 ratio is to be considered as a statistical result only. Furthermore the components belonging to the higher-velocity system ($|v| > 300$ km s^{-1}) have disappeared during these last two years, i.e. in 1974 (see Table 1 of paper I), and 1975.

2. *Equivalent Widths of the Different Components of* H *and* K

We measured the equivalent width of the main absorption components, i.e. H_1, H_2, H_3 (blended with H_ε), K_1, K_2 and K_3 appearing in the H- and K-lines for 8 spectra taken during the period 13–18 August 1975. The accuracy of the measurements is ± 0.03 Å, the greatest error being due to the uncertainty affecting the choice of the continuum level. Table 3 lists the measurements of the equivalent widths of the different components; the night to night variations of the equivalent widths illustrated in Figure 3 are interpreted in the next section.

Table 1. Radial velocities of the blue shifted components of the H and K lines (km s^{-1}) observed in the spectrum of HD 190073 from August 13 to 18, 1975 (all spectra at 20 Å/mm)

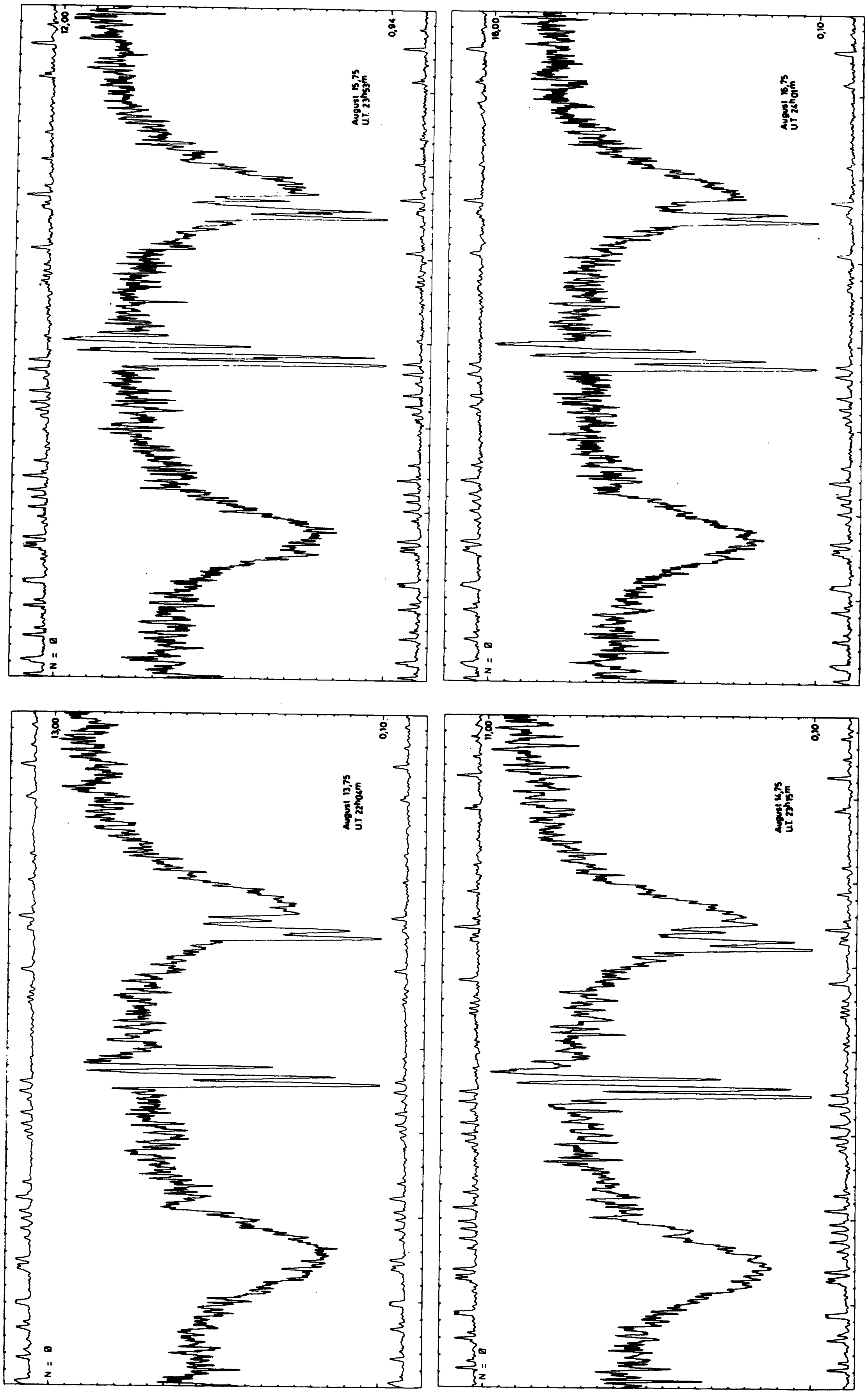
		E^+	A	E^-	110	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390	400
August 13.96	H	54	− 6	57				156			?∼186										291											
	K	P	− 2	P			152			177											295											
August 14.01	H	P	+ 4	61			148				?193						?		274		289											
	K	P	+ 4	53		144					189						247		274			304										
August 15.01	H	38	− 7	57			153					198									288											
	K	104	+ 4	72			150				192									277												
August 16.04	H	52	+ 1	29			146				188									284												
	K	106	+ 7	55		142					190										287											
August 17.04	H	?	+ 4	?			146			182				(216)							291											
	K	101	+ 1	66			145			175	(191)										285											
August 18.04	H	?	− 1	68			152			176	(188)				227					284		299										
	K	112	− 4	63			154			178	(193)									284		296										
August 18.92	H	31	11	50				162				210										303										
	K	94	− 9	70			149			179	210										291											
August 18.99	H	48	− 3	20			154				187									283												
	K	132	+ 2	59			145			184										281												
August 18.75	H	40	P	—				157			190										289											
	K	—	+ 4	82			145			179											285											

