Study of the Circumstellar Medium of Herbig Ae/Be Stars

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Introduction

Recent studies using coronagraphic imaging techniques and the Hubble Space Telescope (Grady et al. 2000, 2001) have shown circumstellar disks around Herbig Ae type stars. Since these stars are pre-main sequence objects, the study of the interaction between the star and the circumstellar medium may provide some understanding of this stage of the stellar evolution. Such interaction may occur as a gain or loss of matter resulting in a change of the star's angular momentum.

The physical process of accretion and/or ejection of matter can be studied using absorption patterns observed in line profiles of hydrogen lines like, Hα, Hβ, Hγ, Hδ and other metallic lines such as Na I D and Ca II. An accretion episode may be identified by a redshifted absorption component (RAC) and a chemical analysis of these RACs characterize the episode as produced by gaseous structures from the inner parts of the disk or by evaporation of a comet-like body in a star-grazing orbit.

In this work we studied a set of Herbig Ae/Be (HAeBe) stars, using synthetic spectra, to search for RACs. When found, we made a kinematic and a qualitative chemical analysis of the event.

Observations and reduction

Twenty HAeBe candidate stars were observed with the 1.52m ESO telescope together with the FEROS echelle spectrograph at La Silla, Chile, from May 7 to 9, 2002.

The data reduction was performed in an standard way using routines developed by Dr. Herman Hensberge from the Royal Observatory of Belgium since the automatic reduction showed some problems as can be seen in figure 1.

