

The Optical and IR Properties of Southern Galactic Unclassified B[e] Stars: The Case of CD-42°11721

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Abstract. In the last few years, we had devoted our time to the study of a sample of southern unclB[e] stars. For most of them, there are few works in the literature, and their physical parameters are still very uncertain. Our research was concentrated on the analysis of the optical and IR data, making use of high (FEROS) and low (B&C) resolution spectra, obtained by us at ESO (La Silla, Chile) and LNA (Brazópolis, Brazil) and using public ISO and IRAS spectra. In this work we present the results for a curious star: CD-42°11721. This object has a doubtful evolutionary stage, being either a pre-main sequence star (HAeB[e]) or an evolved star (supergiant B[e] or sgB[e]). This confusion concerning its nature is caused by the complete absence of reliable physical parameters for this object, especially its distance. Our optical investigation could be splitted in two parts, a qualitative study based on the identification of the numerous emission lines present in the spectra and the classification of their line profiles, which indicate a non-spherically symmetric circumstellar environment, and a quantitative analysis of numerous forbidden lines, e.g. [OI], [OII], [NII] and [SII]. Assuming a typical circumstellar scenario for a sgB[e], i.e. a fast, low-density polar wind and a slow, high-density disc forming equatorial wind, we can reproduce very well the line luminosities of the forbidden lines. From this analysis, we can determine the mass loss rate of the star lying in the range from $\dot{M} \simeq (4.4 \pm 0.8) \times 10^{-6} M_{\odot} \text{yr}^{-1}$ to $\dot{M} \simeq (2.2 \pm 0.4) \times 10^{-5} M_{\odot} \text{yr}^{-1}$, depending on the considered reddening. In addition, our IR study could also be splitted in two parts: the identification of several features in the SWS ISO spectrum, and the modeling of the SED of CD-42°11721. The first part shows the presence of many unidentified features and specially the presence of a mixed chemistry, i.e. C- and O-rich dust in the same circumstellar medium. The presence of specially C-rich dust could in principle favour a young nature, however this is not so clear, since also other evolved stars like e.g. LBVs, show this kind of dust. We have tried to model the SED, by using a numerical code written by us which considers a spherical circumstellar scenario. Although the answer concerning

the evolutionary stage of CD-42°11721 is still not very clear, we believe that our analysis will improve the discussion about the nature of this curious star.

1. Introduction

Unclassified B[e] (unclB[e]) stars cover at least 50% of all galactic stars with the B[e] phenomenon known to date, and their number is increasing steadily (see e.g. Miroshnichenko, this volume). These stars are concentrated towards the galactic plane, suffering severely of a mostly unknown interstellar extinction. Consequently, their distances are poorly known, avoiding a proper and reliable determination of their physical parameters, like effective temperatures, luminosities, and abundances, and consequently the comprehension of their nature and evolutionary stage is rather poor.

In this work, we present the results obtained for the curious star CD-42°11721, based on (i) new observational data obtained by us and using public IRAS and ISO databases and (ii) by modeling the line luminosities of the forbidden emission lines and the dust emission.

2. Observations

Intending to improve the discussion concerning the nature of southern galactic unclB[e] stars that are very poorly studied, including CD-42°11721, we obtained low and high resolution optical spectra during different observing missions at the European Southern Observatory (ESO - La Silla, Chile) and at the Laboratório Nacional de Astrofísica (LNA - Brazópolis, Brazil). The high resolution spectra ($R = 48000$) were obtained at the ESO 1.52-m telescope using the Fiber-fed Extended Range Optical Spectrograph (FEROS) and have a wavelength coverage from 3600 Å to 9200 Å. The low resolution spectra (~ 4.6 Å) were obtained at the same telescope and at the LNA 1.6-m telescope using the Boller & Chivens spectrograph, covering a wavelength region from 3800 to 8700 Å.

We are also using public IR spectra taken with the Short Wavelength Spectrometer (SWS) on the Infrared Space Observatory (ISO) and taken with the Infrared Astronomical Satellite (IRAS). The IRAS Low Resolution Spectra (IRAS LRS) cover a small wavelength range, from 7.5 to 22 μm , with a spectral resolution of about 20-60. On the other hand, the SWS01-ISO spectrum has a higher resolution of ~ 1500 and a wavelength coverage from 2 to 50 μm .

