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The Hα behavior in bright giant stars*

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Abstract. We report high resolution spectroscopic observations of the Hα line profile for a sample of 32 bright giant stars with spectral type between F3 II and G5 II. By studying the link between the Hα behavior and the stellar rotation in such class of luminosity we have found no clear evidence that the rotational discontinuity established around F9 II is related with the Hα profiles. No emission features, neither time variations or asymmetries on the Hα line profiles have been detected for the bright giants analysed in the present work.

Key words: stars: chromospheres – stars: atmospheres – stars: activity – stars: rotation – lines: profiles.

1. Introduction

Several problems regarding the physical conditions within stellar upper atmospheres can be addressed from the study of Hα line profiles. These problems range from the nature of the heating mechanisms responsible for the observed chromospheric activity, to the detection of mass loss in stellar chromospheres, to the production of expanding circumstellar envelopes, to the transition regions. Some of these problems are of fundamental importance to stellar evolutionary models.

Over the past years many observational works have been devoted to the study of the Hα line behavior in evolved stars. A correlation between Hα profile and the Ca II H and K emission in late-type stars was first observed by Kraft et al. (1964). Because the Ca II K line was commonly used as a powerful chromospheric diagnostic, the Hα core was suggested by these authors to be formed in the chromosphere. Subsequent studies have confirmed this result, with the implication of a chromospheric component of the Hα line core, which in the cooler evolved stars completely dominates its photospheric counterpart (Reimers, 1973; Fosbury, 1973; Rodgers and Bell, 1968). Cohen (1976) has detected the presence of emission features at Hα in the spectra of globular cluster red giants. Such result was first interpreted as evidence for an expanding circumstellar envelope produced by mass loss. Further observations by several authors revealed that Hα emission wings are common in globular cluster giants (Mallia and Pagel, 1978; Peterson, 1982; Cacciari and Freeman, 1983; Gratton et al, 1984). A similar Hα emission behavior was found among metal-deficient giant stars (Dupree et al., 1984; Smith and Dupree, 1988). Dupree et al. (1984) have argued that the characteristic Hα emission wings in Population II stars can naturally originate in a warm chromosphere, particularly from relatively high dense regions. Important time variations of the Hα emission profile as well as asymmetries in the Hα core were in addition reported by Smith and Dupree (1988). These authors have argued that such asymmetries imply the existence of differential mass motions in the line-forming region. Furthermore they have proposed that the variability of the Hα emission profile results from fluctuations within the chromosphere, of the column density and/or the temperature gradient possibly as the result of pulsation. Different studies have also pointed out significant filling in of the Hα cores in very active evolved stars (Smith and Bopp, 1982; Fekel et al., 1986). This find is a strong support that chromospheric activity may therefore be also established by the presence of emission in the core of the Hα line. In fact, Strassmeier et al. (1990) have shown that the Hα activity-rotation relation is quite similar to that of the Ca II surface fluxes. More recently Mallik (1993) has reported that in late G- and K-type supergiants the Hα line core appears to be blueshifted, indicating an expanding outward chromosphere.

Concerning the evolved stars, all the previous authors have essentially observed subgiants and giant stars of luminosity class III. As one might see from the different works discussed above, the Hα spectra for bright giants, namely the luminosity class II, are still very scarce. Zarro and Rodgers (1983) have presented in their atlas some luminosity class II southern stars spectra. They have investigated widths and intensities of Hα profile and Ca II K emission but no obvious relationship between these two features has been established for bright giants and supergiants. Anyway it seems from their observations that the Hα line core is generally wider than a computed LTE photospheric profile. This excess seems to be correlated with the strength of the K_3 absorption in the calcium line profile which is supposed to be

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* based on observations at the Observatoire de Haute–Provence

