Rev. Mexicana Astron. Astrof., **20**, 7-14 (1990)

EVOLUTION OF THE Hα PROFILE OF THE BE STAR HD 184279[1]

M. Alvarez

Instituto de Astronomía, UNAM, Ensenada, B.C., México

D. Ballereau and J. Chauville

Observatoire de Paris, Meudon, France

Received 1989 May 25

RESUMEN

Damos un reporte de nuevas observaciones espectrales de la línea Hα de la estrella Be con envolvente (shell) tipo V/R, HD 184279. Las observaciones cubren parte de un ciclo que está alcanzando el estado de quietud de un período de actividad que comenzó cerca de 1971. El mecanismo físico para explicar las observaciones, sugiere que la dispersión electrónica es capaz de explicar las anchas alas de emisión en las líneas espectrales. Una pequeña, pero muy variable envolvente (shell), se encuentra alrededor de la estrella, probablemente en forma de un disco elíptico que aparece y se desarrolla durante una parte del ciclo. Un esquema con un disco excéntrico con semi-ejes de 2 y 15 radios estelares parece ser el adecuado para esta estrella, teniendo una masa de 10^{-9} masas estelares en esta envolvente.

ABSTRACT

We report new Hα spectral observations on the V/R Be and shell star HD 184279. The observations cover part of a cycle that is probably reaching the steady-state of an activity period that started around 1971. The physical mechanism that can explain the observations, suggests that electron scattering is responsible for the very large emission wings observed. A small and very variable shell is present around the star, probably in form of an ellongated disk that develops and grows during part of the cycle. A picture with an eccentric disk with semi-axis of 2 and 15 stellar radius seems to be adequate for this star. This envelope has a total mass of 10^{-9} stellar masses.

Key words: **RADIAL VELOCITIES – STARS-Be – STARS-VARIABLE**

I. INTRODUCTION

We are studying the profile variations of the Hα line of the Be shell star HD 184279 (V1294 Aql.) during different periods, since 1971. It has been irregularly but frequently observed, both in spectroscopy and photometry. Hα emission appeared between 1970 and 1971. Horn *et al.* (1982), observed a strong long term correlation between the photometric and spectroscopic variations, with a general trend showing that the radial velocity (RV) is close to minimum when the star is brightest and vice versa. Alvarez and Ballereau (1987), determined a period of 5.0 years, with a phase difference of 8.9 months (0.15 P), between the minimum of the radial velocity and the maximum of the light flux.

Recently, three papers have been published analysing the spectroscopic variations of this star: Ballereau and Chauville (1987*a*, Paper I), Ballereau and Chauville (1989, Paper II); Ballereau *et al.* (1987, Paper III). A good review of the published bibliography on this star is given on those papers, and their principal results can be summarized as follows:

a) The whole ensemble of shell lines shows a radial velocity variation with an amplitude of 85 km s^{-1}, and the photometric observations show an amplitude change $\Delta m(\lambda 5800 \text{ A}) = 0.4$ mag with the same periodicity of 5 years.

b) On July 1985, during a phase of positive RV, the shell hydrogen lines showed a duplicity

1. Based on observations collected at Haute-Provence Observatory (France), and San Pedro Mártir Observatory (Baja California, México).

and evolution that lasted 5 days. This has been interpreted as a travelling shock wave, that extends up to a distance of 5 R_*.

More recent high dispersion photographic spectra, taken at Haute-Provence (OHP) and San Pedro Mártir (SPM) observatories, show the continuous evolution of the star. Its monitoring will show us its future behaviour.

II. OBSERVATIONS AND REDUCTION OF SPECTROSCOPIC PLATES

a) *Summary of the Observations*

The spectra used in our study, are the Hα intensity tracings of July 1971, published by Svolopoulos (1975), the 15 spectra taken during the September-October 1983 survey at SPM observatory, (Paper III), and our new observations of July 1985 and September 1986, as shown in Table 1.

These observations were secured with an echelle spectrograph attached to the 2.12-m telescope of SPM observatory and with a spectrograph at the Coudé focus of the 1.52-m telescope of OHP. Details of the instrumental characteristics and the reduction methods have been described on Papers I and III.

b) *Accuracy of the Measurements*

In order to study the variability of the spectral features, we have to estimate the precision of our experimental technique and of our data processing for the reduction of the spectroscopic plates.

c) *Accuracy of the Intensity Determination*

The uncertainties result from two types of independent approximations: a) from the measurements of the photographic densities on the calibration plate, (due mainly to photographic noise), and b) from the approximation on the stellar continuum determination.