3. The Case of CD-42°11721

CD-42°11721 (V 921 Sco, Hen 3-1300, IRAS 16555-4237) was observed for the first time by Merrill & Burwell (1949). de Winter & Thé (1990) and Henning et al. (1998) classified it as an HAeBe star, based on the presence of a nebulosity, possible spectral and photometric variations, and some further spectral characteristics, specially in the IR. Voors (1999) has suggested that CD-42°11721 might be a young star but not a pre-main sequence star because of its high temperature and luminosity. On the other hand, a possible nebular overabundance

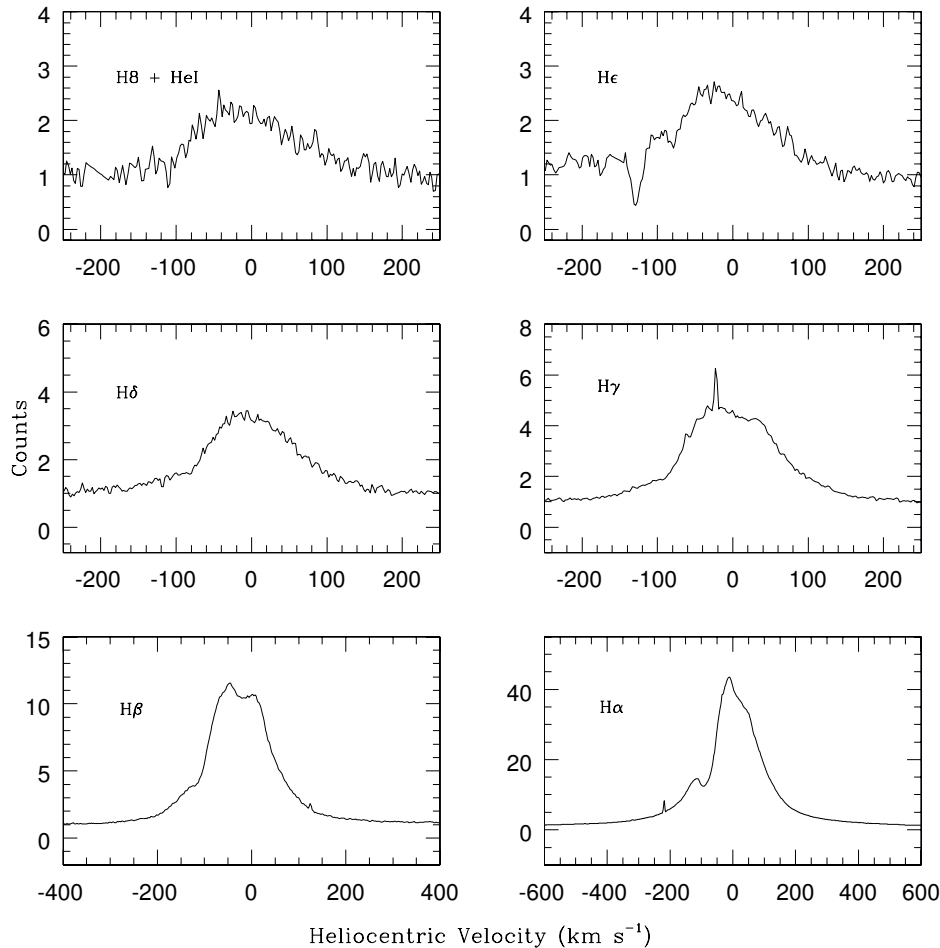


Figure 1. Balmer lines taken from the CD-42°11721 high resolution (FEROS) spectrum. The lines are in emission. $H\alpha$ and $H\beta$ show double peaked profiles, while the higher Balmer lines are single peaked. The absorption line blended with $H\epsilon$ is the interstellar Ca II 3968 Å line. Due to the chosen scale the total extension of the $H\alpha$ and $H\beta$ wings is not clearly visible.

of N/O in addition to its high luminosity, as well as some spectral similarities to other B[e] supergiants induced Hutsemékers & Van Drom (1990) to consider CD-42°11721 as an evolved object. This is why Lamers et al. (1998) have included it in the list of objects presenting the B[e] phenomenon but with an unclear nature, the so-called unclassified B[e] stars.

The confusion concerning the evolutionary stage of CD-42°11721 is strictly linked to the absence of any reliable information about its physical parameters. Since the spectrum does not show any photospheric lines, the spectral type ranges from B0 to Aep (depending on the method used) and consequently the T_{eff} is lying between 31600 K and 12300 K, respectively (Hillenbrand et al. 1992;

Cidale, Zorec & Tringaniello 2001). Its luminosity is not well known either, ranging between $1.9 < \log(L/L_{\odot}) < 4.9$ (McGregor et al. 1988; Shore et al. 1990; Hillenbrand et al. 1992), not only because of the uncertain effective temperature, but mainly due to the unclear distance, ranging from 136 pc to 2.6 kpc (Shore et al. 1990; de Winter & Thé 1990; Hillenbrand et al. 1992; Elia et al. 2004), and the uncertain extinction being either 4.2 or 7.1 mag¹.

3.1. Our Optical Analysis

Using our FEROS spectrum (that has a higher resolution than any other previously published for this star) we could make a qualitative analysis, by identifying the lines and describing their profiles.