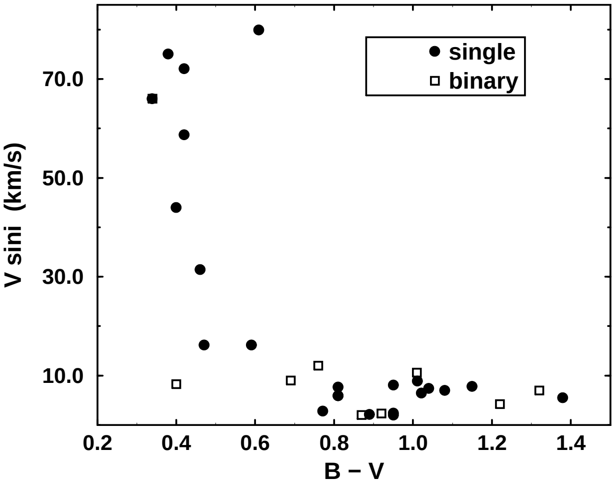

Fig. 1. Distribution of the projected equatorial rotational velocity Vsini as a function of (B−V) colour. The CORAVEL VSini values present an uncertainty of about 2.0 kms^{-1} for the bright giants with low to moderate rotation rates.

formed in layers located above those where Hα line core is formed.

Because of the very limited number of F-G bright giants included in these earlier surveys, we have obtained further Hα spectra for this class of luminosity. We want to know if spectral features associated to chromospheric activity or to mass loss process could be detected on these Hα profiles. Moreover De Medeiros and Mayor (1989, 1996) have measured very accurate rotational velocities for bright giant stars. These authors have defined a remarkable discontinuity in rotational velocity for such class of luminosity near the spectral type F9II. Its origin is not yet well understood but De Medeiros (1990) and De Medeiros and Mayor (1989) have proposed that such cutoff is the result of an age and mass mixing associated with the very short duration of the first crossing phase of F-G bright giant stars. Nevertheless one might also ask whether magnetic braking effects are also contributing for this rotational discontinuity and if such discontinuity is also reflected in the Hα behavior.

In the present paper, we attempt to establish the behavior of the Hα line profiles for bright giant stars located at the rotational discontinuity spectral region and through the Herztsprung gap. In particular we search for a possible link between rotational discontinuity and Hα behavior for bright giants into the spectral region F3II – G5II. In Sect. 2 we present the data sample and describe the observational procedure. In Sect. 3 we present and discuss the results of this survey. Finally, a summary is given in Sect. 4.

2. The observational data

2.1. Data sample

All single and some binary bright giants observed by De Medeiros and Mayor (1996) covering the spectral region between F3II and G5II, were selected for the present program. These stars are northern of -25 deg and have visual magnitudes lower than 8.5. This amounted to about 70 stars, but in the present work we discuss the observations for only 32 stars. Table 1 lists the program stars in order of increasing HD number. Additional information concerning the observed stars – such as spectral type, (B−V) index and duplicity – is also presented in Table 1. The spectral types are from the list of supergiants compiled by Egret (1980). Information on duplicity, when available, is taken from Batten et al. (1988) and De Medeiros and Mayor (1996). Rotational and radial velocities from De Medeiros and Mayor (1996) are also presented in Table 1. Let us recall here that these rotation measurements were obtained at the Observatoire de Haute Provence (OHP, France) by using the CORAVEL spectrometer (Baranne et al., 1979). As shown by De Medeiros (1990), from an external comparison with Fourier transform measurements, the CORAVEL rotation values for evolved stars present a typical uncertainty of about 1.0 kms^{-1}. However, for bright giant stars De Medeiros and Mayor (1996) have adopted, conservatively, an uncertainty of 2.0 kms^{-1}.

Table 1. Rotational and radial velocities for the program stars.