Our measurements made around the 'very intense' Hα line, give us an intensity precision of the order of 6% or better, (in only one case, we obtained a value of 8.7%). The stellar continuum for the spectra is obtained by a graphic method at the computer. We have tested the precision obtained in our measurements and found it better than 2% (in the wings of the Hα line, the difference between two independent measurements was smaller than 0.5%). As a result, we can determine our intensity measurements with an error smaller than 8 or 9% (this is indeed an upper limit considering the worst experimental conditions).

d) *Accuracy on the Determination of Radial Velocities*

In the first, place, we have to consider the errors due to the computation of the wavelengths of our spectra from the Argon spectral lines with a 4th degree polynomial used. The standard deviation goes from 0.005 to 0.011 A, that represents for the Hα region a precision better than 0.5 km s^{-1}.

For our spectral lines that show both emission and absorption, there are two main conditions to consider. For Vx and Vy (the intersection with the stellar continuum), their values come from the determination of the continuum only (a 2% precision, since the calibration affects equally the line profiles and the continuum). We also have to consider the slope of the line profile at these

TABLE 1

SPECTROSCOPIC PLATES USED

Plate No.	Observatory	Dispersion	Date	JD 2'400,000+	Time Exposure	Emulsion	Observer(s)
GA 700	OHP	20 A/mm	13-07-71	41145.473	120 mn.	103a-F	S.N. Svolopoulos
EA 210			28-09-83	45606			D.Ballereau
to	SPM	11 A/mm	to	to	90 mn.	09802	M.Alvarez
EA 228			03-10-83	45611			(7 spectra)
EA 238			09-10-83	45617			D.Ballereau
to	SPM	11 A/mm	to	to	90 mn.	09802	M.Alvarez
EA 285			13-10-83	45621			(8 spectra)
GB 8904	OHP	12.4 A/mm	17-07-85	46264.478	370 mn.	09802	J.Chauville
EA 467	SPM	11 A/mm	09-09-86	46682.651	70 mn.	09802	
EA 476	—	—	10-09-86	46683.646	70 mn.	—	
EA 485	—	—	11-09-86	46684.648	70 mn.	—	D.Ballereau
EA 494	—	—	12-09-86	46685.652	70 mn.	—	J.Chauville
EA 499	—	—	13-09-86	46686.653	78 mn.	—	M.Alvarez
EA 500	—	—	14-09-86	46687.638	70 mn.	—	J.P.Sareyan
EA 517	—	—	16-09-86	46689.655	60 mn.	—	
EA 529	—	—	17-09-86	46690.635	70 mn.	—	

intersection points {X and Y}. For our spectra, we found that for a variation of 0.02 in intensity, Vx varies by 2.5 km s^{-1} and Vy by 1.3 km s^{-1}. The difference Vx–Vy changes by 4 km s^{-1} approximately, since the error is the sum of these two quantities. Hence our radial velocities {Vx, Vy and Vx–Vy} are well determined to a precision of 3.0, 2.0 and 5.0 km s^{-1} respectively.

For the determination of the radial velocities from violet, absorption, and red features {Vv, Va Vr}, the precision comes from the photographic noise and the determination of the maximum (or minimum) of the adjusted parabola to the observed points. In the worst case, we have computed for our 8 spectra taken at SPM observatory a precision of 15 km s^{-1} for Vv, 6 km s^{-1} for Va and 8.5 km s^{-1} for Vr.

III. VARIATION OF THE Hα LINE PROFILE WITH TIME

We are studying the profile variations as a function of the phases reported in Papers I, II and III, and in Alvarez and Ballereau (1987), which show the radial velocity and light variations of the shell lines of the star mainly between 1976 and 1987.

1) Concerning the *long term variations*, both spectroscopical and photometrical, we can see that there has been no Hα emission from 1953 up to 1960, and the continuum fills-up at different epochs up to 1970, according to Hubert-Delplace and Hubert (1979). The light curve is decreasing, reaching a minimum around 1973.

The 'long term' spectroscopic changes are illustrated in our Figure 1, where we show a tracing of the Hα line. The principal features are: the violet (v) and red (r) emission components; the central absorption (a); the total width of the emission line (AB in km s^{-1}), and the full width at half maximum (MN in km s^{-1}) for the 1971 and 1983 spectra. Ve is the radial velocity of the ensemble of the emission line at midpoint between AB. For the 1985 and 1986 data, we also give the radial velocities of the points X, Y (intersection with the horizontal axis of intensity 1).