Notes to Table 1: P the component is present, but not measured
? implies caution due to probable uncertainty in the measurement
() means that a component is present, but very weak!

Table 2. Groups and subgroups to which belong the different absorption and emission components of the H and K lines in the spectrum of HD 190073

Group	Line	Subgroup	$\bar{v}$ (km s^{-1})	Δv (km s^{-1})	Present	Measured
1	H	E^+	44	9	9	6
1	K	E^+	108	13	9	6
1	H	E^-	49	18	9	7
1	K	E^-	65	10	9	8
1	H	a_1	−2	5	9	9
1	K	a_1	1	5	9	9
2	H	a_2	153	5	9	9
2	K	a_2	147	4	9	9
2	H	c_2	188	7	8	8
2	K	c_2	183	6	9	9
3	H	a_3	291	6	9	9
3	K	a_3	289	8	9	9

Notes: a_1, a_2, a_3 correspond to the core of the three strong absorptions in H and K. c_2 corresponds to an inflexion in the blue wing of a_2


August 15,75
U.T. 23h53m
12,00
0,94
N = 0
August 16,75
UT 24h01m
18,00
0,10
N = 0
August 13,75
U.T 22h04m
13,00
0,10
N = 0
August 14,75
U.T 23h15m
11,00
0,10
N = 0

