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Unveiling the structure and kinematics of B[e] stars' disks from FEROS and CRIRES spectra

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Abstract. We are investigating the circumstellar material for a sample of B[e] stars using high spectral resolution data taken in the optical and near-infrared regions with ESO/FEROS and ESO/CRIRES spectrographs, respectively. B[e] stars are surrounded by dense disks of still unknown origin. While optical emission lines from [O I] and [Ca II] reflect the disk conditions close to the star (few stellar radii), the near-infrared data, especially the CO band emission, mirror the characteristics in the molecular part of the disk farther away from the star (several AU). Based on our high resolution spectroscopic data, we seek to derive the density and temperature structure of the disks, as well as their kinematics. This will allow us to obtain a better understanding of their structure, formation history and evolution. Here we present our preliminary results.

1. Introduction

B[e] stars are found in different evolutionary phases ranging from the pre-main sequence Herbig Ae/B[e] stars to the post-main sequence B[e] supergiants and compact planetary nebulae (Lamers et al. 1998). They are characterized by the presence of permitted and forbidden emission lines in their optical spectra, and a strong infrared excess emission due to circumstellar dust (e.g. Zickgraf et al. 1986). Some of these stars also show molecular bands in emission in their infrared spectra (McGregor et al. 1988). All this points to the existence of a large amount of circumstellar material, but the kinematics and physical conditions in these extended envelopes (winds and/or disks) are still unknown.

It is important to study the emission of the different components of the circumstellar medium, because they trace regions at different distances from the star, allowing us to obtain information about the structure and kinematics that helps us characterize the circumstellar environment around these stars.

2. Observations

We obtained high-resolution optical spectra for a sample of B[e] stars using FEROS (R~48000), a bench echelle spectrograph mounted at the 2.2-m telescope of the European Southern Observatory (ESO) in La Silla (Chile). The wavelength range covered by this instrument is 3600 - 9200 Å. The observations were carried out during two missions: 2005 April 19-21 (Hen 3-298, CPD-52 9243), and 2008 December 21-22 (HD 62623, GG Car, CPD-57 2874).

For the same stars we also obtained near-infrared high-resolution observations with CRIRES (R~50000), an echelle spectrograph attached to one of the 8m VLT unit telescopes at the ESO site in Paranal (Chile). The spectra extend approximately from 2.276 to 2.326 μm, and were obtained on 2009 November 29 and December 2, and 2010 April 6.

In both cases the ESO automatic pipeline reduction was adopted, and the telluric and heliocentric velocity corrections were performed.

3. Results

The optical spectra display strong emission in the forbidden lines of [O I] and [Ca II]. These lines have recently been shown to be valuable tracers of high-density disk regions in a sample of B[e] supergiants (Aret et al. 2012). Their line profiles are mostly double-peaked, as can be seen in Fig. 1, indicating either rotation or equatorial outflow.

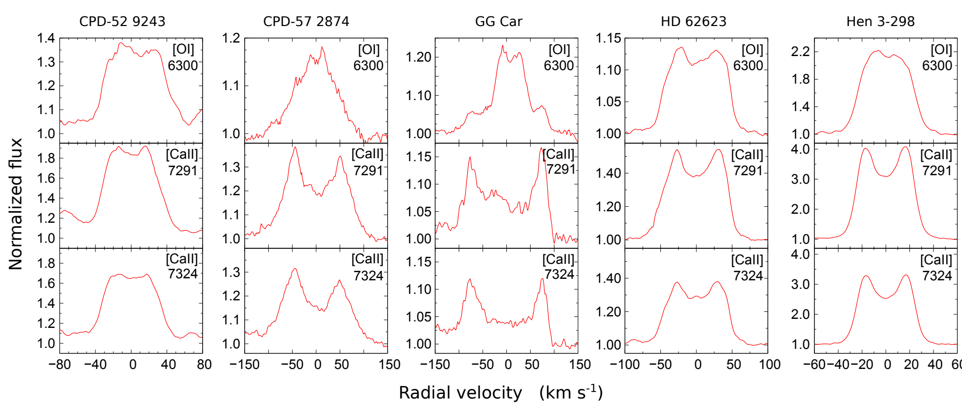

Figure 1. Profiles of the [Ca II] 7291 Å, [Ca II] 7324 Å, and [O I] 6300 Å lines.

From their peak-separation (Table 1) we can extract the kinematics, while a detailed modeling of their line luminosities will provide information on the density and temperature in the line-forming regions (e.g. Kraus et al. 2007, 2010). To discriminate which scenario (outflow or rotation) is correct, we need to know under which conditions the forbidden emission lines are formed. This has been studied in detail so far for the [O I] lines (Kraus et al. 2007, 2010), but not much is known about the origin of the [Ca II] lines. Recently, Aret et al. (2012) found that for the disks around B[e] supergiants the [Ca II] lines are formed at distances closer to the star (i.e. at higher densities) than the [O I] lines. If true, the [O I] line forming region should have a lower velocity in the case of Keplerian rotation and a higher velocity for an outflow scenario. Inspection of the velocities listed in Table 1 shows that most stars might be surrounded by a Keplerian rotating disk, while for CPD-52 9243 an outflow scenario might be appropriate. However, detailed modeling of especially the [Ca II] lines is necessary before final conclusions can be drawn.

