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# Line identification in the Ca II K spectral region of sharp-lined B-type stars

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**Abstract.** Previous Ca II K observations of the B-type star HD 83206 have revealed putative high-velocity interstellar clouds (HVCs) at Local Standard of Rest (LSR) velocities of $-80$ and $-110\,\mathrm{km\,s^{-1}}$. Similar results were also found for the sightline towards HD 135485. In this article, we show that these absorption lines are in fact due to stellar S II features. As the Ca II K absorption line in B-type stars is often used to assess the presence and distance of HVCs, we also present a very high quality spectrum of HD 83206 in the Ca II K region ($\sim\pm4$ Å or $\pm300\,\mathrm{km\,s^{-1}}$), so that in the future confusion between stellar lines and HVC features may be avoided.

**Key words.** line: identification – stars: early-type – stars: individual: HD 83206; HD 135485 – ISM: individual object: high-velocity clouds

## 1. Introduction

High-velocity clouds (HVCs) are defined as clouds whose radial velocities cannot be explained by any reasonable model of differential Galactic rotation. B-type stars, or evolved spectral analogues of these objects, such as post-Asymptotic Giant Branch (PAGB), Blue Horizontal Branch (BHB) and early-type subdwarf stars (sdB), are often used to search for such clouds because (i) their spectra are relatively free of stellar absorption lines compared to late-type stars, (ii) they often have large projected rotational velocities ($v \sin i$) that broaden the stellar photospheric lines, (iii) their high luminosities allow them to be used to investigate HVCs at distances of tens of kpc, and (iv) simple spectral analyses lead to accurate distance determinations. Distance determinations are particularly important for HVCs since without this quantity the origin and physical structure remain largely unknown (see e.g. Wakker & van Woerden 1997).

Ryans et al. (1997) observed the B-type star HD 83206 in the Ca II K spectral region, along with other stars, to constrain the distances of the HVCs Chain A and Complex M (LSR velocities between $-80$ and $-140\,\mathrm{km\,s^{-1}}$; see van Woerden et al. 1999a). Further studies were performed by Lehner et al. (1999) to study the substructure of these clouds. HVCs towards HD 135485 were detected by Albert et al. (1993) in their high-resolution survey of Galactic halo gas. However follow-up IUE observations of this star did not show any HVC absorption in the strong ultraviolet resonance lines (Danly et al. 1995).

HD 83206 and HD 135485 both have very low values of $v \sin i$, making it difficult to differentiate stellar and high velocity interstellar components. In this short note, we show that the blue-shifted (with respect to Ca II K) features detected in the spectra of these stars are in fact sharp ($v \sin i < 6\,\mathrm{km\,s^{-1}}$) S II stellar lines. A very high quality spectrum of HD 83206 is presented to circumvent future ambiguity between interstellar and stellar lines in the Ca II K wavelength region.

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## 2. HD 83206 and HD 135485

HD 83206 is classified as a B2 V star (Lehner et al. 2000), while HD 135485 is a peculiar metal-rich evolved B-type star (Trundle et al. 2001; but see also Dufton 1973; Schönberner 1973). These stars have the similar property of very narrow photospheric metal lines. For HD 83206, Lehner et al. (2000) showed that $v \sin i = 5\,\mathrm{km\,s^{-1}}$, or even less if the microturbulence is considered, while for HD 135485 the $v \sin i$ is about $3\,\mathrm{km\,s^{-1}}$ (Trundle et al. 2001).