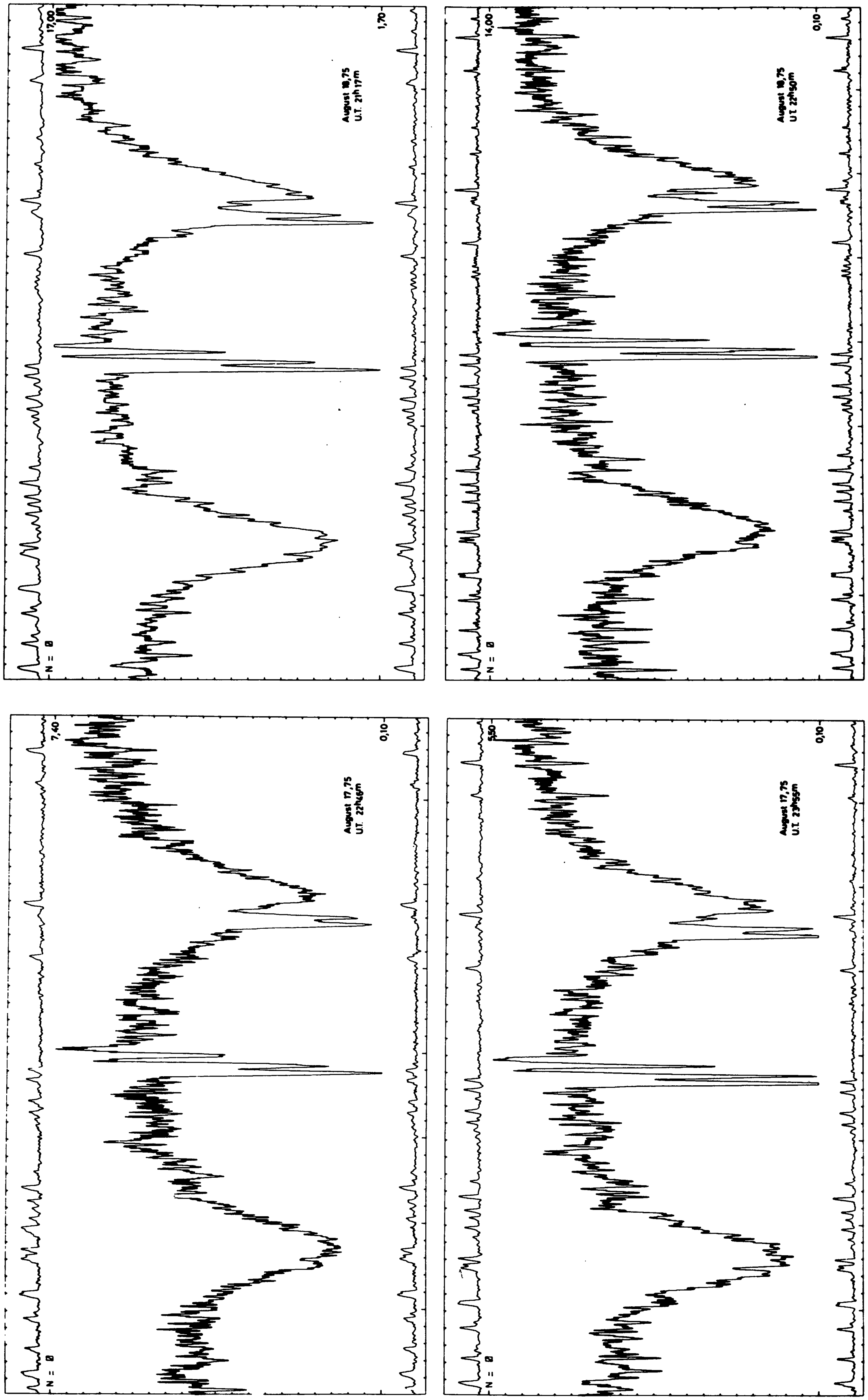


Fig. 2. Intensity tracings of the plates reproduced in Figure 1, showing variations in the structure of H and K, from night to night, or during the course of single nights. For each tracing the numbers indicated on the right represent the intensities of the highest and lowest points on a linear scale, $N = 0$ means that no filtering was applied to the data

Table 3. Equivalent widths (in Å) of the different absorption components of the H and K lines in the spectrum of HD 190073

	Group	Line	Equivalent width		Group	Line	Equivalent width
August 13, 1975	3	K	1.0	August 17, 1975	3	K	1.0
U.T. 22^h04^m	2	K	0.7	U.T. 22^h46^m	2	K	0.7
	1	K	0.3		1	K	0.2
	3	H	1.1		3	H	1.4
	2	H	1.3		2	H	1.0
	1	H	0.6		1	H	—
August 14, 1975	3	K	0.8	August 17, 1975	3	K	0.9
U.T. 23^h15^m	2	K	0.7	U.T. 23^h55^m	2	K	0.7
	1	K	0.3		1	K	0.2
	3	H	1.2		3	H	1.1
	2	H	1.3		2	H	1.0
	1	H	0.5		1	H	0.5
August 15, 1975	3	K	0.9	August 18, 1975	3	K	1.1
U.T. 23^h53^m	2	K	0.7	U.T. 21^h17^m	2	K	0.7
	1	K	0.2		1	K	0.3
	3	H	1.1		3	H	1.4
	2	H	1.1		2	H	1.4
	1	H	0.4		1	H	0.5
August 16, 1975	3	K	1.0	August 18, 1975	3	K	1.0
U.T. 24^h01^m	2	K	0.6	U.T. 22^h50^m	2	K	0.8
	1	K	0.2		1	K	0.3
	3	H	1.3		3	H	1.1
	2	H	1.0		2	H	1.5
	1	H	—		1	H	0.5