star	Sp. Type	(B − V)	Vrad kms^{-1}	Vsini kms^{-1}	spectro binary
HD 371	G3II	1.04	- 6.43	7.4	
HD 9900	G5II	1.38	-10.81	5.5	
HD 12568	G1II	0.76	8.28	12.0	sb
HD 13122	F5II	0.34	- 5.08	66.0	
HD 13437	G5II	1.22	9.60	4.2	sb
HD 14173	G5II	0.95	2.96	2.0	
HD 15000	F5II	0.40	-15.60	44.0	
HD 15784	F4II	0.47	1.60	16.1	
HD 20084	G3II	0.92	32.20	2.3	sb
HD 20123	G5II	1.15	1.17	7.9	
HD 23010	F5II	0.38	30.27	75.0	
HD 23230	F5II	0.42	- 9.91	58.7	
HD 26673	G5II	1.01	-17.58	10.6	sb
HD 34658	F5II	0.42	10.37	72.0	
HD 38232	F5II	0.69	- 4.77	9.0	sb
HD 39455	F5II	0.46	-13.99	31.5	
HD 41994	G5II	1.02	5.56	6.5	
HD 43282	G5II	1.32	- 2.90	7.0	sb
HD 45207	F8II	0.59	-35.96	16.2	
HD 52497	G5II	0.95	- 9.57	8.0	
HD 57048	G5II	0.95	- 2.04	2.3	
HD 57728	G2II	0.87	- 0.96	2.0	sb
HD 67542	G0II	0.81	19.37	5.9	
HD 68752	G5II	1.08	16.39	6.9	
HD 84441	G0II	0.81	4.61	5.9	
HD 85015	F3II	0.40	- 6.22	8.3	sb
HD 92125	G0II	0.81	- 8.49	7.7	
HD 101828	G5II	0.89	-17.05	2.1	
HD 101841	F3II	0.34	-13.15	66.0	sb
HD 106556	G5II	1.01	-21.76	8.9	
HD 114988	G2II	0.77	- 2.20	2.8	
HD 254429	F8II	0.61	4.26	80.0	

Let us recall that different studies have shown that the effects of the atmospheric turbulence in bright giant stars decrease from

