

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

II. Interpretation: The Selective Effect of Radiative Forces

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Summary. Radiative forces acting selectively via a resonance scattering mechanism of Ca^+ atoms are capable of producing the main features described in paper I concerning the complex profiles of H and K in HD 190073 and in a series of stars exhibiting similarities to HD 190073.

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

A. Introduction

In paper I, we described the complex profiles of the Ca II H- and K-lines in the spectrum of HD 190073 and their evolution during three decades (1943–1974). In the present paper we try to explain how such profiles are formed in terms of a model based on the selective effect of radiative forces (Milne, 1926).

Several publications (Struve and Swings, 1942; Beals, 1942, 1968; Merrill, 1951, 1959; Struve, 1952; Scargle, 1971, 1973) deal with attempts to find physical phenomena explaining the Ca II complex profiles.

A few preliminary remarks are to be considered:

(i) The parallel behaviour of H and K excludes any interpretation in terms of absorption lines (or blends) due to other elements;

(ii) The blue-shifted components are not due to Doppler displaced lines originating in high velocity interstellar clouds (Merrill, 1951). The galactic latitude of HD 190073 is only -14° ; no star around HD 190073 shows similar Ca II profiles; the Na I lines (D_1 and D_2) exhibit only a weak interstellar component in HD 190073.

(iii) Small displacements in the $2S$ or $2P^\circ$ levels of Ca II were discussed, but rejected (Merrill, 1951).

(iv) Since the components at -180 and -320 km s^{-1} have been observed during about half a century they cannot be attributed to sudden mass ejections as in novae, for instance, where absorptions at discrete velocities correspond to envelopes leaving the star, the intensity of the individual components varying rapidly with time.

It thus appears that the forces responsible for the ejection of atoms should be of radiative type. Scargle (1973) has proposed a pure scattering model in order to explain the ejection of Ca^+ atoms from the atmo-

sphere of HD 190073 in which he attempts to explain a 2:1 ratio between the radial velocities of some components of the H- and K-lines. We have however shown in paper I that such a ratio does not appear to be significant on the 24-spectrum sample for which we measured the component velocities. On the contrary, we find a correlation between the aspect of the structure of the H- and K-lines and the complex profile of the Balmer lines, especially H_α . In the following sections, we shall consider a resonance scattering mechanism in order to interpret the observations of paper I.

B. Intensity Distribution in the Spectral Region around the H- and K-Lines

We have taken as an example the 10 \AA/mm spectrogram of HD 190073 obtained on May 23, 1950 by P. W. Merrill at the Mount Wilson 100-inch telescope. The density curve (appearing among others in Fig. 3 of paper I) treated by the corresponding calibration curve becomes the intensity tracing shown in Fig. 1.

The dashed curve represents the absorption profile of H_α ; an emission component is noticeable through the fact that the emission wings are less separated in H_1 than in K_1 (see paper I). In order to visualize the spectrum of HD 190073 around H_α as the Ca^+ atoms would from an extended atmosphere around the star one may subtract the contribution of H to H_α . Since the intensity profile of K is known, it is indeed possible to reconstruct the profile of H_α using the proportionality factor 0.875 between the laboratory intensities of the two Ca II lines. Such a factor is often observed for strong stellar lines, in contradiction to a 0.5 ratio deduced from the gf-values of H and K. Small deviations from