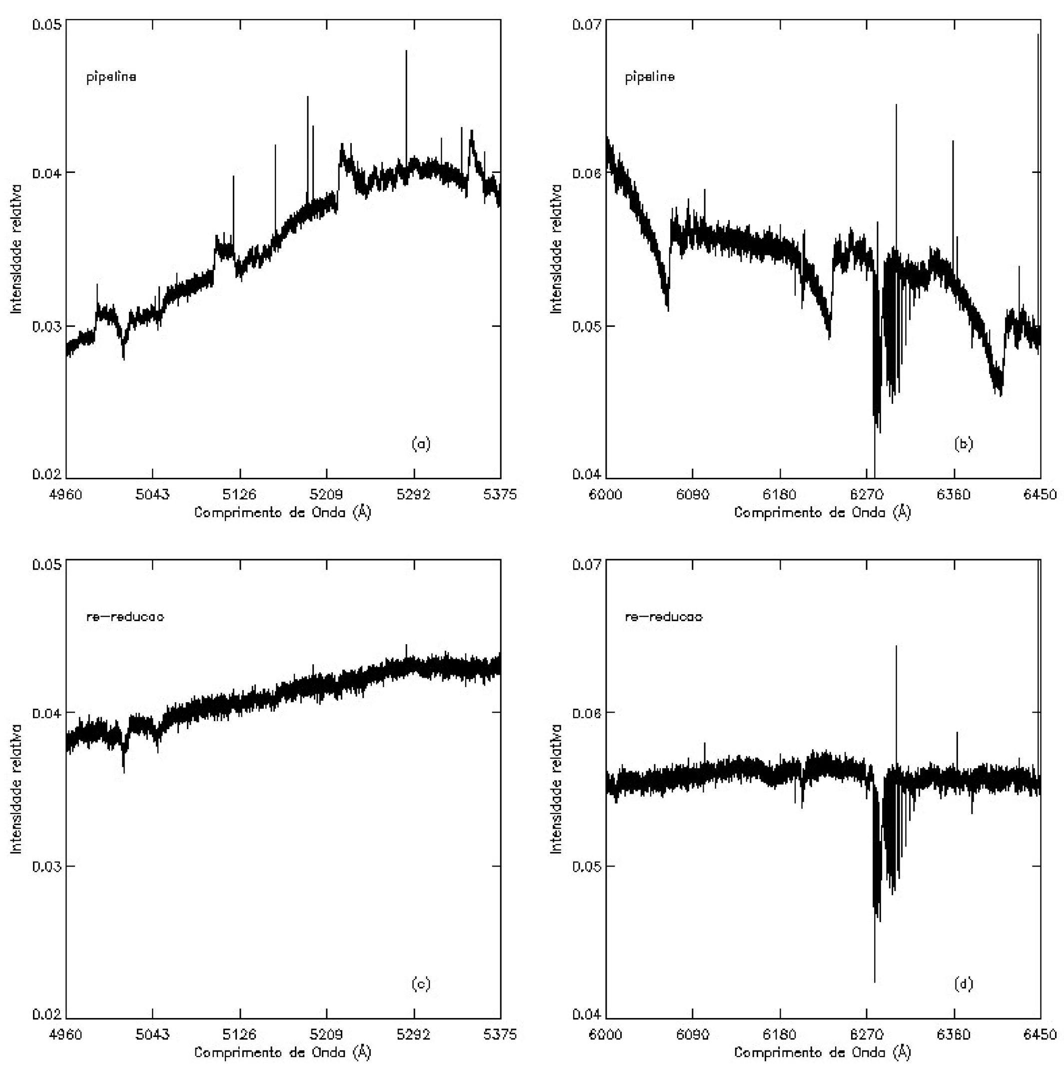

Figure 1. The upper panels show two regions where defects caused by the automatic reduction can be seen. The lower panels show the same region after the new reduction using Dr. Hensberge routines.

Methodology

To find RACs it is necessary to subtract the observed spectra from the stellar. Since HAeBe star are close to the Main Sequence (MS), we assume that a synthetic spectrum generated for a MS star can be used. These spectra were constructed using the SME (Spectroscopy Made Easy) code (Valenti & Piskunov, 1996).

The SME needs the following parameters: T_{eff}, $v\sin(i)$ and $\log(g)$. To determine these parameter for our sample, a set of constant photospheric lines were selected. Using these lines, the SME code generates the synthetic spectrum that better fits the line, releasing the physical parameters. The parameters obtained are listed in table 1.

Table 1: Physical parameters for the observed HAeBe stars.

PDS	T_{ef} (K)	$\log g$	$v\sin i$ (km s^{-1})	v$_{rad}$ (km s^{-1})
057	10500 $\pm$ 500	4.0 $\pm$ 0.2	6 $\pm$ 1	17 $\pm$ 2
069N	17000 $\pm$ 2000	4.0 $\pm$ 0.2	90 $\pm$ 10	-7 $\pm$ 2
076	7300 $\pm$ 200	4.0 $\pm$ 0.2	66 $\pm$ 3	-6 $\pm$ 2
078	7000 $\pm$ 200	3.4 $\pm$0.2	80 $\pm$ 3	-6 $\pm$ 2
080	7300 $\pm$ 200	3.8 $\pm$ 0.4	115 $\pm$ 4	-7 $\pm$ 2
303	11000 $\pm$ 500	3.6 $\pm$ 0.2	105 $\pm$ 4	10 $\pm$ 2
327	25000 $\pm$ 3000	4.0 $\pm$ 0.2	80 $\pm$ 20	-1 $\pm$ 2
339	6900 $\pm$ 200	4.0 $\pm$ 0.2	48 $\pm$ 2	14 $\pm$ 2
340	10000 $\pm$ 500	4.0 $\pm$ 0.2	100 $\pm$ 20	14 $\pm$ 2
395	7400 $\pm$ 200	4.5 $\pm$ 0.2	25 $\pm$ 1	3 $\pm$ 2
398	10000 $\pm$ 500	4.3 $\pm$ 0.1	250 $\pm$ 50	-13 $\pm$ 2
473	9500 $\pm$ 500	4.0 $\pm$ 0.2	100 $\pm$ 20	-20 $\pm$ 2
514	7600 $\pm$ 200	4.2 $\pm$ 0.2	55 $\pm$ 2	-3 $\pm$ 2
545	25000 $\pm$ 3000	4.0 $\pm$ 0.2	100 $\pm$ 20	-1 $\pm$ 2
564	10300 $\pm$ 500	4.0 $\pm$ 0.2	72 $\pm$ 3	17 $\pm$ 2

With the physical parameters, the photospheric spectrum is constructed and subtracted from the observed one. The result is the circumstellar spectra.

Using this methodology RACS were found in two objects: PDS076 (HD142666) e PDS080 (HD145718).

Analysis and Discussion

The qualitative chemical analysis was made using a method proposed by Natta, Grinin & Tambovtseva (2000). They quantified the absorption produced by the circumstellar environment using the depth of the circumstellar absorption component (τ):

$$\tau = 1 - \frac{F_{obs}}{F_{syn}} \qquad (1)$$

where F_{obs} and F_{syn} represent respectively the observed and the synthetic photospheric intensity at peak wavelength. where F_{obs} and F_{syn} represent respectively the observed and the synthetic photospheric intensity at peak wavelength. If $\tau = 1$ the circumstellar line is saturated and if $\tau = 0$ there is no circumstellar contribution.