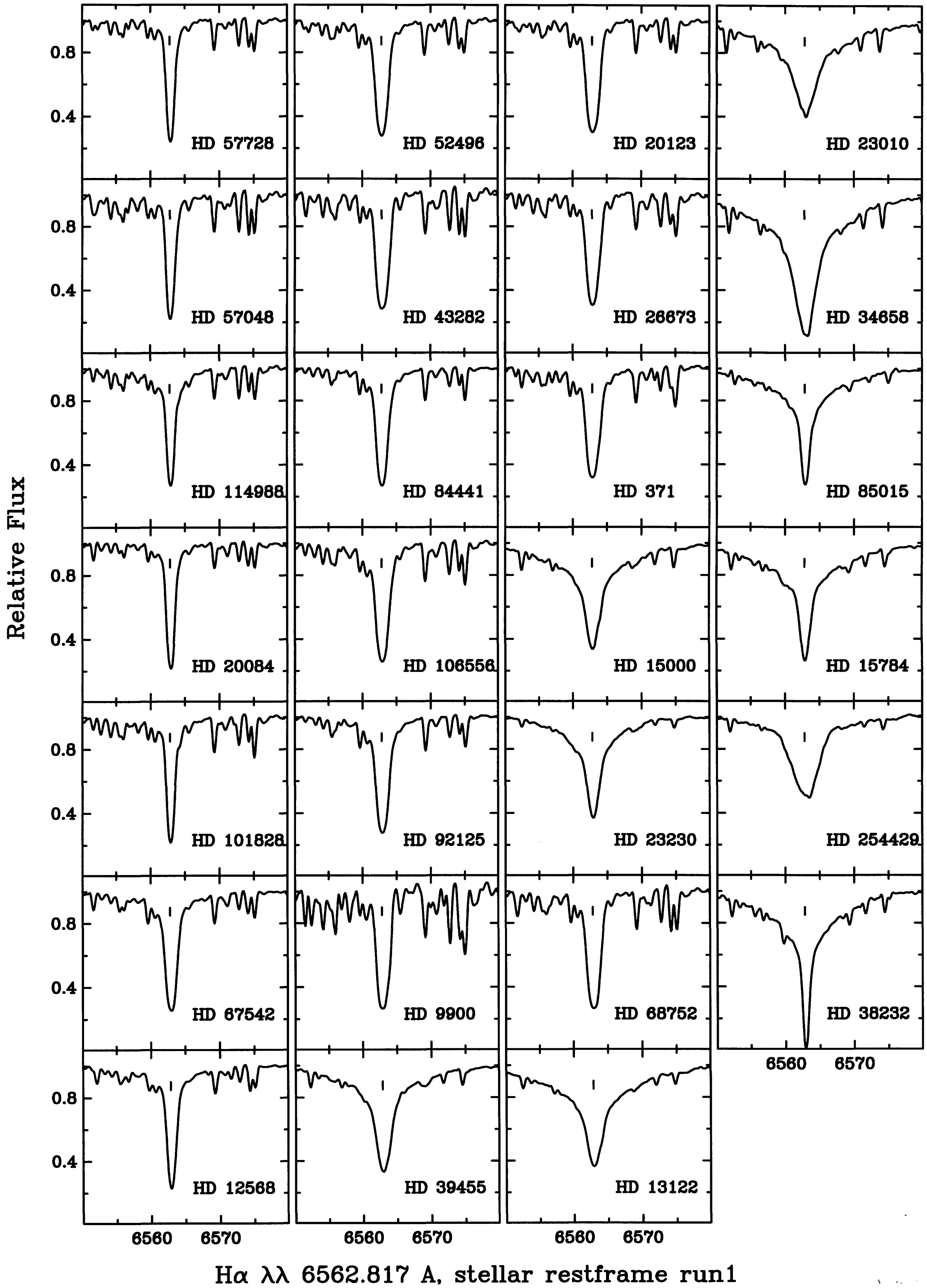

Fig. 2. Hα spectra for the 27 different stars observed during run1. Hα laboratory wavelength is indicated with the straight line.

Table 2. Journal of the spectroscopic observations

Ident	α_{1950}	δ_{1950}	Date run 1	HJD^a run 1	Exp. time (sec)	Date run 2	HJD^a run 2	Exp.time (sec)
HD 371	00 05 54.7	62 55 32	03/11/1991	327.29	2946	01/17/1992	639. 255	1800
HD 9900	01 34 50.2	57 43 25	03/11/1991	327.46	1800	01/17/1992	639.274	600
HD 12568	02 01 46.9	62 42 59	03/11/1991	327.35	7200	—	- —	—
HD 13122	02 06 50.1	59 44 41	03/12/1991	328.29	2400	01/17/1992	639.291	1200
HD 13437	02 09 54.2	58 57 44	—	—	—	01/31/1992	652.519	9409
HD 14173	02 16 02.3	59 46 59	—	—	—	03/18/1992	700.339	5400
HD 15000	02 23 44.7	58 52 57	03/12/1991	328.44	7200	01/29/1992	651.488	6113
HD 15784	02 31 25.6	68 09 00	03/10/1991	326.45	3300	03/18/1992	700.403	3600
HD 20084	03 20 06.2	84 44 23	01/15/1991	272.36	984	01/17/1992	639.352	900
HD 20123	03 12 36.9	50 45 13	01/15/1991	272.34	763	01/17/1992	639.341	400
HD 23010	03 38 51.2	-11 57 46	03/09/1991	325.30	5400	01/17/1992	639.317	2700
HD 23230	03 41 47.2	42 25 19	01/16/1991	273.43	361	01/17/1992	639.366	244
HD 26673	04 11 28.7	40 21 31	01/16/1991	273.45	1870	01/17/1992	639.447	400
HD 34658	05 16 34.5	02 32 43	03/10/1991	326.36	827	01/17/1992	639.458	900
HD 38232	05 42 20.6	29 16 43	03/10/1991	326.39	3600	03/24/1992	706.334	9000
HD 39455	05 50 31.1	18 09 36	03/11/1991	327.42	3600	—	- —	—
HD 41994	06 06 18.4	27 12 11	—	—	—	03/18/1992	700.465	5400
HD 43282	06 13 12.4	19 04 21	03/09/1991	325.26	4500	01/17/1992	639.492	3600
HD 45207	06 24 18.9	29 40 23	—	—	—	01/30/1992	651.600	7286
HD 52497	06 59 21.9	24 17 17	03/09/1991	325.41	644	01/17/1992	638.657	900
HD 57048	07 17 17.5	16 14 01	03/10/1991	326.49	2100	01/18/1992	639.560	2400
HD 57728	07 20 10.3	15 27 19	01/17/1991	273.57	7200	01/18/1992	639.528	1800
HD 67542	08 06 30.0	29 14 24	03/11/1991	326.53	2700	01/18/1992	639.588	1600
HD 68752	08 11 01.9	-15 38 09	03/09/1991	325.43	1166	01/18/1992	639.614	1800
HD 84441	09 43 00.9	24 00 18	01/17/1991	273.62	112	01/18/1992	639.631	100
HD 85015	09 47 10.3	44 14 05	03/09/1991	325.49	6000	03/03/1992	684.588	10800
HD 92125	10 35 54.6	32 14 10	01/17/1991	273.63	447	01/18/1992	639.636	400
HD 101828	11 41 23.3	82 35 54	03/11/1991	326.64	5400	03/04/1992	685.630	7200
HD 101841	11 40 46.2	28 19 55	03/10/1991	325.55	3600	01/17/1992	638.685	3600
HD 106556	12 12 46.2	47 23 36	03/11/1991	326.57	3600	01/31/1992	652.608	3978
HD 114988	13 11 24.3	32 47 13	01/17/1991	273.67	2766	01/18/1992	639.650	1800
HD 254429	06 13 59.6	12 05 30	03/12/1991	328.44	7200	—	- —	—