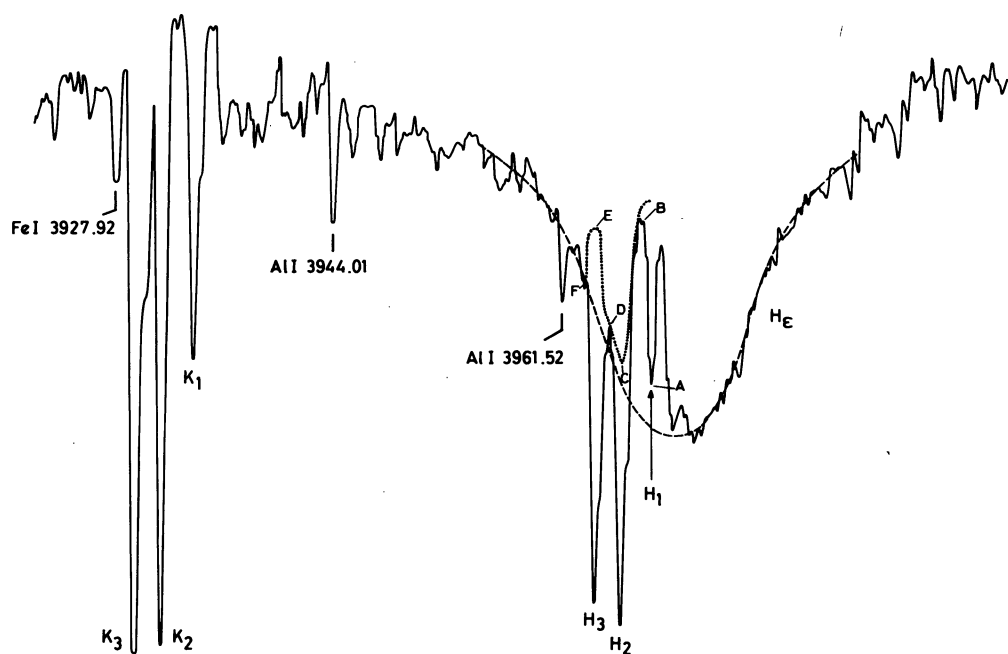


Fig. 1. Intensity profile of the H- and K-lines of Ca II in the May 23, 1950 spectrum of HD 190073 (Mt Wilson 100-inch, 10 Å/mm, observer: P. W. Merrill)

the proportionality factor chosen here would not alter the conclusion of the present paper. The continuum in the region around H_{ϵ} can thus be obtained and is indicated by dots in Fig. 1: it represents the spectrum as seen by Ca^{+} atoms in the higher layers of the atmosphere of HD 190073.

C. Resonance Scattering Mechanism Acting on Ca^{+} Atoms

In quantum theory a monochromatic radiation appears as a beam of photons having an energy $h\nu$ and a momentum $p = h\nu/c$. When such a photon is absorbed by a Ca^{+} atom it yields its momentum to the latter: the Ca^{+} atom will thus move in the direction of the incident photon. After a time characteristic of its lifetime in an excited state the atom will spontaneously re-emit the photon $h\nu$ in a random direction in space¹). While de-exciting itself the Ca^{+} atom will gain a momentum equal to that of the emitted photon, but in the opposite direction. The average of this momentum is thus zero on a short time scale. The overall effect of the radiative forces on the Ca^{+} atoms will therefore be a displacement of these atoms in the direction of the incident photons. This is what we define as resonance scattering mechanism acting on Ca^{+} atoms.

In an extended atmosphere the equilibrium of the atoms is governed by a balance between the effects of radiative forces and gravitation (Milne, 1924, 1925, 1926, 1927;

¹) Induced emission can indeed be neglected with a good approximation.

Kanto Sur, 1925). As in Milne (1924), it is assumed that the collisions between atoms, ions, ... are unimportant in external layers consisting mostly of Ca^{+} atoms. If the amount of the radiation flux for the wavelengths at which the atoms absorb suddenly increases with respect to its value when equilibrium exists in the extended atmosphere around the star, radiative forces acting selectively via the resonance scattering mechanism will become greater than gravity: Ca^{+} atoms may then be ejected and forced away from the star.

The action of this mechanism in the case of HD 190073 will be the following: although at rest in the extended atmosphere the Ca^{+} atoms responsible for the undisplaced absorption component are affected by small velocity fluctuations (Milne, 1926). Because of Doppler effects the wavelengths at which the Ca^{+} atoms are absorbing will differ from their stellar values, and the corresponding monochromatic fluxes seen by the Ca^{+} atoms will vary accordingly. It can be seen from Fig. 1 that when moving away from the star the flux seen by a Ca^{+} atom is greater than that at rest velocity. Therefore the equilibrium between radiative forces and gravitation no more exists: gravitation is overwhelmed by radiation, and consequently the Ca^{+} atoms are accelerated away from the star.