The first reported spectra of July 1971 (Svolopoulos 1975), shows two peaks with approximately the same intensity and the central absorption reaches the stellar continuum. The intensity of the Hα emission line continues to increase, reaching maximum in 1975 where strong shell lines of H, He and Fe are present. The photometry shows an increase of light intensity.

Between July 1983 and May 1984, a strong Hβ emission line develops, and at the same time the shell signature decreases. The 15 Hα profiles published in Paper III (Sept-Oct. 1983), show a strong

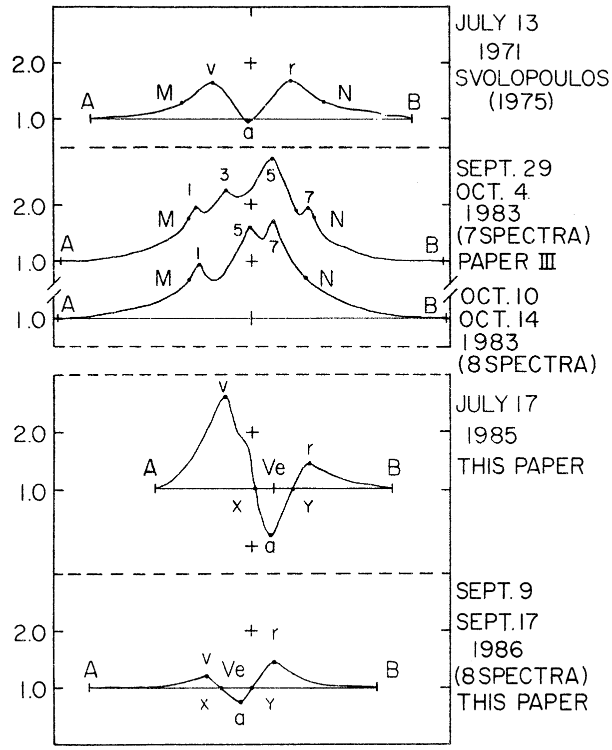

Fig. 1. The Hα line of HD 184279 at different epochs. From top to bottom, the July 13th, 1971 profile reported by Svolopoulos (1975), showing two symmetric emission peaks with V/R = 0.98. The following two tracings are the averages of the September 29th - October 4th (7 spectra) and October 10th - 14th 1983 (8 spectra), obtained at SPM observatory and reported on Paper III. There is only an emission line with several important features marked. The fourth trace corresponds to July 17th 1985, where the Hα line shows an 'anti P-Cygni' profile. The bottom trace is the smoothed average of the Hα line profile of our September 9 - 17th 1986 (8 spectra), observations where a 'P-Cygni' type profile is shown. These features are explained in the text. A very important change on AB (the total emission) of the Hα line is also present on the observations.

emission of a 'piramidal' shape with several variable features. The light curve is again in a descending phase after maximum in 1982, and the RV curve is reaching its maximum. McLaughlin (1961) points out a similar effect for other Be stars.

On July 1985, an 'anti P Cygni' profile is observed on the Hα emission line. It changes to a 'P Cygni' profile in 1986. A visual inspection of other spectra taken on 1988, shows an enhancement of this 'P Cygni' profile.

On Tables 2 and 3, we have the results for the Hα line observations. For the 1971 data, we expect important errors (of the order of 15 km s^{-1}), because we measured from the published tracings. The 1983 plates are separated in two series. Our observations of July 17th 1985 (Figure 2*a*) and the

TABLE 2

Hα EMISSION LINE PARAMETERS

PLATE No. DATE	Vv Iv	Va Ia	Vr Ir	V/R	d(e)	Wv	Wr	We	Wa	AB	MN	Ve
GA 700	-140.4	-10.5	137.4		278					1128	470	0
(07-71)	1.65	0.98	1.69	0.98		-2.67	-3.10	-5.77	—			
GB 8904	-97.0	67.0	192.2		289					836	—	76.9
(07-85)	2.61	0.19	1.46	1.79		-3.73	-1.41	-5.14	0.49			
EA 467 to	-164.4	-40.4	69.6		234					1014	—	-70.9
EA 529	1.18	0.72	1.44	0.82		-0.72	-1.11	-1.83	0.29			
(09-86)												
	V1 I1	V3 I3	V5 I5	V7 I7	d(e)	Wv	Wr	We	Wa	AB	MN	Ve
EA 210 to	-192.5	-90.2	72.4	190.0	—					1354	406	3.8
EA 228	1.95	2.28	2.83	1.90		—	—	-13.9	—			
(09-83)												
EA 238 to	-191.0	—	-13.0	72.70	—					1362	378	-0.8
EA 285	1.91	—	2.61	2.69		—	—	-15.1	—			
(10-83)												