Table 1. Peak separations (km s^{-1})

Object	[Ca II] 7291 Å	[Ca II] 7324 Å	[O I] 6300 Å
CPD-52 9243	30 ± 4	33 ± 4	37 ± 4
CPD-57 2874	94 ± 4	93 ± 2	not resolved
GG Car	149 ± 2	150 ± 2	33 ± 2
HD 62623	58 ± 1	56 ± 1	50 ± 1
Hen 3-298	33 ± 1	33 ± 1	14 ± 1

The near-infrared spectra display the first bandhead of CO in emission. The shape of the bandhead implies that either rotation or equatorial outflow broadens the CO band. We applied the model of Kraus et al. (2000) to determine the (rotation or outflow) velocity of the CO gas projected to the line-of-sight. Our preliminary fits are shown in Fig. 2 together with the values obtained for the velocities.

The CO bands typically originate from a very narrow ring representing the inner edge of the molecular disk part (e.g. Liermann et al. 2010). Due to its much lower temperature compared to gaseous disk regions, the molecular ring is usually located at (much) larger distances. It is hence surprising that the velocities obtained from the CO bandheads are of similar order or even higher than those of the forbidden emission lines. Whether this discrepancy is real (e.g., caused by the existence of two distinct outflowing rings) or artificial due to the combination of optical and infrared spectra taken at different epochs, needs to be studied in more detail.

4. Conclusions

We obtained high-resolution optical and near-infrared spectra of a sample of B[e] stars. The forbidden emission lines and the CO bandhead show kinematical broadening due to either rotation or an equatorial outflow. A detailed analysis of both the optical forbidden lines and the molecular bands will allow us to extract the structure and the kinematics of the circumstellar material around our stars. This will help to understand the nature of their disks.

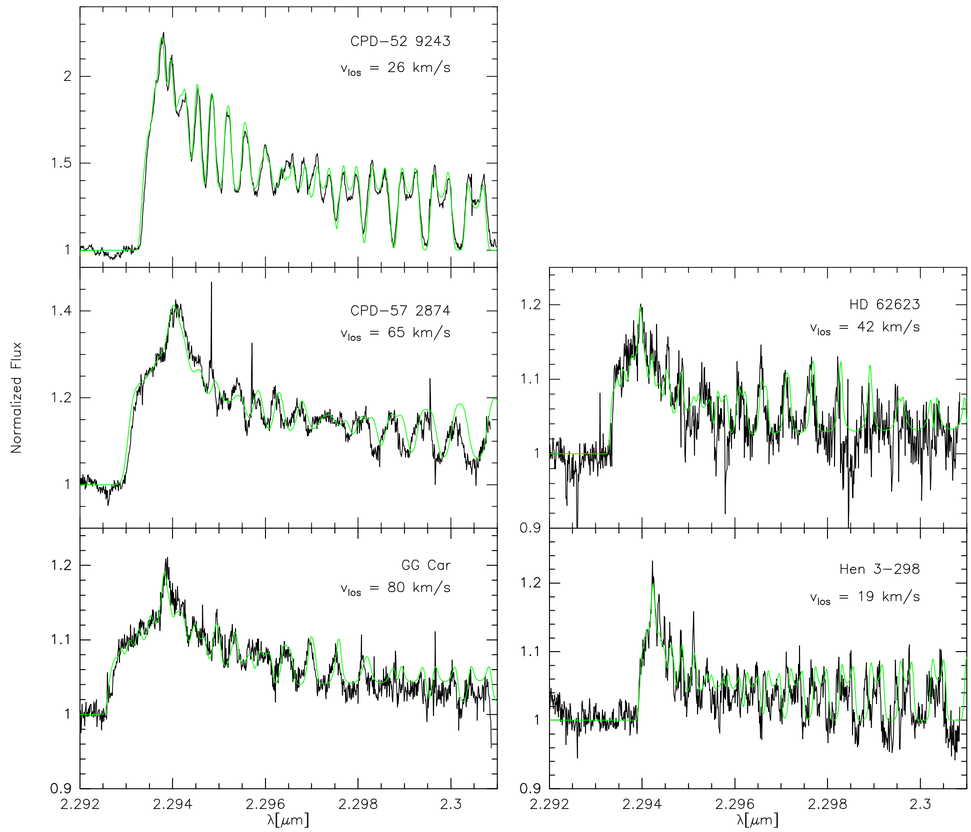

Figure 2. Fit (green) to the observed CO bandhead (black). The velocity projected to the line-of-sight, v_{los}, is given in each panel.

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