In order to solve rigorously the problem of resonance scattering on Ca^{+} atoms in the extended atmosphere of HD 190073 one should take into account the interaction with radiation of not only the H- and K-lines, but also with Ca II lines from metastable levels, i.e. $\lambda\lambda 8498-8542-8662 \text{ \AA}$, and consider some weighted mean of these contributions. Since our knowledge of

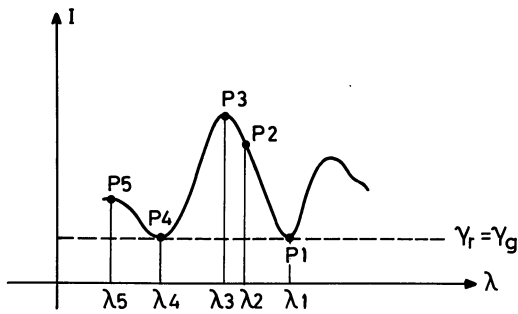


Fig. 2. Distribution of radiative energy as seen by a Ca^+ atom in an extended atmosphere around HD 190073

the line profiles and energy distribution of HD 190073 around 8500 \AA is fairly limited we shall restrict ourselves to the resolution of the quantitative problem of only the H line of $\text{Ca II } \lambda 3968.5 \text{ \AA}$. As far as the energy distribution around 3968 \AA seen by the Ca^+ atoms is concerned we refer to the one determined in the previous chapter.

D. Discrete Components of the H- and K-Lines in the Spectrum of HD 190073: Formation Mechanism

We first consider that there exists around HD 190073 an extended atmosphere rich in Ca^+ atoms that is responsible for the H_1 and K_1 components, as well as for the emission wings of H_1 and K_1 (see paper I). We assume next that the Ca^+ atoms are in equilibrium under the opposite influences of gravitation and radiative forces. In the case where an atom is ejected it will no longer see the stellar radiation at a zero velocity wavelength λ_1 but at a shorter wavelength.

$$\lambda = \left(1 - \frac{v}{c}\right) \lambda_1$$

where v is the velocity of the atom with respect to the star and c the velocity of light.

The knowledge of the distribution of radiative energy emitted by HD 190073 at each wavelength as seen by a Ca^+ atom (Fig. 2) enables us to follow the life of a such an atom and see what accelerations it suffers. Initially at rest (position P_1) the atom receives a positive acceleration (direction star \rightarrow Ca^+ atom) due to radiative forces, i.e. γ_r , and a negative one due to gravity, i.e. γ_g : at equilibrium $\gamma_r = \gamma_g$. It is obvious that γ_r is proportional to $I(\lambda)$ (i.e. the level of the radiation flux emerging from HD 190073 at wavelength λ , and measured in the extended atmosphere) and inversely proportional to the square of the distance between the center of the star and the atom. If because of some perturbation the atom leaves the star at a velocity $V(\lambda_2)$ (corresponding to position P_2 in Fig. 2), $I(\lambda_2)$ becomes greater than $I(\lambda_1)$: the acceleration due to radiative forces overruns that of gravity. The atom will then have the tendency to go farther and farther away from the star, will "climb

up" the violet wing of the line it originated, and will acquire higher and higher velocities. The velocity will keep on increasing except if $I(\lambda)$ becomes again equal to/or lower than $I(\lambda_1)$: this happens at position P_4 in Fig. 2. If $I(\lambda_4)$ is not too much smaller than $I(\lambda_1)$ it could be possible for the Ca^+ atom to overcome the depression and again keep leaving the star.