TABLE 3

INDIVIDUAL MEASUREMENTS OF THE Hα LINE PROFILES

Date	Plate No.	Vv	Va	Vr		d(e)	Vx	Vy	Vy-Vx	Wv	Wa	Wr	Wv/Wr
(HJD 2'446,000+)		Iv	Ia	Ir	V/R								
17-07	GB 8904	-97.0	67.0	192.2		289	—	—	—				
1985	264.478	2.6	0.2	1.46	1.79					-3.73	0.49	-1.41	2.65
09-09	EA 467	-152.8	-43.6	73.6		226	-90.5	-10.1	80.4				
1986	682.651	1.17	0.75	1.45	0.81					-0.73	0.29	-1.21	0.60
10-09	EA 476	-166.9	-42.3	68.9		236	-97.2	-6.8	90.4				
1986	683.646	1.17	0.63	1.45	0.81					-0.71	0.37	-1.19	0.60
11-09	EA 485	-184.9	-36.9	73.6		259	-92.5	-3.4	89.1				
1986	684.648	1.19	0.70	1.48	0.80					-0.80	0.32	-1.20	0.67
12-09	EA 494	-156.8	-40.3	72.3		229	-92.5	-4.8	87.7				
1986	685.652	1.21	0.69	1.48	0.82					-0.77	0.35	-1.19	0.65
13-09	EA 499	-151.5	-40.3	70.2		222	-87.2	-6.8	80.4				
1986	686.653	1.18	0.73	1.44	0.82					-0.78	0.26	-1.09	0.72
14-09	EA 500	-189.0	-40.3	64.9		254	-97.2	-12.1	85.1				
1986	687.638	1.13	0.81	1.38	0.82					-0.58	0.18	-0.96	0.60
16-09	EA 517	-168.9	-35.6	64.9		234	-89.2	-6.1	83.1				
1986	689.655	1.17	0.74	1.38	0.85					-0.69	0.26	-0.92	0.75
17-09	EA 529	-144.1	-43.6	68.2		212	-89.2	-8.8	80.4				
1986	690.635	1.20	0.72	1.46	0.82					-0.73	0.28	-1.13	0.65

average of those from September 1986 (Figure 2*b* and Table 3), are given. The separation between the red and violet emission d(e) = Vr–Vv is shown in column 6. The other parameters are the same as described in Figure 1.

Several correlations can be found between the RV features and the light curve: the variable shell is small (it even disappears) when the RV is equal or close to zero in the ascending branch (1971 and 1983), while its presence is very important in the descending part of the curve (1985 and 1986). The distance between the emission peaks d(e) decreases by 20% between July 1985 and September 1986 during a positive RV phase. Although it is more difficult to observe on the Hβ profiles, because one of the emission components is frequently absent, we can see an increase on d(e) from mid-1979 to mid-1980, where we also measure positive RV, and find a more or less regular decrease from mid-1980 to mid-1983, where the shell lines have negative RV.

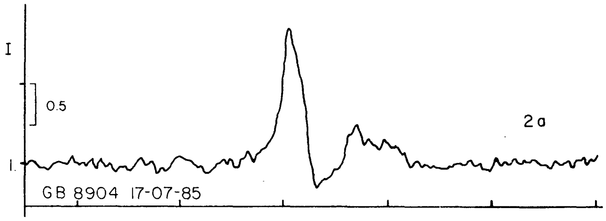

Fig. 2*a*. Hα line profile of HD 184279 on July 17th 1985, showing an 'anti P-Cygni' type profile with V/R = 1.79 and a weak red absorption component.

