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K- and L-band spectroscopy of Be stars

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Abstract. We describe the behaviour of IR hydrogen emission lines of a sample of Be stars and discuss the physical properties of the circumstellar envelopes of Be stars classified in Groups I and II (Mennickent *et al.* 2009). We find that while Humphreys and Pfund lines of Group I stars form in an optically thick envelope/disk, Group II stars show Pfund lines that form in an optically thick medium and Humphreys lines originating in optically thinner regions. The transition between Groups I and II could be understood in terms of the evolution of the circumstellar disk of the star and might bring clues on the mechanism originating the Be phenomenon.

Keywords. stars: emission-line, Be, circumstellar matter

1. Introduction

Be stars have a circumstellar envelope revealed in the infrared through moderate flux excesses and the appearance of hydrogen recombination lines. K- and L- band spectra of Be stars present numerous lines of Pfund (Pf), Humphreys (Hu) and Brackett (Br) series. Their profiles are sensitive to the physical properties and dynamical structure of the line-forming regions and thus become useful probes of circumstellar environments. An inspection of the L-band hydrogen spectra of Be stars allows a classification in three groups following Mennickent *et al.* (2009): Group I contains the stars with Brα and Pfγ equally intense as Hu lines, Group II consists of those with Brα and Pfγ more intense than Hu lines, and Group III is made up of those with no detected emission. This classification scheme reflects the optical depth conditions in the Be star envelope. Group I stars have a more compact Hu line-forming region than Group II stars, whereas Group III stars might have lost their envelopes (Mennickent *et al.* 2009, Granada *et al.* 2010). In this work we analize K- and L- band spectra of a sample of 26 B-type emission line stars (see Table 1) and relate them to the optical depths of their line-forming regions.

2. Results

We show the line fluxes of Hu and Pf lines relative to a reference transition (Fig. 1), for the stars in Table 1. The continous lines indicate the optically thin limit predicted by Menzel Case B recombination theory while the dashed line represents the thick case.

Hu and Pf lines of Group I stars come from an optically thick envelope (Figs. 1.1a and 1.1b). Fig. 1.2a shows the range of Hu line flux ratios covered by Be stars of Group II. In some cases these ratios are close to Menzel Case B, whereas some objects depart from this case. Pf line ratios (Fig. 1.2b) correspond to an optically thick envelope. B[e] stars have Hu and Pf line ratios (Fig. 1.3), close to those of Menzel Case B, likely to form in an isothermal stellar wind (Lenorzer *et al.* 2002a).

Table 1. Sample. a)Lenorzer *et al.*(2002b); b)Mennickent *et al.*(2009); c)Granada *et al.*(2010)

Star (HD)	Name	S.T.	Group	Ref	Star (HD)	Name	S.T.	Group	Ref
	MWC349A	O9III[e]	II	a	120991	V767 Cen	B3IIIe	I	b
5394	γ Cas	B0IVesh	II	a	148259	OZ Nor	B2II	I	b
20336	BK Cam	B2.5 Ve	I	c	162732	88 Her	Bpshe	I	c
23862	28 Tau	B8 IVev	II	c	164284	66 Oph	B2Ve	II	c
29441	V1150 Tau	B2.5Vne	I	b	178175	V4024 Sgr	B2V	I	b
45677	MWC 142	B2V[e]	II	a	183656	V923 Aql	Bpshe	II	c
50013	κ CMa	B1.5IVne	I	a	186272	V341 Sge	B2.5V	II	b
56139	ω CMa	B2IV-Ve	II	a	187811	12 Vul	B2.5Ve	I,II	a,b
93308	η Car	Bpe	II	a	191610	28 Cyg	B2.5Ve	II	a,c
94910	AG Car	B2pe	II	a	193237	P Cyg	B2pe	II	a
105521	V817 Cen	B3 IVe	I	b	200775	MWC 361	B2V[e]	II	a
105435	δ Cen	B2IVne	II	b	209409	omi Aqr	B7IVe	II	a
120324	μ Cen	B2IV-Ve	II	b	217050	EW Lac	B3 IVshe	II	c

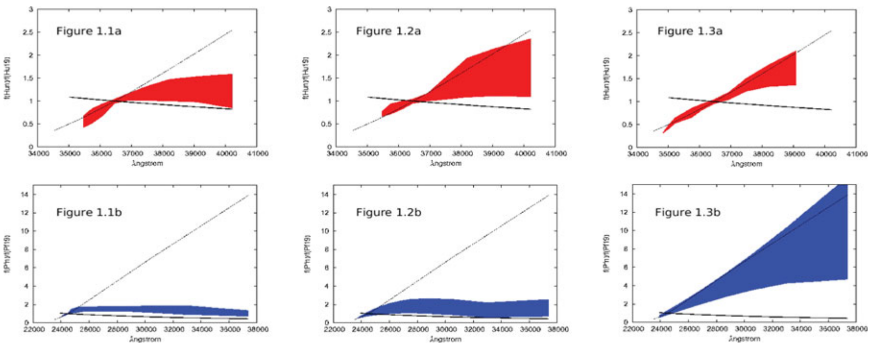

Figure 1. Line Flux Ratios: 1) Group I; 2) Group II; 3) Other emission lines

3. Discussion

Most of the objects in Table 1 are B2-3 type stars. Thus, if we consider similar central stars, the differences observed in the IR spectra evidence differences in the line-forming regions. We obtain a rough estimate of the column density of atoms in the lower excitation level (that is N_6 for Hu lines and N_5 for Pf lines) as well as the relative extension, Δr of the forming region of Hu (R_{Hun}/R_{Hu16}) and Pf (R_{Pfn}/R_{Pf16}) lines, using line flux ratios (Granada *et al.* 2010). We find that for Group I stars the Hu line-forming regions seem to be more dense and compact than those for Group II stars; whereas the mean column density obtained for Group I stars ranges from 1.2 to 3.7×10^{14} cm^{-1} and Δr from 0.38 to 1.28, for Hu_{18} to Hu_{14}, Group II stars have column densities from 0.22 to 1.39×10^{14} cm^{-1} with Δr from 0.28 to 1.90 for the same lines. Moreover, higher members of Pf series for B2 stars of both Groups also form in compact and dense regions.

Many Be stars of our sample show strong spectroscopic variability. For 12 Vul and 28 Cyg, we reported changes from one Group to another, which are possibly indicating structural changes in the circumstellar environment (Mennickent *et al.* 2009, Granada *et al.* 2010). Time resolved near-IR spectroscopy of Be stars would allow us to study the origin and evolution of the envelopes as well as to set constraints to different models.

References

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