Nevertheless there will be an accumulation of atoms at wavelength λ_4 and thus an absorption line is formed in the stellar spectrum. Supposing that an atom continues to travel away from HD 190073 it will attain greater and greater distances from the star; however because of the dilution of the radiation ($\div 1/r^2$) the positive acceleration will reach a negligible value (at point P_5 in Fig. 2). From there on the atom will keep a constant velocity: again an accumulation of atoms at such a saturation velocity will form a blueshifted absorption line in the stellar spectrum. It thus seems possible, knowing the energy distribution seen by a Ca^+ atom, to calculate the distance(s) and speed(s) reached by the atom as a function of time. Such a calculation is performed in chapter E. Let us first consider the qualitative implications of the mechanism described above on the formation of components H_2 , K_2 and H_3 , K_3 .

We measured on 18 spectra of the sample described in paper I the mean wavelength and the width of the blueshifted P Cygni absorption in H_γ and found respectively $\lambda 4336.88 \pm 0.28 \text{ \AA}$, and $\sim 2 \text{ \AA}$.

A similar component is visible in H_β , but is hard to see in H_β because of the presence of the Ca II H line. One can however find its location on the basis of the data available for H_γ and H_β : the absorption component of H_β lies at $-150 (\pm 30) \text{ km s}^{-1}$ (i.e. to the blue) of the H_1 component of Ca II . A depletion of the radiation at wavelengths corresponding to that velocity (similar to point P_4 in Fig. 2) will cause an accumulation of atoms travelling at that corresponding velocity, thus an absorption line at wavelengths fitting H_2 and K_2 . As far as H_3 and K_3 are concerned, it is shown later that they correspond to the saturation velocity mentioned above. It is also remarkable to note, as in paper I, that in the cases where the blueshifted P Cygni absorption of H_γ and H_β is particularly strong and wide ($\sim 4 \text{ \AA}$) there exists on the same spectra a blending tendency of H_2 and H_3 , and of K_2 and K_3 . This is due to the fact that the radiation forces being severely reduced, there appears an accumulation of atoms for a wider range of velocities, thus an additional source of absorption.

It was also mentioned in paper I that K_3 (H_3) is stronger than K_2 (H_2) when a distinct blueshifted emission is present in the hydrogen lines H_γ and H_β . Such an effect may be explained by the fact that the influence of radiative forces being greater for atoms travelling with the corresponding velocity, they will receive a greater acceleration, being able in this case to reach their saturation velocity on shorter lengths. This will produce a greater accumulation of Ca^+ atoms for such a velocity,

Table 1. Atoms ejectable via radiative forces

| Atom | Ion. Pot. | Resonance Lines | Atomic Weight | Abundances: Log N_A (Withbroe, 1973) |
|-------|-----------|-----------------------------|---------------|--|
| Na I | 5.12 | D_1, D_2 | 22.99 | 6.24 |
| Ba II | 10.0 | $\lambda\lambda 4554, 4934$ | 137.36 | 1.80 |
| Sr II | 11.0 | $\lambda\lambda 4077, 4215$ | 87.63 | 2.82 |
| Ca II | 11.9 | H, K | 40.08 | 6.33 |
| H I | 13.6 | Ly_α | 1.00 | 12.00 |
| Mg II | 15.0 | $\lambda\lambda 2795, 2803$ | 24.31 | 7.54 |
| He I | 24.6 | $\lambda 584$ | 4.00 | ≥ 11.0 |

then causing a stronger absorption component (K_3 or H_3). It therefore seems convincing that the profile of H_α modulates that of H and K.

Next, one should try to answer the question: why is the ejection of atoms from HD 190073 limited to Ca^+ ? The probability for an atom to be ejected will actually be important if the following requirements are fulfilled:

(i) The spectrum of the atom must possess at least one high-transition probability line that will interact strongly with the radiation; a resonance line, originating from the level of highest population; i.e. the ground state, will be most suitable.

(ii) The wavelength of such a resonance line should not lie far from the peak of the continuous energy distribution of the star.

(iii) The ionization potential of the atom should be sufficiently high so that the atom may accumulate in its original state the momentum required to give rise to the observed velocities.