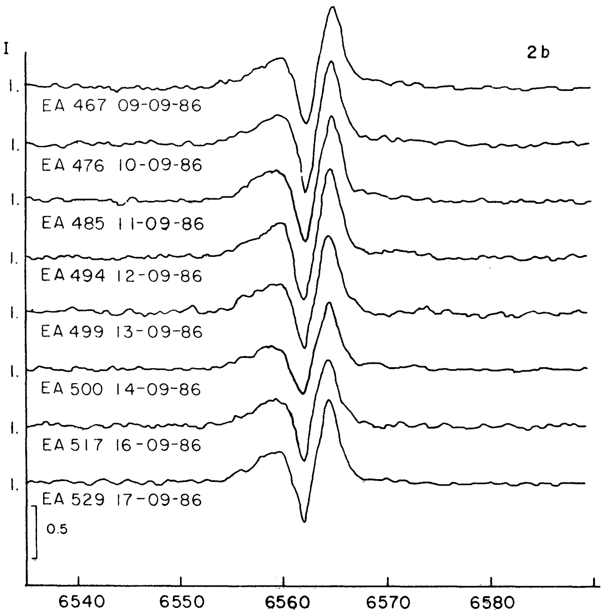

Fig. 2*b*. Hα line of the star between September 9th through September 17th 1986. A 'complex P-Cygni' type profile has developed. V/R = 0.73 and an important blue absorption component is shown.

The total width of the emission feature (AB), varies also by large amounts. It is very large on 1983 when there is no shell component on Hα. During 1971 its value is 83% smaller, it decreases to 75% on 1986 and it is only 61% on 1985, where there is a small shell absorption component on the Hα line. Adding these values to Figure 20, Paper III, we may appreciate a better correlation between {AB and V sin i} *during the shell phase* of the evolution of the star. As seems to be the case for the most active Be stars, we need to consider its particular stage, to understand the existing correlations found. This may give us an explanation for the lack of correlation reported by Doazan (1970), or the general trends found by Slettebak (1976) on wide emission lines associated to large values of V sin i, or those reported by Andrillat (1983) between AB and the spectral type.

During 1983, the full width at half maximum (MN), decreases by 15% to 20% of its maximum value of 1971. Dachs *et al.* (1986) have studied a sample of stars with V sin i between 100 and 400 km s^{-1} and found the same behavior for several Be stars.

The {I and We} of the Hα emission line decrease as the RV of the shell lines reaches a maximum on July 1985. During 1986, they become even smaller while the RV of the shell lines reaches a large negative value.

2) *Mid-term Variations* can be seen on our eight spectra taken at SPM, during September 1986, (Figure 2*b* and Table 3), where we give the {I, RV and W} for the features shown. These line profiles show a double peaked structure of a 'complex' P-Cygni type with a value V/R = 0.82 and a central absorption with a negative radial velocity Va = -40.4 km s^{-1}. Our measurements show that around May 15th 1986, the whole ensemble of shell lines have changed from positive to negative values of the RV. Similar profiles can be seen on other OHP spectra from October 1986. Although some trenus can be noticed, no real periodicities are found on these data. Probably a larger set of high quality observations and the use of 'linear' detectors, will give us better information on the study of daily changes.

3) *Short term Variations* are present on our September 1986 observations (Figure 2*b*, and can also be noticed on the 1983 data (Paper III). The precisi n of our measurements (paragraph b), allow us the following conclusions: the intensity of the violet and red peaks (Iv and Ir), remains constant (within 6%). However, the central absorption shows a significant variation (ΔIa = 25%) as do the equivalent widths for which the changes are: ΔWv = 30%, ΔWa = 65% and ΔWr = 26%.

Radial velocity variations of the different features indicated on our Figure 1 are real: RV of the points X and Y change by 10 km s^{-1} and by 8.7 km s^{-1} respectively. The violet peak shows a very important displacement Δ(Vv) = 44.9 km s^{-1}, while the central absorption and the red peak move within the limits of detection, with only Δ(Va) = 8.0 km s^{-1} and Δ(Vr) = 8.7 km s^{-1}. No possible 'short' periods can be obtained with this 'punctual' data. In order to obtain better information, one needs a 'continuous' coverage both in spectroscopy and photometry. The use of new observing techniques, including continuous coverage, and better detectors, will allow us to improve the study of these very interesting objects.