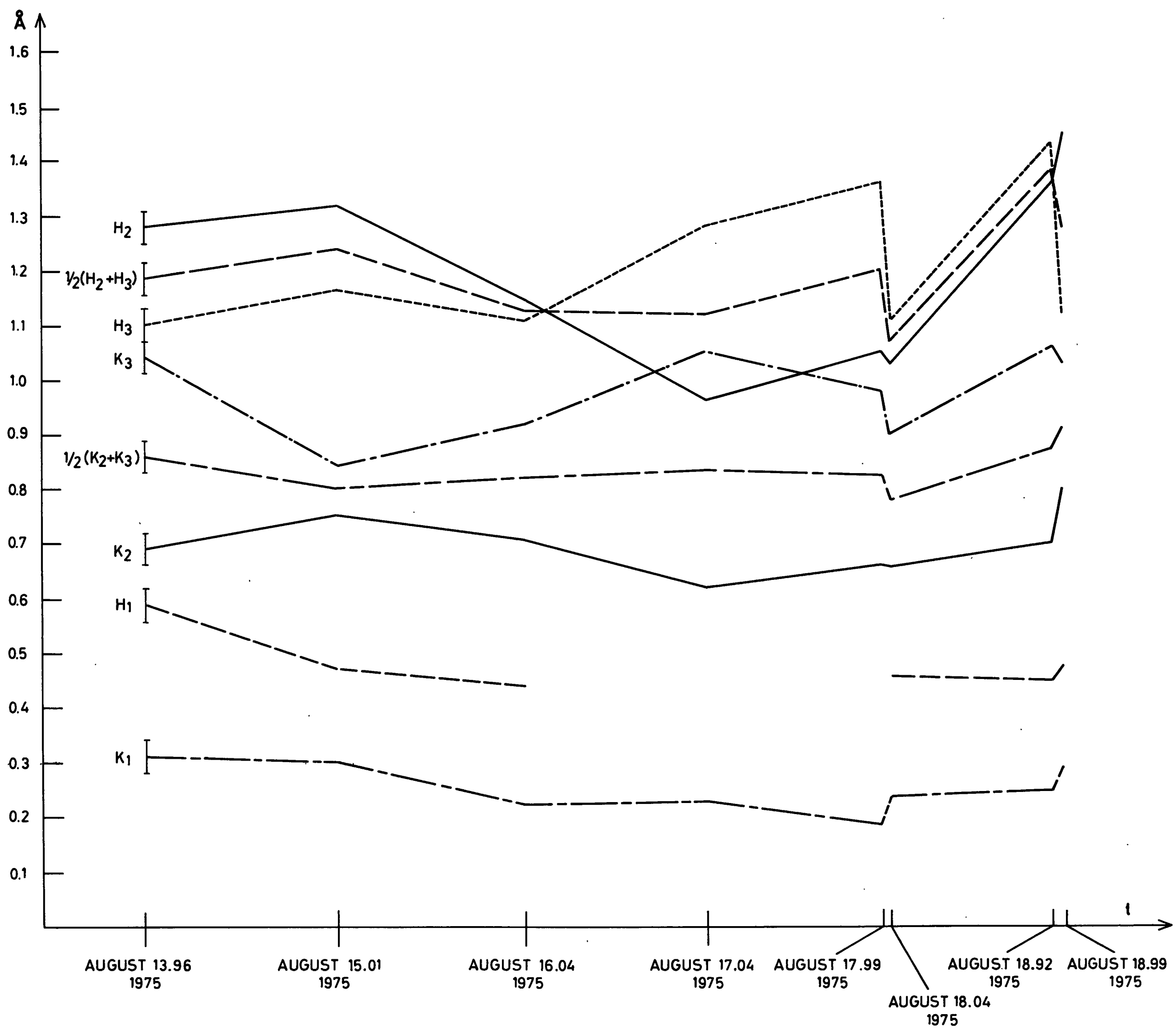


Fig. 3. Equivalent widths of the three main components of H and K (plates of Figures 1 and 2). K_1 exhibits a minimum around August 16 and 17, whereas H_2, H_3 and K_2, K_3 increase after those dates. See text for interpretation