(iv) The mass of the atom must be as small as possible for the radiative forces to overrun the gravitational forces.

Furthermore the abundance of the element considered must be as important as possible, otherwise no absorption line due to the ejected atoms will be observable.

The atoms whose characteristics fit some of the above-listed criteria are given in Table 1, and ordered according to increasing ionization potentials.

Of the atoms of Table 1, Na I as well as Ba II and Sr II should not be considered in the case of the AO star HD 190073, the former having too low an I.P. and the latter two too low an abundance.

For hydrogen, although $\lambda 1216$ is in the U.V., and far from the peak of a $10000^\circ K$ blackbody, the other requirements are fulfilled. It is to be noted that P Cygni profiles are observed in the visible for the hydrogen lines.

The He I line $\lambda 3888$ originating from a metastable level ($2^3 S$) might play a role similar to that of resonance lines. No He I line is however observed in HD 190073, but $\lambda 3888$ may be important in some cases (see later, e.g. AG Pegasi).

It thus appears from Table 1 and from the considerations above that Ca^+ remains the most likely candidate in

the visible, since the Mg II lines are only observable from above the earth's atmosphere.

E. The Equation of Motion of a Ca^+ Atom under the Only Influences of Selective Radiation Forces and Gravitation

The profile of the energy distribution of HD 190073 seen by a Ca^+ atom was obtained for Fig. 1 and is reproduced schematically in Fig. 3 to which we refer for illustration of the equations to be given hereafter.

In A the acceleration γ_r due to radiative forces is proportional to I_a and to $1/a^2$ where a is the radius of the Ca^+ region, i.e. approximately the radius of HD 190073 ($\approx 2.1 R_\odot \approx 1.46 \cdot 10^{11}$ cm); thus

$$\gamma_r = \frac{\alpha I_a}{a^2}, \quad \text{where } \alpha \text{ is a constant determined below;}$$

the acceleration in A due to gravity is

$$\gamma_g = \frac{MG}{a^2} = g$$

$$\begin{aligned} \text{where } M &= \text{stellar mass} \approx 3.2 M_\odot \approx 6.37 \cdot 10^{33} \text{ g} \\ G &= 6.668 \cdot 10^{-8} \text{ dyne cm}^2 \text{ gm}^{-2}. \end{aligned}$$

If the Ca^+ atoms are in equilibrium at point A , the fact that $\gamma_r = \gamma_g$ implies

$$\alpha = \frac{ga^2}{I_a}. \quad (I)$$

The acceleration acting on an atom at point X , at a distance r from the star, having a velocity V and absorbing radiation at wavelength $\lambda = \lambda_x$ is

$$\gamma = \gamma_r - \gamma_g$$

where

$$\gamma_r = \frac{\alpha I}{r^2} = \frac{\alpha \Delta I}{r^2} + \frac{\alpha I_a}{r^2} \quad \text{if } \Delta I = I - I_a$$

and

$$\gamma_g = \frac{ga^2}{r^2}.$$

Thus

$$\gamma = \frac{\alpha \Delta I}{r^2} + \frac{\alpha I_a}{r^2} - \frac{ga^2}{r^2}.$$

Taking relation (I) into account the expression for the total acceleration becomes

$$\gamma = \frac{\Delta I}{I_a} \frac{ga^2}{r^2}. \quad (II)$$

In order to determine the motion of an atom initially at rest and acquiring a continuous series of velocities up to the saturation velocity V_f , the motion is to be

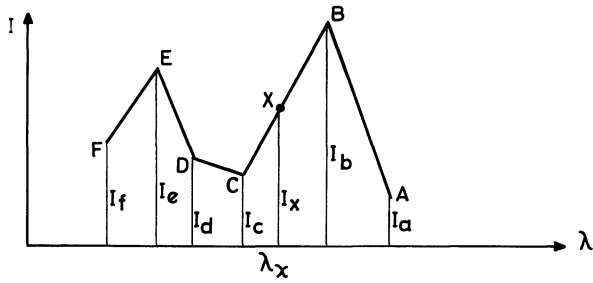


Fig. 3. Schematic profile of the radiative energy distribution seen by a Ca⁺ atom