The very complex central absorption seen on our Hα spectra of July 17th 1985 (Figure 2*a*),

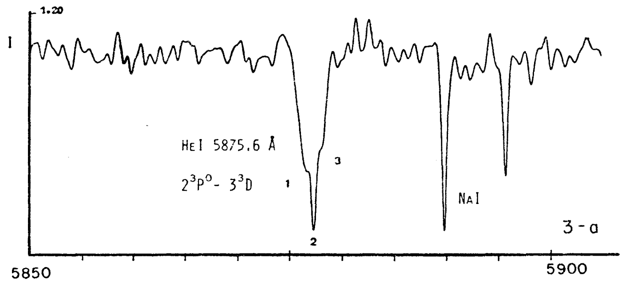

Fig. 3*a*. He I λ5875.6 A of HD 184279 on July 17th 1985, showing an important absorption I_{a2} = 0.88 with RV_{a2} = 84.4 km s^{-1}. The half-depth width is 109 km s^{-1}. A blue weak emission is present on this line with RV_v = −72.2 km s^{-1}, I_v = 1.1 and also an extended red emission is also detected with RV_r = 317 km s^{-1} and I_v = 1.1. Some other features can be detected on this line (see Table 4).

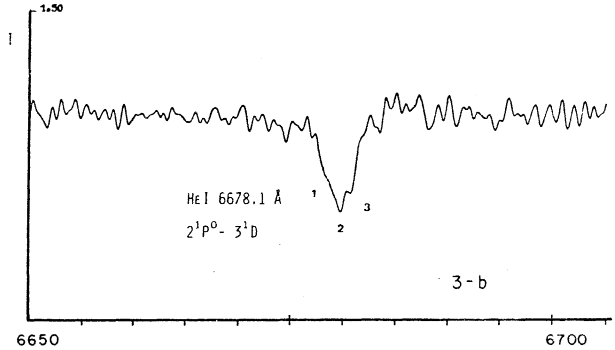

Fig. 3*b*. He I λ6678.1 A line of the same spectra. The absorption line is 'blue winged' with the maximum absorption having I_a = 0.48 and RV_{a2} = 75.0 km s^{-1}. The half-depth is 135.0 km s^{-1}. There is a slight blue emission component and a red emission feature is present with RV_r = 312.0 km s^{-1} and I_r = 1.06. On Table 4 are reported the values of the features marked.

supports the hypothesis of a travelling shock wave in the atmosphere of HD 184279 as observed by Ballereau and Chauville (1987*b*). They report a discrete hydrogen component on July 27th, that is well detached 4 days later. Our Hα spectra seems to be the beginning of this short lived episode. The central absorption is 'red-cored' and shows three discontinuities, with the following values for the radial velocity: RV_1 = 19.2 km s^{-1}, RV_2 = 67.0 km s^{-1} and the third (and less deep) is RV_3 = 110.7 km s^{-1}. From their Table III, we can recognize both the shell component and the shock wave component. The shock-wave component of the Hα line seems to be deeper than the Hβ and Hγ components.

IV. ANALYSIS OF THE HELIUM LINES ON THE SPECTRA OF HD 184279

Our figures 3*a* and *b*, show the intensity profiles of the helium lines λ5875.6 A (close to Na I) and λ6678.1 A, from our July 17th 1985 observations. In Table 4 we give the {RV, I and W} of the emission wings and central absorption features, and the FWHM (minimum). These are the first of the diffuse series (triplet and singlet) that are not very sensitive to broadening due to the Stark effect. Their wings seem to show, within the limits of detection, a very weak emission. The blue wing of λ5875 A is sharp and narrow, while the red wing of both lines is wide and diffuse. These absorption profiles show the following differences: the first (λ5875 A) is deep and symmetric, while the second (λ6678 A) is 'blue winged' and it shows two well marked discontinuities (2 and 3 in Figure 3*b* and an inflection point in the blue side (1 in the same figure). The emission of the He I lines is of course smaller than the Hα line.

There is a clear evidence of a velocity gradient on the shell emitting regions: the separation between the violet and red peaks for the first line is d(e) = 390 km s^{-1}; for the second is d(e) = 382 km s^{-1} while it is only d(e) = 289 km s^{-1} for the Hα line (Table 2). Helium lines are formed deeper in the atmosphere than the Hα lines. Hanuschik (1987), has found a similar effect for the stars o Pup and HR 4830.