If the infalling material is produced by evaporation of solid bodies in star-grazing orbits then the RACs must appear in metal lines and simultaneously be absent in Balmer lines since such material should be strongly depleted in hydrogen. The presence of RACs in Balmer lines, with τ values close to 1, and the absence of them in metallic lines (e.g. Na I D , Fe, Si etc) implies that the infalling material is rich in hydrogen.

PDS076

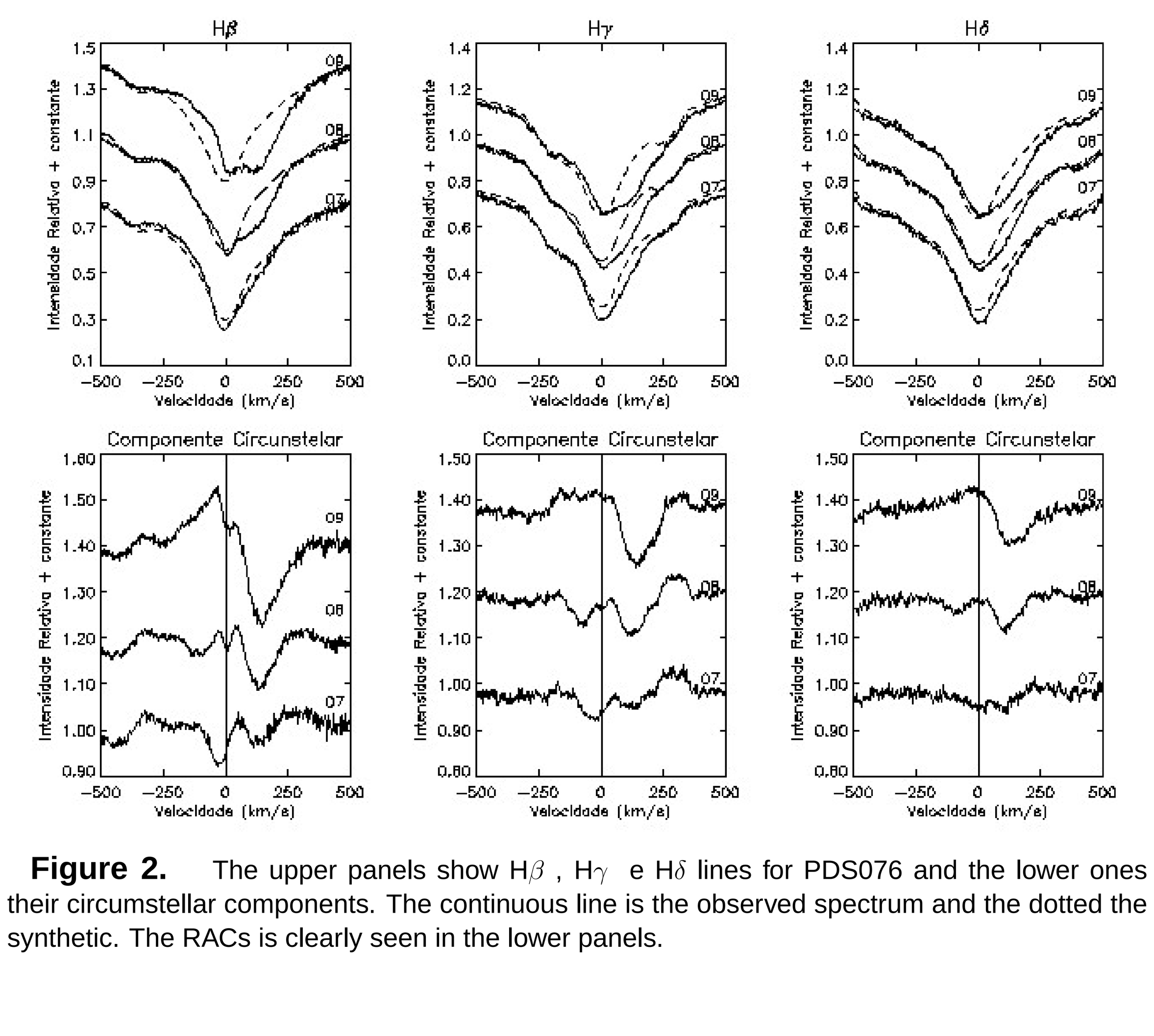

Figure 2. The upper panels show Hβ , Hγ e Hδ lines for PDS076 and the lower ones their circumstellar components. The continuous line is the observed spectrum and the dotted the synthetic. The RACs is clearly seen in the lower panels.