The spectrum of CD-42°11721 is dominated by emission lines and some (few) interstellar absorption lines. We could confirm the presence of the B[e] phenomenon and see that Fe II is by far the ion with the largest number of lines. Other highlights are the Balmer lines presenting very intense emission (Fig. 1). We could also identify several forbidden lines of [O I], [O II], [S II], [N II], [Fe II], [Ni II] and [Cr II].

Using the Boller & Chivens spectrum, we could derive the luminosities of some forbidden lines, e.g., [O I] ($\lambda\lambda$ 5577, 6300, 6363), [O II] ($\lambda\lambda$ 7318, 7330), [N II] ($\lambda\lambda$ 5754, 6548, 6584) and [S II] ($\lambda\lambda$ 4068, 4076, 6716, 6731), assuming a mean distance of 1.15 kpc and adopting the two different values of A_V (4.2 and 7.1).

Next, we calculated the line luminosities of these forbidden lines, considering either a spherical scenario (to prove or disprove the necessity of a disc) or a two-component wind scenario. By modeling self-consistently the observed line luminosities it is possible to fix the mass loss rate of the star (see e.g. Kraus et al. 2005). Our best results were obtained with the two-component wind scenario, i.e. assuming a polar wind plus an equatorial disc (with an open angle of $\sim 25^\circ$). We assumed an effective temperature for CD-42°11721 of 15 000 K, and terminal wind temperatures of 12 000 K for the polar wind and 8 000 K for the equatorial disc. The results for the [N II] lines, which are produced in the polar wind only, are shown exemplarily in Fig. 2.

The derived mass loss rates, accounting for the two different extinction values of 4.2 and 7.1 mag, are $4.4 \pm 0.8 \times 10^{-6} M_{\odot}\text{yr}^{-1}$ and $2.2 \pm 0.4 \times 10^{-5} M_{\odot}\text{yr}^{-1}$, respectively. Interestingly, when modeling the line luminosities it turned out that nitrogen has to be overabundant compared to solar, while all other elements could be modeled with solar abundances. This N overabundance and the high mass loss rates found from the modeling favour a supergiant nature (Kraus et al. 2006, in preparation).

3.2. Our IR Analysis

We have also made a description of the CD-42°11721 infrared spectrum based on IRAS LRS and especially SWS01 ISO public data. We could identify several new features that were not cited previously in the literature (Borges Fernandes et al. 2006). The presence of the many H recombination lines and the forbidden

¹But see Borges Fernandes et al. (2006) for a more reliable derivation of the foreground extinction.

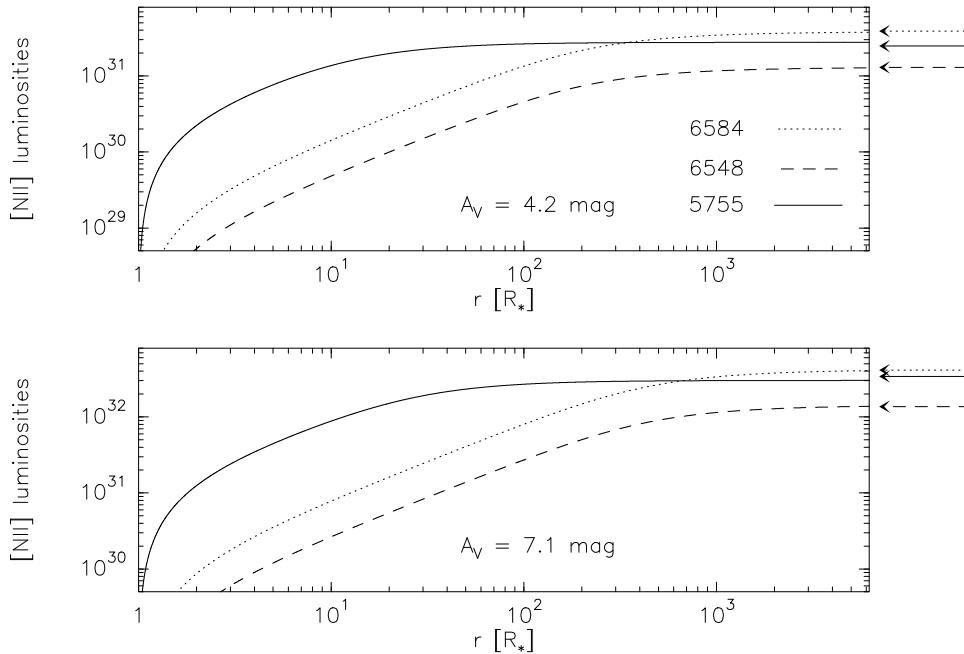


Figure 2. Model results for the [NII] lines considering the two different reddening. These lines are produced in the polar wind only. The arrows on the right side indicate the observed value for each emission line (same line style). The outer edge of the modeling is set by the slit width used and the adopted distance to CD-42°11721.

lines is remarkable, and especially the so-called "dual-dust" chemistry (Waters & Molster 1999), characterized by the simultaneous presence of solid state bands of C-rich and O-rich dust being produced in the same environment. The C-rich material is represented by PAH emission bands (Jourdain de Muizon et al. 1990) and the O-rich dust by some features caused by crystalline silicates (Voors 1999).