TABLE 4*a*

INDIVIDUAL MEASUREMENTS OF HELIUM LINES

He I	Vv Iv	Va1 Ia1	Va2 Ia2	Va3 Ia3	Vr Ir	Wv	Wa	Wr	FWHM (MN)
5875.6 A	-72.2	55.2	84.4	119.7	317.7				
	1.10	0.59	0.88	0.48	1.10	-0.09	1.65	-0.25	109.0
6678.1 A	-70.2	17.9	75.0	114.9	312.0				
	0.99	0.31	0.48	0.38	1.06	—	1.49	-0.2	135.0

TABLE 4*b*

OTHER HELIUM, SODIUM AND IRON LINES

He I	Va1	Va2	Na I	Va1	Ia1	W	Fe III	Va1
4471.5 A	85.6	—	5890 A	-9.8	0.88	0.56	4419.6 A	95.5
4713.2 A	83.5	—	5896 A	-10.8	0.61	0.38	5127.3 A	88.4
4921.9 A	83.5	—					5156.0 A	78.1
5015.7 A	96.2	25.9						
5047.7 A	73.4	—						

The observed profiles of He lines in the visible-red spectra are less deep than those computed under LTE conditions, according to Leckrone (1971). These two He lines show a luminosity effect: the wing broadening is larger for class V than for class III; Underhill (1982) shows that a strong absorption of shell type for the lines coming from level 2 $^3p^0$ indicates the presence of a low density plasma (10^{13} cm^{-3}) at high temperature (2 to 5 × 10^4 K), at the external region of the shell. The He I (λ5876 A) line shown in Figure 3*a* follows the above criteria.

The effects of non-LTE on the equivalent widths, are smaller for He lines in the violet blue region, while the singlet lines are reinforced with respect to the triplets. Also, as we move towards the red, these non-LTE effects become more important. Although singlet lines are always reinforced, there is also an additional effect due to the effective temperature of the star, that does not allow the prediction of the line intensity. Auer and Mihalas (1973), using Norris (1971) results, show that the ratio of the equivalent widths of lines 5876 to 6678 A increases with effective temperature, when going from LTE to non-LTE conditions. For our results, this ratio is W(6678)/W(5875) = 0.90.

Other neutral helium lines are also observed on our spectra GB-9804. The line at 5015.7 A does not show the emission wing, while the absorption line shows two well separated components, with RV_1 = 96.2 km s^{-1} for the deepest and RV_2 = 25.9 km s^{-1} for the second one. The other helium lines are observed without emission, with blue winged profiles and a single absorption component, as we see from our Table 4*b*. These values also support the idea of a velocity gradient present in the atmosphere of the star.

V. STRUCTURE OF THE SHELL OF HD 184279

Following the first ideas of Struve (1931) and collaborators, we accept that Be stars are rapid rotators that eject mass in a regular fashion, mainly at the equatorial plane, forming a rotating cloud around the star. The spatial and temporal evolution of the envelope shows up as a series of emission and absorption lines in the *UV*, visible and *IR* part of the spectrum.

From the analysis of our data, we try to determine a physical model capable to explain (at least some of) the observed features.

a) The very broad emission wings observed, indicate that the electron scattering seems to be the dominant process in the envelope according to Poeckert and Marlborough (1979).

b) According to Hirata and Kogure (1984), the external radius of the shell that surrounds the star, can be estimated from the distance between the emission peaks d(e) of the first Balmer terms. For HD 184279 this quantity varies from 278 km s^{-1} in 1971, to 289 km s^{-1} in 1985 and decreases again to 234 km s^{-1} in 1986, showing a very variable and extended shell around the star.

c) From a comparison of AB (the maximum distance that defines the total emission of the Hα line) with V sin i, we can distinguish between a spherical shell or an ellongated disk around the star. When AB/2 > > V sin i, a ring is present around the star as is the case for HD 184279 where AB = 1358 km s^{-1} in 1983, it was reduced to AB = 836 km s^{-1} in 1985, larger than V sin i = 256 km s^{-1}. These observed changes can be interpreted as if the elliptic disk rotates around the star, maybe following the phase of the RV of the envelope.

d) The equatorial shell extension (SE), can be determined from the difference SE = {AB/2 – d(e)}. From our measurements, we have SE = 286 km s^{-1} in 1971, SE = 129 km s^{-1} in 1985 and it comes back to SE = 273 km s^{-1} in 1986. As for other quantities, these changes vary according to phase of the RV and light curves.

An *elongated disk model* has been proposed in Paper II from the analysis of the observations, considering two different epochs of the cycle of this star. Namely a non axisymmetric disk with internal and external semi-major axis of 2 and 15 R_* is computed. Our Hα observations strongly support this model.

Our 1985-1986 observations correspond to an epoch where the RV is decreasing, going from positive to negative values. From Figure 1 in Paper II, the ellongated disk is facing the observer. Our Hα line shows a very small intensity (only 40% to 50% of its 1983 value), with a small absorption displaced to the blue. We interpret this as due to the contribution of the shell absorption (there is a strong shell component of H, He and Fe lines) and a strong emission superimposed, giving as a net result the observed spectra. The spherical model does not fit the presence of the shell lines observed during this epoch.