3. *Interpretation of the Night to Night Variations of the* H- *and* K-*line Components*

Since the physical model used for the interpretation of the profiles was described in detail in paper II we consider here only its application to the 1975 spectra. On 7 spectra of the sample we measured the mean wavelength and the width of the blueshifted P Cygni absorption in H_δ and found respectively $\lambda\, 4097.8 \pm 0.3$ Å, and $\Delta\lambda \sim 1.5$ Å. A similar component is visible in H_γ and H_8 but cannot be seen in H_ε because of the presence of the Ca II H line. Nevertheless one can find its location on the basis of the data given above; the absorption component in H_ε lies at about $175(\pm 30)\,\mathrm{km\,s^{-1}}$ to the blue side of the H_1 component of Ca II. Similarly we find that the center of the emission component in H_ε should lie at about $80(\pm 30)\,\mathrm{km\,s^{-1}}$ to the blue side of the H_1 component of Ca II. As shown in paper II a depletion of the radiation at wavelengths corresponding to the absorption component of the P Cygni profile in H_ε will cause an accumulation of Ca^+ atoms travelling at that corresponding velocity, thus the absorption line at wavelengths fitting H_2 and K_2. As far as H_3 and K_3 are concerned they correspond to a saturation velocity of the Ca^+ atoms at great distances from the photosphere of HD 190073. Intensity tracings were obtained for the spectra of Figure 1; they clearly show that the H- and K-profiles vary on time scales ranging from days to hours (August 17 and 18, 1975). The emission wings and first absorption component (H_1, K_1) vary as well as the other components. From Figures 2 and 3 one may readily conclude that when H_ε is filling in the undisplaced absorption component H_1 (August 16, 17, 1975), the extended atmosphere surrounding HD 190073 (mainly composed of Ca^+ atoms) is partially removed, because of an ejection of the Ca^+ atoms under the enhanced selective radiative forces described in paper II. Indeed the equivalent width of the unblended K_1 component presents a minimum around August 16 and 17, 1975 (see Fig. 3) because of a decrease of the opacity in the extended envelope at rest. The matter ejected from HD 190073 creates a noticeable increase of the opacity of the moving envelopes at about August 18, 1975: this is shown in Figure 3 by the fact that the equivalent widths of K_2 and K_3 (and of H_2 and H_3) which had remained fairly constant up to then (especially if one considers the mean of the equivalent widths of K_2 and K_3 i.e. $(K_2+K_3)/2$ and of H_2 and H_3 i.e. $(H_2+H_3)/2$ start to increase after the two-to three-day minimum of K_1.

D. Conclusion

Because the variations occurring in the extended atmosphere around HD 190073 are so sudden and rapid, we do not intend to interpret the very fine details of the complex profile of the H- and K-lines of Ca II. However the study of the radial velocities and equivalent widths of the different components of the Ca II H and K lines observed during the period 13–18 August 1975 is strongly in favor of the model proposed in paper II, in which selective radiative forces are responsible for the ejection of Ca^+ atoms from the outer atmosphere of HD 190073.

Observations over time scales of a few minutes and with greater dispersion will certainly reveal new and interesting features concerning the active extended atmosphere of HD 190073. It is the wish of the authors to be able to perform such observations in the near future, especially with the use of échelle spectrographs and/or electronic cameras or image tube equipments.

Acknowledgements. We are greatly indebted to Mr. A. Tilkin for having generated the intensity tracings shown in Figure 2, after setting up the data acquisition and reduction-programs for our Institute's digitized microdensitometer. The help of Mr. J. Bricteux is also acknowledged with thanks, as well as that of many persons, especially Dr. J. M. Vreux, involved in the updating of that equipment. The kindness of Anna Surdej in allowing her husband to observe at the Haute Provence Observatory during their honey-moon was of course quite remarkable!

References

Merrill, P. W.: 1951, *Astrophys. J.* **113**, 55
Surdej, J., Swings, J. P.: 1976a, *Astron. Astrophys.* **47**, 113, paper I
Surdej, J., Swings, J. P.: 1976b, *Astron. Astrophys.* **47**, 121, paper II