[a] Heliocentric Julian Day: + 2 448 000.00

the F to the K spectral region, indicating that turbulence affects mostly the rapidly rotating stars, which are particularly F-type stars (Gray and Toner, 1986; De Medeiros, 1990).

2.2. Spectroscopic data

The stars were observed during two different double runs in January/March 1991 (run 1) and in January/March 1992 (run 2) at the 1.52 m telescope of the Observatoire de Haute Provence (OHP). The AURELIE spectrometer (Gillet et al., 1994) was used at the Coudé focus with a 1200 lines/mm grating in the first order. The detector consists of two independent arrays of 2048 photodiodes (pixel size: 13 X 750 μm).

The central wavelength was chosen to be 6620 Å so as to observe through the same spectral region both Hα and Li I 6707.81 Å lines. Results concerning the lithium line in these bright giant stars will be presented in a forthcoming paper. The resolution (FWHM of thorium lines) was close to 0.278 Å around our chosen central wavelength (6620 Å). The resolving power (R = $\lambda/\Delta\lambda$) was about 24,000 and the signal to noise ratio between 90 and 150. Table 2 lists the journal of these observations. Note that only 25 stars over 32 from our observational program were observed during both runs.

The data were processed with the ESO IHAP software at the Institut d'Astrophysique de Paris and were analysed with the eVe software at the GRAAL institute of Montpellier. The wavelength calibration was performed with a dispersion curve determined from at least 30 thorium lines over a 210 Å spectral range. The internal accuracy is always less than 6mÅ (rms). The contribution to the earth's motion to the observed radial velocities was calculated from the BARVEL subroutines (Stumpff, 1980). Finally a pseudo–continuum has been determined and removed from each spectrum. The wavelength scale has been also transformed into the stellar rest frame; for that purpose we used the radial velocity determined from CORAVEL observations (and displayed in Table 1). Because of the high precision of the CORAVEL spectrometer for radial velocity measurements on cool stars, leading to uncertainties of about 0.3 kms^{-1} for low and moderate rotators, here we used the radial veloc-