When the RV is very small in the ascending part of the curve during 1983, the shell signature of the Hβ line is very weak. At this epoch, there are rapid and non-periodic variations of the very strong Hα line. From Figure 1 of Paper II, this corresponds to the epoch where the narrow part of the disk is facing the observer and consequently, the Hα emission line comes from the material surrounding the star.

During 1985, the lines have a shell component displaced to the red, as expected from the model. At this epoch, the ellongation of the extended disk as given by d(e) = 289 km s^{-1} is the largest of our observations.

Considering the above arguments, we can make a 'very crude' estimate of the material forming this elliptic disk. If we consider the disk as a slab with 'characteristic' dimensions of {5, 15 and 2} stellar radii, having an average density of 10^{11} to 10^{13} cm^{-3}, the total mass of this slab is only 10^{-10} to 10^{-8} stellar masses.

This work has been supported by Consejo Nacional de la Ciencia y Tecnología (CONACYT), Dirección Adjunta de Relaciones Internacionales (México), and Centre National de la Recherche Scientifique (CNRS), Direction des Relations et de la Cooperation International (France) under the program CONACYT-CNRS 140106G202-160. We wish to thank the staff of the Observatorio Astronómico Nacional, and the staff of the Haute Provence Observatory, where the observations were gathered. The facilities of the Computer Center of the Centro de Investigación Científica y Educación Superior de Ensenada (CICESE) and of Meudon Observatory are also acknowledged.

REFERENCES

Alvarez, M. and Ballereau, D. 1987, *Pub. Astr. Inst. Czechoslovakia*, **70**, Vol. 5, 63.

Andrillat, Y. 1983, *Astr. and Ap. Suppl.*, **53**, 319.

Auer, L.H. and Mihalas, D. 1973, *Ap. J. Suppl.*, **25**, 433.

Ballereau, D., Alvarez, M., Chauville, J., and Michel, R. 1987, *Rev. Mexicana Astron. Astrofis.*, **15**, 29 (Paper III).

Ballereau, D. and Chauville, J. 1987*a*, *Astr. and Ap. Suppl.*, *70*, 229 (Paper I).

Ballereau, D. and Chauville, J. 1987*b*, in *Physics of Be Stars, IAU Symposium No. 92*, eds. A. Slettebak and T.P. Snow (Cambridge: University Press).

Ballereau, D. and Chauville, J. 1989, *Astr. and Ap.*, **214**, 285 (Paper II).

Dachs, J., Hanuschik, R., Kaiser, D., and Rohe, D. 1986, *Astr. and Ap.*, **159**, 276.

Doazan, V. 1970, *Astr. and Ap.*, **8**, 148.

Hanuschik, R.W. 1987, *Astr. and Ap.*, **173**, 299.

Hirata, R. and Kogure, T. 1984, *Bull. Astr. Soc. India*, **12**, 109.

Horn, J. *et al.* 1982, *Bull. Astr. Inst. Czechoslovakia*, **33**, 308.

Hubert-Delplace, A.-M. and Hubert, H. 1979, *An Atlas of Be Stars*, Observatoire de Paris.

Leckrone, D.S. 1971, *Astr. and Ap.*, **11**, 387.

Mc Laughlin, D.B. 1961, *J.R. Astr. Soc. Can.*, **55**, 13 and 73.

Norris, J. 1971, *Ap. J. Suppl.*, **23**, 193.

Poeckert, R. and Marlborough, J.M. 1979, *Ap. J.*, **233**, 259.

Slettebak, A. 1976, in *Be and Shell Stars, IAU Symposium No. 70*, ed. A. Slettebak (Dordrecht: D. Reidel), p. 123.

Struve, O. 1931, *Ap. J.*, **74**, 225.

Svolopoulos, S.N. 1975, *Astr. and Ap.*, **41**, 199.

Underhill, A. 1982, in *B Stars with and without Emission Lines*, eds. A. Underhill and V. Doazan, CNRS and NASA.

M. Alvarez: Instituto de Astronomía, UNAM, Apartado Postal 877, 22830 Ensenada, B.C., México.

D. Ballereau and J. Chauville: Observatoire de Paris, Section de Meudon, F-92195 Meudon Cedex, France.