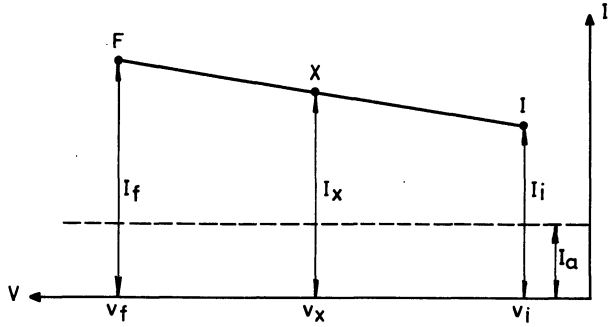


Fig. 4. Energy distribution seen by the Ca⁺ atom for the different velocities between V_i and V_f

considered between *A* and *B*, then *B* and *C*, ... up to *F* (see Fig. 3). One therefore has simply to study the motion of an atom between an initial point *i*, where the radiation it absorbs at velocity V_i has an intensity I_i , and a final point whose characteristics are V_f and I_f . This is schematically reproduced in Fig. 4.

The following quantities are known: I_i , I_f , V_i , V_f , r_i , t_i , where r_i is the distance between the center of the star and the atom and t_i is the time necessary for the atom to reach radius r_i .

One may express ΔI of Eq. (II) in terms of V .

If $J = \frac{I_f - I_i}{V_f - V_i}$ is the slope of the line joining initial and

final points in Fig. 4.

J is also equal to

$$J = \frac{I - I_i}{V - V_i} = \frac{(I - I_a) - (I_i - I_a)}{V - V_i} = \frac{\Delta I - \Delta I_{ia}}{V - V_i}$$

where $\Delta I_{ia} = I_i - I_a$.

One gets $\Delta I = J(V - V_i) + \Delta I_{ia}$

or $\Delta I = JV + L$, if $L = \Delta I_{ia} - JV_i$.

The equation of motion then becomes

$$\ddot{r} = \frac{ga^2(JV + L)}{I_a r^2} \quad \left(\text{with } \gamma = \frac{d^2 r}{dt^2} = \ddot{r} \right).$$

Let us introduce $M = \frac{ga^2 J}{I_a}$ and $N = \frac{ga^2 L}{I_a}$.

$$\text{Finally } \ddot{r} = \frac{M\dot{r}}{r^2} + \frac{N}{r^2} \quad \left(\text{with } V = \frac{dr}{dt} = \dot{r} \right).$$

We can then find an expression for the final radius r_f in terms of the initial one r_i and the two corresponding velocities V_i and V_f :

$$r_f = \frac{1}{\frac{1}{r_i} + \frac{1}{NK^2} \left[K(V_i - V_f) + \ln \left(\frac{1 + KV_f}{1 + KV_i} \right) \right]} \quad \text{(III)}$$

$$\text{where } K = \frac{M}{N}.$$

We then determine the time required for an atom to go from r_i to r_f

$$\Delta t = \int_i^f dt = \int_i^f \frac{dr}{V} \quad \text{where } dr = \frac{r^2 dV}{M + N/V},$$

$$\Delta t = \int_i^f \frac{r^2 dV}{MV + N}.$$

V_f being replaced by V in (III) and in the expressions of $K(V)$ and $N(V)$ one finds:

$$\Delta t = \int_i^f \left(\frac{1}{\frac{1}{r_i} + \frac{1}{NK^2} \left[K(V_i - V) + \ln \left(\frac{1 + KV}{1 + KV_i} \right) \right]} \right)^2 \cdot \frac{1}{MV + N} dV. \quad \text{(IV)}$$

This integral will be solved numerically.