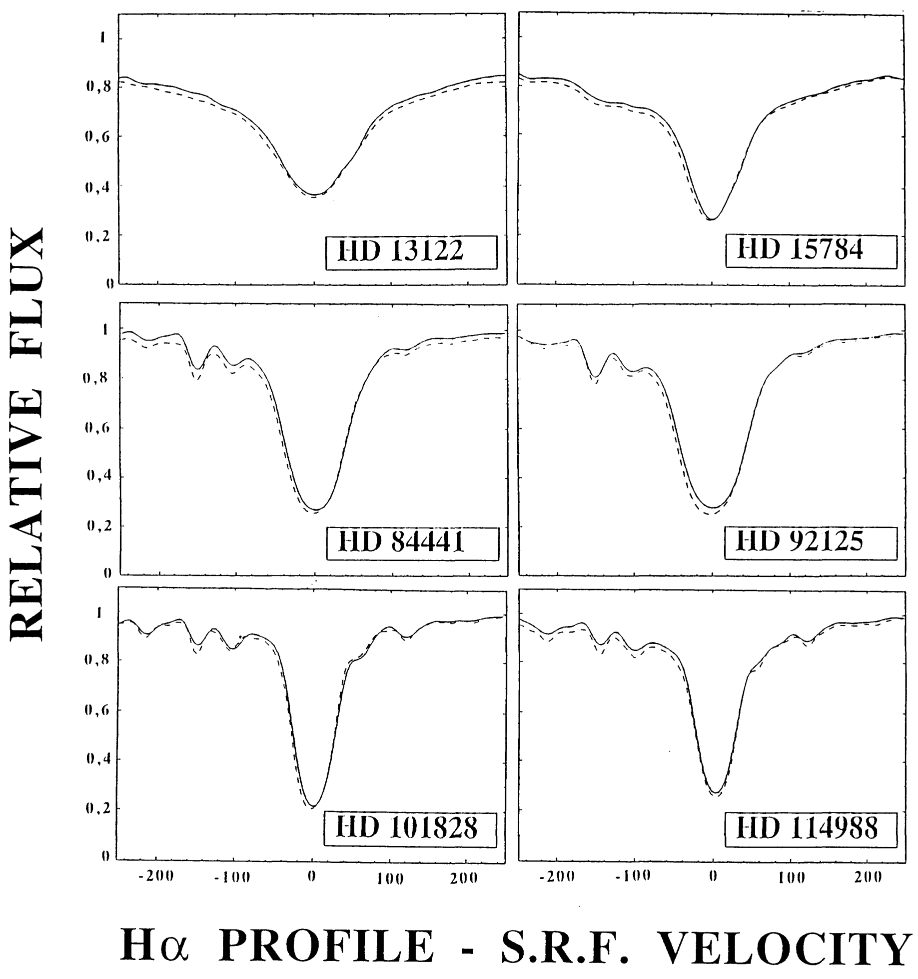

Fig. 3. Comparison of Hα profiles for 6 stars observed during the two runs. Zoom has been performed so as to present the symmetric shapes of the lines. Full and dashed lines refer respectively to observations taken during the first (1991, January & March) and second (1992, January & March) run. Note that the X-axis refers to the Stellar Rest Frame velocity values.

ity values obtained with such spectrometer and not those from photospheric lines or from the Hα core, which, very probably, present errors higher than 0.3 kms^{-1}. With such CORAVEL precision, pulsation and binary variability can be easily detected. As pointed out by De Medeiros and Mayor (1996) all the stars were observed at least twice, separated by approximately one-year intervals, to search for spectroscopic variability (due to pulsation or binarity). For a few stars (mentioned in the last column of Table 1) binarity has been detected. Further, we have observed no clear sign of pulsation, which is confirmed by the Hα profiles discussed in Sect. 3.

3. Results and discussion

3.1. The rotational discontinuity

Fig. 1 presents the behavior of the distribution of projected equatorial rotational velocity Vsini as a function of (B−V) index colour. The well defined rotational discontinuity near B−V = 0.65 (F8II – F9II), established by De Medeiros and Mayor (1989) is very clear, despite the size of the sample used here (32 stars only). On the right side of such rotational discontinuity all single stars studied here have Vsini lower than about 10 kms^{-1}. In fact, as shown by De Medeiros (1990) to the right of this discontinuity single bright giant stars presenting high rotation rates are unusual. To the left of such discontinuity the Vsini values range from a few kms^{-1} to about 100 kms^{-1}. As proposed by De Medeiros and Mayor (1989, 1996) evolutionary effects and a mixing of populations seem to be the origin of such discontinuity. Indeed blue loops become important for stars with mass larger than about 4 $M_{\odot}$ and then a fraction of slowly rotating bright giants may be in blue loops evolutionary stage. A strong observational evidence supporting the proposition by De Medeiros and Mayor (1989, 1996) is presented by Barbuy at al. (1996). These authors have found that, among the low rotators F-G yellow supergiants located into the rotational discontinuity spectral region, a fraction of them shows no dredge-up mixing, and another fraction does show dredge-up mixing effects, probably depending on their evolutionary stage.