3.3. Modeling of the SED

Using photometric data from the literature, we could obtain the spectral energy distribution (SED) of CD-42°11721. It is double peaked, similar to those HAeBe stars called "group I" (Meeus et al. 2001). We have tried to model this SED, considering different physical parameters (including those obtained by our optical study), using a code that treats the radiative transfer in a spherical envelope making use of the Monte Carlo method (Lorenz Martins & Pompéia 2000). As can be seen in the Fig. 3, we could not model properly this SED, indicating that a non-spherical model, most plausibly a disc scenario, is indeed necessary to account for the observed SED, in agreement with our optical analysis. A study involving a non-spherical dust distribution is presented in Borges Fernandes et al. (2006).

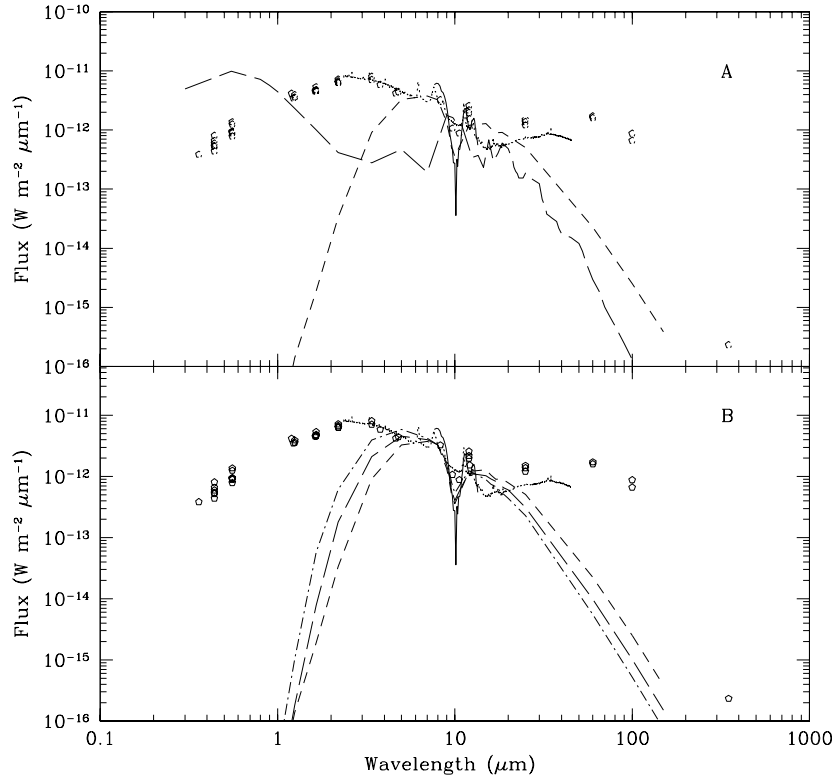


Figure 3. Different spherical models trying unsuccessfully to reproduce the SED of CD-42°11721.

3.4. Conclusions

CD-42°11721 is a very curious star whose evolutionary stage is still unclear. Our analysis resulted in arguments for as well as against the classification as either a young or an evolved object:

In favour of a young H AeBe nature speak its IR characteristics, specially its double peaked SED and the position of this object in colour-colour diagrams. However, we can not discard a possible contamination of the photometric data, since CD-42°11721 is lying in a crowded region, hosting several stars as well as a cloud which might be of interstellar nature.

In favour of a supergiant nature speaks our optical analysis which shows excellent results considering a supergiant two-component wind scenario, and which, in addition, indicated the necessity of an N overabundance. Against this scenario speaks, however, the dual-dust chemistry, specially the presence of C-rich dust which is difficult to explain with a supergiant scenario whose spectrum is dominated by H recombination lines. We clearly need more multiwavelength and high spatial resolution observations of CD-42°11721 and its close-by circumstellar medium for a better determination of its nature.

4. Summary

In this work, we are showing clearly how hard the life is for those people that are studying unclB[e] stars. However, the future is very promising since new observations using different techniques, like high resolution spectroscopy, spectropolarimetry and interferometry in different spectral regions, will allow us to understand better on the one hand the nature of these fascinating objects, and on the other hand some important stellar evolutionary phases that are still poorly known and investigated.

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