It is also of interest to determine at how many stellar radii corresponds the distance r_f reached by the atom from the surface of the star this quantity is called Δr^*

$$\Delta r^* = \frac{r_f - 1.46 \cdot 10^{11}}{1.46 \cdot 10^{11}} \quad \text{(V)}$$

where r_f is given in cm.

F. Numerical Application to HD 190073

Using the velocity measurements listed in Table 2 of paper I, as well as the intensities from Fig. 1 of the present paper it becomes possible to calculate numerically the expressions (II) to (V). Taking the time at which the atom leaves the extended atmosphere $r = a$ to be zero one may determine r_f , Δr^* , γ and t using respectively formulae III, V, II and IV. The results are listed in Table 2.

Among the stars presented in paper I showing the same characteristics as HD 190073 (complex H and K-lines, I-R excess, P Cygni profiles for the Balmer lines), we chose XX Ophiuchi for supporting the validity of the model proposed here.

Table 2. Distances, accelerations and times relative to a Ca^+ atom at the points numbered in Figures 1 and 3

| Point and Component | Observed Velocity V_i | $r_f(\text{cm})$ | Δr^* (in stellar radii) | γ (km s^{-1}) | t |
|-----------------------------|-------------------------|----------------------|------------------------------------|------------------------------------|--------------|
| A: H_1, K_1 | 0 | $1.46 \cdot 10^{11}$ | 0 | 0 | 0 |
| B: | 53 | $1.49 \cdot 10^{11}$ | 0.02 | 0.1 | 15 min |
| C: H_2, K_2 | 177 | $1.96 \cdot 10^{11}$ | 0.3 | 0.008 | 1 hr 30 min |
| D: | 239 | $3.60 \cdot 10^{11}$ | 1.5 | 0.007 | 3 hrs 30 min |
| E: H_3, K_3 | 321 | $8.24 \cdot 10^{11}$ | 4.5 | 0.003 | 8 hrs |
| | 378 ^{a)} | $1.16 \cdot 10^{15}$ | 7900 | $9 \cdot 10^{-10}$ | 1 yr |

^{a)} The saturation velocity being 378 km s^{-1} it is not possible for the atom to reach 392 km s^{-1} (which was the highest velocity recorded on the spectrograms of paper I) and therefore one cannot determine the distance at which the atom would reach such a velocity. Columns 3 to 6 thus refer to the computed saturation velocity of 378 km s^{-1} .

It appears that the atoms responsible for the blueshifted components of the Ca II lines having velocities of around 180 and 320 km s^{-1} reach zones distant from the extended atmosphere of 0.3 and 4.5 stellar radii respectively.

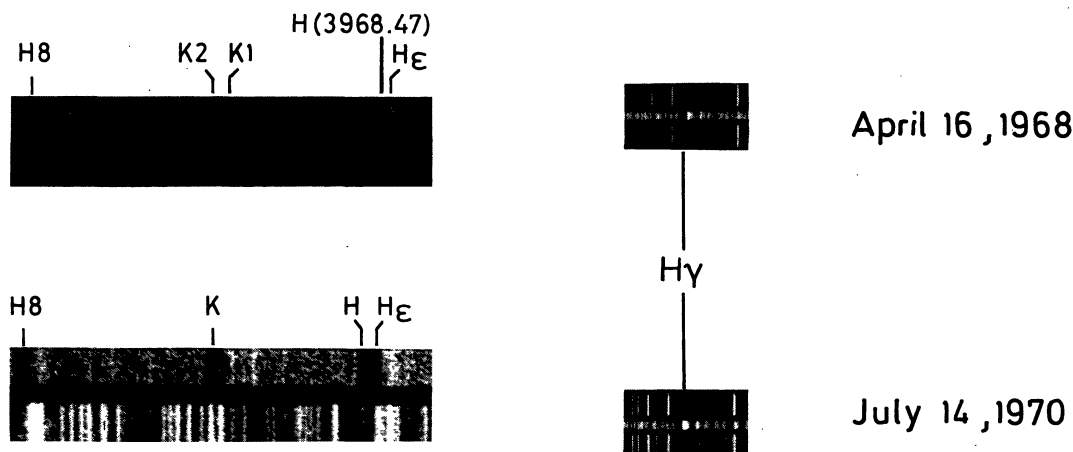


Fig. 5. Spectra of XX Ophiuchi in 1968 and 1970 show differences in the discrete absorption components of H and K, and in the profile of H_γ ,