3.2. The Hα profile

What is the Hα behavior for bright giant stars situated in the spectral region of the rotational discontinuity?

One might also ask whether the behavior of the Hα profile is affected by rotation.

Fig. 2 shows the Hα spectra for 27 of the stars observed during our first run (1991, January and March). Only HD 101841 is not displayed there because already discussed in a previous paper (De Medeiros et al., 1994). For each star presented in Fig. 2 the Hα profile is deep in absorption and rather well symmetric. In addition one sees no sign of emission on the Hα wings. The large majority of the stars have been also observed during the second run (1992, January and March) but no drastic variation in the shape of the profiles has been detected from one run to the other, with one-year interval. Fig. 3 presents some comparative profiles from both observational runs. Only two stars, HD 13122 and HD 15784 show a tendency for a weak asymmetric shape in the core of the line. These results are, in fact, in contrast with those ones for metal-poor field red giants and globular cluster red giants for which strong emission in the wings of the Hα absorption line as well as asymmetries in the core of this line are found to be quite common (Smith and Dupree, 1988; Cohen, 1976; Gratton et al., 1984). Because the stars observed in the present work are essentially of the population I our find seems to indicate that emission in the wings of the Hα absorption line is not prevalent among population I bright giant stars. Let us recall that such emission is attributed to be most likely chromospheric in origin (Dupree et al., 1984). In addition, it seems important to point out that emission in the core of the CaII K chromospheric line is relatively common among metal deficient field red giants (Smith et al., 1992).

In Table 3 we report the width (FWHM in kms^{-1}) and shift measurements on the Hα lines. One sees no significant blueshift from the present data. It is interesting to underline that, despite the limited number of binary stars, the different results presented in this work indicate that binarity per se within the F- and G-types bright giants plays apparently no role on the behavior of the Hα profile. All the observational works refer, in particular, for low rotator stars, with a very limited number of bright giants. This fact prevents a more conclusive analysis on the Hα behavior in this class of luminosity as well as a comparative study with the present results.

3.3. The rotational discontinuity and the behavior of the Hα profile

A rapid inspection of the Vsini values given in Table 1 shows that our sample of stars presents a range of rotational velocities from a few kms^{-1} to about 80 kms^{-1}. A comparison of these Vsini values with the spectra given in Fig. 2 shows clearly the effects of rotation on the width of the Hα profile, but in spite of this fact there is no clear link between rotation and the shape of the profiles. In particular, there is no link between rotation and emission features in the observed stars. Fig. 4 shows the widths (FWHM) of the Hα profile as a function of the colour index (B−V). In the spectral region of the rotational discontinuity, namely for (B−V) around 0.60, one sees a gap in the distribution of the widths (FWHM). May we consider that such a gap indicates a discontinuous change in the characteristical activity of bright giants, which would be associated with the rotational discontinuity? Of course, one can also inquire that this gap is not just an artefact resulting from the limitation of the present sample. In Fig. 5 we present the logarithm of the rotational velocity versus the logarithm of the widths (FWHM), which seems to indicate that the effects of rotation on the width of the Hα profile follow the same trend independently of the location of the star: before (F stars) or after (G stars) the rotational discontinuity.