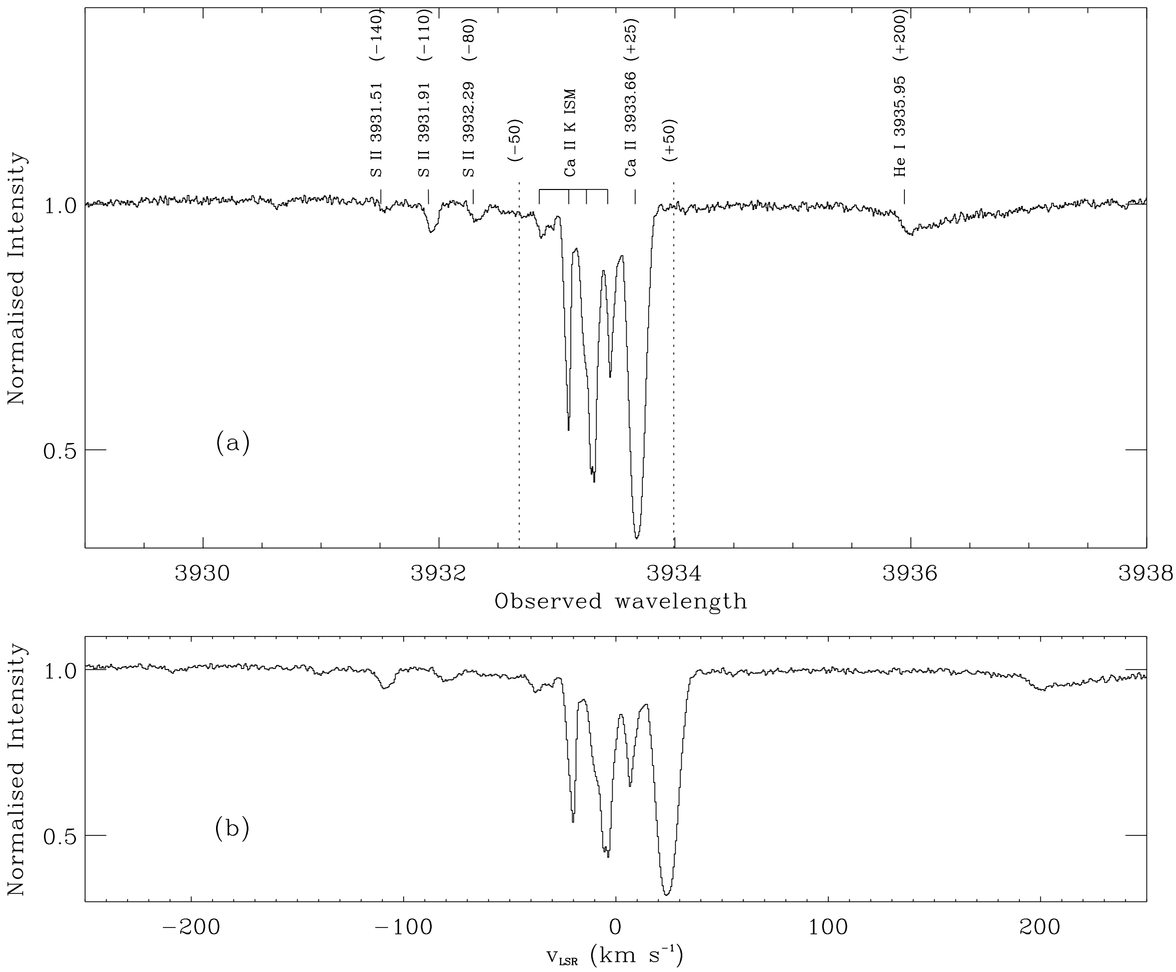


**Fig. 1. a)** Normalized spectrum of HD 83206 (McDonald 1999 data) plotted against the observed wavelength. Values in brackets are the dynamical LSR velocities (in $\mathrm{km\,s^{-1}}$; see b). **b)** Blow-up of panel **a)** but plotted against the dynamical LSR velocity with respect to the Ca II K transition. The strong line at $25\,\mathrm{km\,s^{-1}}$ is the stellar Ca II K line

Spectra of HD 135485 were obtained with the 4.2 m William Herschel telescope (WHT) at La Palma Observatory in July 1999 using the Utrecht Echelle spectrograph (at a resolution of about $6\,\mathrm{km\,s^{-1}}$ and $S/N = 120$), while observations of HD 83206 were carried out using the coudé spectrograph on the 2.7 m telescope at McDonald Observatory in December 1996 (resolution of $1.9\,\mathrm{km\,s^{-1}}$ and $S/N = 130$) and November 1999 (resolution of $1.8\,\mathrm{km\,s^{-1}}$ and $S/N = 230$). Procedures for the data reduction are fully discussed by Lehner et al. (1999, 2000) and Trundle et al. (2001).

We show the Ca II K spectral region of HD 83206 in Fig. 1. The panel (a) in this figure presents the normalized spectrum versus the observed wavelength. This high quality spectrum clearly reveals weak absorption at velocities blueward of the Ca II K line at 3933.663 Å. The bottom panel (b) shows how theses lines could be identified as Ca II K HVC interstellar lines at LSR velocities of $-80, -110, -140\,\mathrm{km\,s^{-1}}$, especially in this region of the sky. HVC Complexes L (which is projected on HD 135485) and M have velocities between $-140$ and $-80\,\mathrm{km\,s^{-1}}$ and Chain A has velocities between $-210$ and $-90\,\mathrm{km\,s^{-1}}$ (Wakker & van Woerden 1991; Wakker & van Woerden 1997; van Woerden et al. 1999a).

However, the non-detection of any HVC features in the IUE spectra of HD 135485, and the conspicuous match of these lines at exactly the same wavelengths for the two sightlines, when referred to the stellar Ca II K line (see Fig. 2), indicate that they are most probably stellar lines rather than interstellar features.

## 3. Identification of the stellar lines

To identify the lines in Figs. 1 and 2 we used the atomic line database compiled by Peter van Hoof[1]. The best match was for S II lines at 3931.507, 3931.911 and 3932.290 Å. Moreover, using the LTE atmospheric parameters found by Lehner et al. (2000) and Trundle et al. (2001), we were able to derive LTE absolute abundances using the equivalent widths of these transitions. Our results are summarized in Table 1, where we also present the LTE S II abundances for HD 83206 and HD 135485

[1] Currently accessible at
`http://www.cita.utoronto.ca/~vanhoof/`

**Table 1.** S II equivalent widths (*EW*) and LTE absolute abundances for HD 83206 and HD 135485

| Ions | HD 83206 | | HD 135485 | |
|---|---|---|---|---|
| | *EW* | 12 + log[X/H] | *EW* | 12 + log[X/H] |
| | mÅ | dex | mÅ | dex |
| S II $\lambda$3931.507 | 1.7 | 6.90 | 6.4 | 7.50 |
| S II $\lambda$3931.911 | 6.2 | 7.23 | 16.7 | 7.51 |
| S II $\lambda$3932.290 | 3.2 | 7.12 | 11.3 | 7.53 |
| S II$^a$ | | $7.13 \pm 0.26$ $^b$ | | $7.45 \pm 0.22$ $^c$ |

Note: ($a$): LTE mean absolute abundance from ($b$) Lehner (2000), $n = 32$, ($c$) Trundle et al. (2001), $n = 14$. Quoted errors are $1\sigma$ on $n$ measurements.