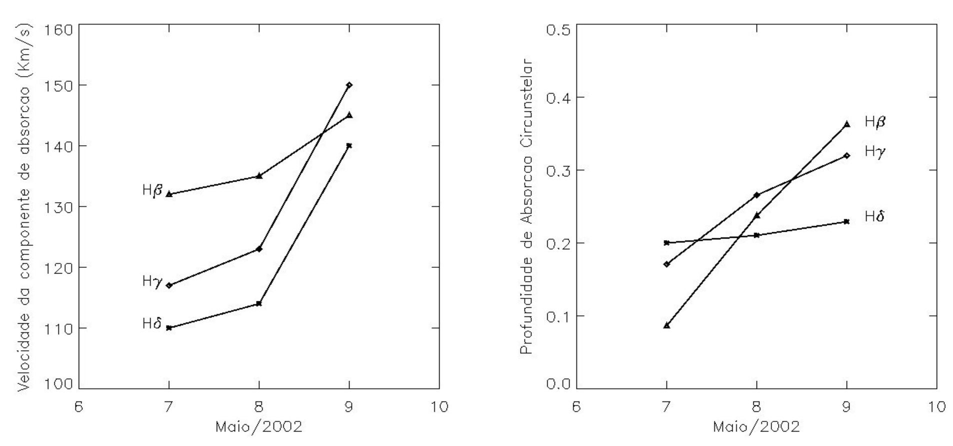

Figure 3. The left panel shows the temporal evolution of the velocity components, while the right one shows the temporal evolution for τ value. In both cases can be seen a growth in τ and the velocity. One possible explanation is a structure in free fall.