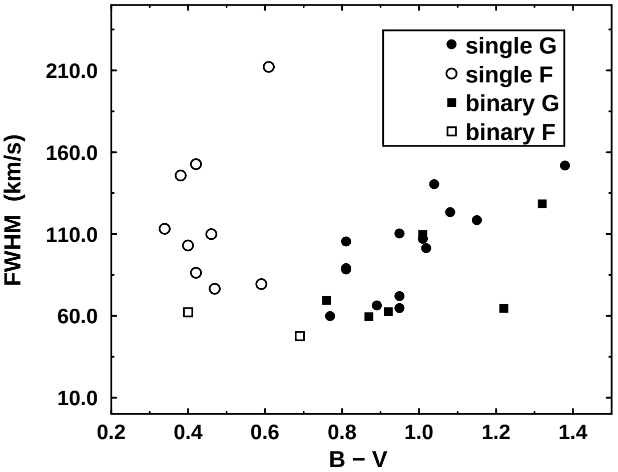

Fig. 4. FWHM (in kms^{-1}) of the Hα profile as a function of (B−V) colour.

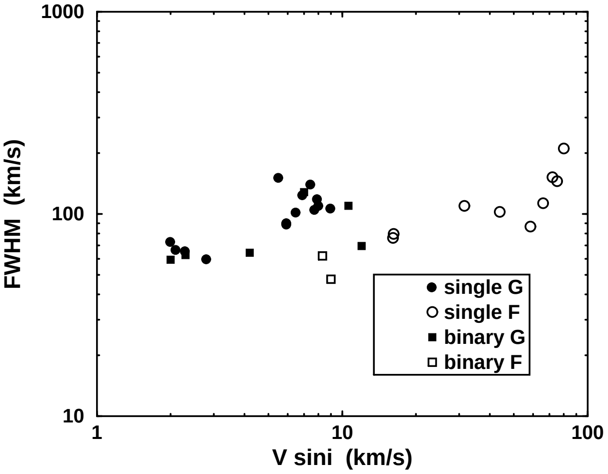

Fig. 5. The FWHM of the Hα line as a function of the rotational velocity.

4. Summary

High precision Hα spectra were obtained for 32 F– and G–type bright giant stars presenting low to moderate rotational velocities. No emission has been detected on the Hα profiles of the observed stars. No variation in the shape of the Hα profiles has been detected from one run to the other one, separated by one year. No obvious link between the rotational discontinuity around the spectral type F8II and the shape of the Hα profiles can be established. Despite these finds one can not establish the level of chromospheric activity in bright giant stars located around the spectral region of the rotational discontinuity, namely late-F and early-G bright giants. Maybe the Hα profile is not a relevant diagnostic for the chromospheric activity in such spectral inter-

Table 3. Spectroscopic measurements on Hα profiles (from the data of run 1, except the stars labelled with $*$ for which the measurements are referring to the data of run 2).

star	Shift kms^{-1}	FWHM kms^{-1}
HD 371	1.70	140.24
HD 9900	2.10	151.66
HD 12568	1.56	69.43
HD 13122	1.29	113.29
HD 13437*	0.04	64.41
HD 14173*	1.34	72.17
HD 15000	1.05	102.78
HD 15784	1.52	76.29
HD 20084	1.52	62.58
HD 20123	1.65	118.31
HD 23010	0.96	145.72
HD 23230	1.47	86.34
HD 26673	1.74	109.63
HD 34658	0.47	152.57
HD 38232	1.56	47.51
HD 39455	1.25	110.09
HD 41994*	4.66	101.41
HD 43282	2.14	128.36
HD 45207*	4.13	79.48
HD 52497	-1.65	110.55
HD 57048	1.61	64.87
HD 57728	1.47	59.38
HD 67542	1.61	89.53
HD 68752	1.70	123.79
HD 84441	1.65	88.16
HD 85015	1.43	62.12
HD 92125	1.56	105.52
HD 101828	1.34	66.69
HD 106556	1.87	106.89
HD 114988	3.48	59.84
HD 254429	0.42	211.96

val studied here. In this sense, the observation of Ca II H and K lines may be very useful for the study of the diagnostic of the chromospheric activity in bright giants and for the study of the link between rotation and activity in such class of luminosity, in particular in the spectral region of the rotational discontinuity.

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