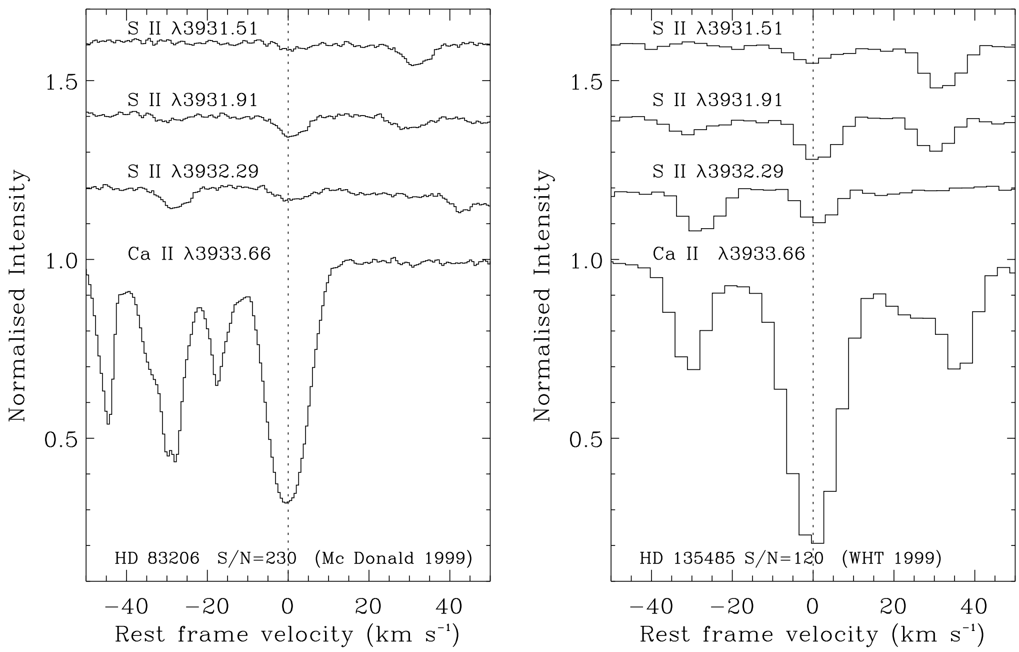


**Fig. 2.** Normalized spectra of HD 83206 and HD 135485 versus the velocity, such as the velocities are in a reference frame where the stars are at rest (the S II lines were incremented by 0.2 on the $y$-scale)

obtained by Lehner (2000) and Trundle et al. (2001), respectively. We note that the transitions considered in the present paper were not included in the abundance determinations by Lehner and Trundle et al. However the two sets of S II abundances agree remarkably well, and hence we conclude that the lines in Fig. 1 are indeed stellar S II features.

## 4. Concluding remarks

Main-sequence B-type stars are often used to derive upper limits to HVC distances; usually there is no ambiguity between stellar and interstellar features, if the stars have large projected rotational velocities that broaden the stellar lines. However, there is not a large number of such young B-type stars in the Galactic halo, and therefore it is often necessary to use evolved, slowly rotating B-type stars (e.g. PAGB, BHB, sdB) as alternative tracers of HVC absorption. In Fig. 1 we therefore present a very high quality spectrum in the Ca II K wavelength region, where the only stellar features in this spectrum that could be confused with HVCs ($v_{\rm LSR} < -50\,{\rm km\,s^{-1}}$) are the S II lines described above. We note that the red part of the spectral region ($v_{\rm LSR} > 50\,{\rm km\,s^{-1}}$) is effectively free of stellar lines, with only one feature detected at $+200\,{\rm km\,s^{-1}}$ that could be He I $\lambda$3935.95, which is possibly blended with other stellar transitions. The features marked as Ca II K ISM in Fig. 1 are certainly interstellar lines because (i) superimposing the HD 135485 and HD 83206 spectra does not reveal any obvious matches such as the ones observed in Fig. 2, and (ii) a comparison with the Na I D interstellar lines (Lehner et al. 1999) shows good agreement with the velocities of the Ca II K features (except at 3932.85 Å which does not appear in the Na I D spectrum). Finally, other evolved spectral analogues of B-type stars may also exhibit other weak stellar lines (see e.g. van Woerden et al. 1999b) and a systematic comparison with the Ca II H feature might help in some cases to disentangle stellar and interstellar features.

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