PDS080

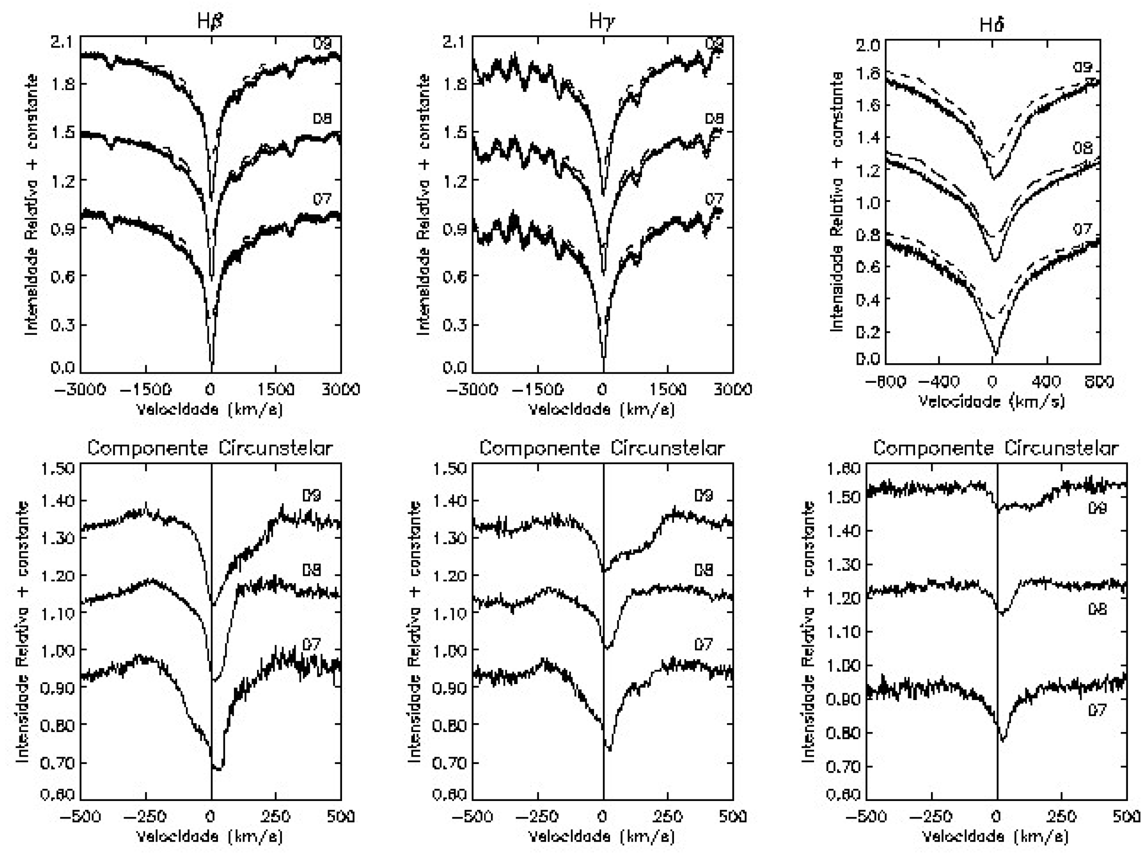

Figure 4. The upper panels show the observed spectra and the lower ones the circumstellar components for PDS080. The RACs is clearly seen in the lower panels.

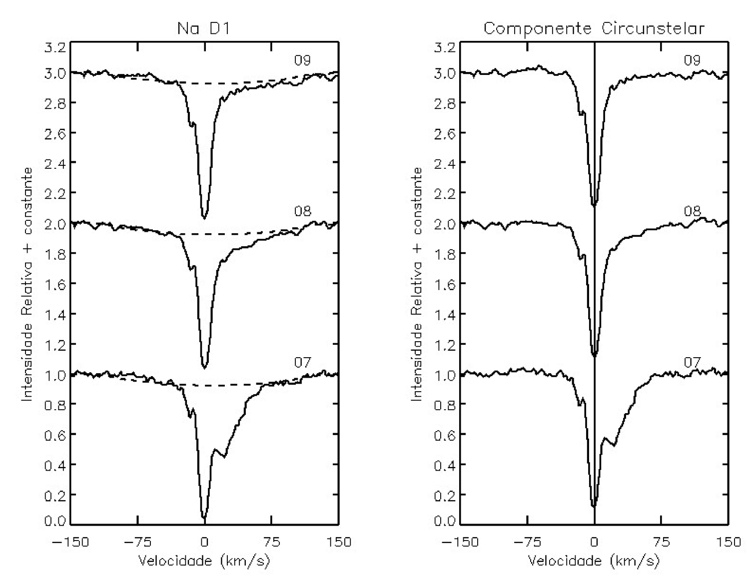

Figure 5. The left panel shows the first component for Na I D and the left one the circumstellar component.

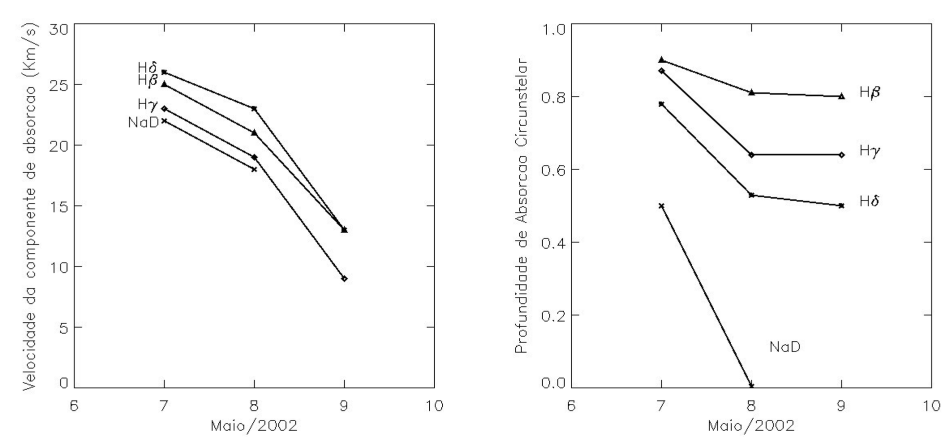

Figure 6. The left panel shows the kinematic of the material falling toward PDS080 and the right one temporal evolution of τ. This RAC showed a different behavior from the one observed in PDS076. In this case, the velocity and amount of material decrease during the observation. A possible explanation is the magneto-accretion model.

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