G. The Case of XX Ophiuchi

In order to illustrate the correlation between the shape of the Balmer lines and the structure of H and K of Ca II in XX Ophiuchi Fig. 5 reproduces portions of 20 \AA/mm spectra obtained at the Observatoire de Haute Provence by Miss M. Bloch and one of the authors (J. P. Swings) in April 1968 and July 1970: it shows that in 1968 the K line had two components, whereas only one was visible in 1970. It is possible to explain such profiles as in the case of HD 190073 by observing the Balmer lines on the same spectra (see Fig. 5 for H_γ): the P Cygni absorption is much more displaced toward short wavelengths in 1970 than in 1968. In the upper spectrum the P Cygni absorption in H_ϵ causes a depletion of radiation that induces the accumulation of Ca^+ atoms at a velocity V_1 causing the first absorption component (H_1, K_1). The H_2, K_2 components result from the absorption due to an accumulation of Ca^+ atoms at saturation velocity, as in HD 190073. On the contrary, for the 1970 spectrum the P Cygni absorption in H_ϵ is much more blueshifted ($V_2 > V_1$): no depletion occurs for a velocity V_1 , but only for V_2 which in this case is close to the saturation velocity. Therefore

only one component (H, K) is present in the lines of Ca II on the 1970 spectrum of XX Oph.

H. Discussion and Conclusion

Because the assumptions made (collisions negligible in the Ca^+ extended atmosphere, consideration of only the H line of Ca II at 3933 \AA , ...) we do not intend to interpret with our very simple model all the details of the complex structure of the Ca II H and K lines in the May 23, 1950 spectrum of HD 190073, but only its main features, i.e. the H_2, K_2 and H_3, K_3 components. However, it seems convincing that the radiative forces, whose action is selective, constitute the basis phenomenon responsible for the ejection of Ca^+ atoms from the outer atmospheres of peculiar objects such as HD 190073. The mechanism for one atom is the following: a Ca^+ atom initially in equilibrium under the opposite forces of radiation and gravitation is ejected from the stellar extended atmosphere because of some instability. Because of its motion away from the star, the atom is under the influence of radiative forces that have

become greater than gravitation: such radiative forces act selectively on a Ca^+ atom via its characteristic resonance lines. A radiation depletion due to a blueshifted P Cygni absorption in the Balmer line H_ϵ will reduce the strength of radiative forces at a wavelength located in the violet wing of the Ca II H line. An accumulation of atoms at the corresponding velocity will lead to an absorption line, i.e. the H_2, K_2 component. Nevertheless, some atoms will overcome such a depression and will continue being accelerated until they reach the saturation velocity. At this velocity, there will be a second accumulation of atoms, giving rise to the H_3, K_3 component.

The velocity of escape from the gravitational field of HD 190073 is $V_\infty = \sqrt{2ga} \approx 760 \text{ km s}^{-1}$. Since the Ca^+ atoms reach only lower velocities, they will not leave the surroundings of HD 190073, and may form a Ca^+ rich envelope far from the star, perhaps partially at the origin of the observed infrared excess.

The fact that the profile of the Balmer line H_ϵ modulates those of Ca II appears to be observable in a series of stars having similarities to HD 190073 (infrared excess, P Cygni profiles of the Balmer lines). A typical example is illustrated in the case of XX Oph, where it is possible to explain the variations in the profile of the H- and K-lines of Ca II with the mechanism we developed for

HD 190073, i.e. the selective effect of radiative forces. It is our intention to monitor several stars showing variations in the profiles of their H- and K-lines in order to give further arguments in favor of the resonance scattering mechanism described in the present paper.

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