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Spectroscopic study of the B[e] supergiant LHA 120-S 35

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Abstract. LHA 120-S 35 is a poorly studied supergiant of the Large Magellanic Cloud which displays the B[e] phenomenon. In this work, we present a spectroscopic description of this star based on high-resolution optical spectra (3600 to 9200 Å), taken with the Du Pont Telescope at Las Campanas Observatory (LCO), Chile. In addition, we obtained medium resolution K-band near infrared spectra for this object with SINFONI on the VLT UT4 telescope at the European Southern Observatory (ESO). The near infrared spectra show strong CO band emission. This is the first detection of molecular emission in this peculiar star.

Resumen. LHA 120-S 35 es una estrella supergigante de la Nube Mayor de Magallanes, pobremente estudiada, que presenta el fenómeno B[e]. En este trabajo presentamos una descripción espectroscópica de esta estrella basada en espectros ópticos de alta resolución (3600 a 9200 Å), tomados con el Telescopio Du Pont en el Observatorio de Las Campanas (LCO), Chile. Además, obtuvimos espectros de resolución media de este objeto en la banda K en el cercano infrarrojo con el espectrógrafo SINFONI acoplado al telescopio VLT UT4 del Observatorio Europeo Austral (ESO). Los espectros en el cercano infrarrojo muestran una fuerte emisión en la banda de CO. Esta es la primera detección de emisión molecular en esta peculiar estrella.

1. Introduction

B[e] supergiants are luminous, massive post-main sequence stars exhibiting rich low-excitation emission-line spectra dominated by Balmer lines and by narrow permitted and forbidden emission lines of singly ionized metals. They are characterized by the presence of non-spherical winds and a strong mid-IR excess at-

tributed to thermal radiation of circumstellar dust (Zickgraf et al. 1986; Lamers et al. 1998). Disk or ring-like structures, which provide ideal conditions for the condensation of molecules and dust particles, have been confirmed by polarimetry and interferometry (Magalhães 1992; Melgarejo et al. 2001; Domiciano de Souza et al. 2007). The physical properties of their circumstellar environments are not well understood, so the study of B[e] supergiants is of great importance for a deeper understanding of these rich and complex circumstellar structures.

Very little is known about the peculiar star LHA 120-S 35. Located in the Large Magellanic Cloud, it was first identified as an emission-line star by Henize (1956) and classified as a B[e] supergiant by Gummersbach et al. (1995) based on the analysis of its optical spectrum (3800-5200 Å). They reported the presence of strong and complex P Cygni-type Balmer lines and permitted and forbidden emission lines of singly ionized metals, mainly of Fe II, which are typical features observed in stars with the B[e] phenomenon. These authors also derived the following stellar parameters: T_{eff} = 22 000 K, log g = 3.0, E(B-V) = 0.06, $L_\star = 1.6 \times 10^5$ $L_\odot$, $R_\star$ = 28 $R_\odot$, and a ZAMS mass of M $\sim$ 22 $M_\odot$, from fitting atmospheric models to the observed continuum energy distribution between the ultraviolet and infrared spectral regions. Recently, Bonanos et al. (2009) presented its spectral energy distribution from 0.3 to 24 μm, showing infrared features that confirmed the presence of dust.

2. Observations

We obtained high-resolution optical spectra with the echelle spectrograph attached to the 2.5-m DuPont Telescope at LCO, Chile. The observations were performed on 2008 November 15. The chosen instrumental configuration gave a spectral resolution of R $\sim$ 45 000 and a spectral coverage from 3600 to 9200 Å. The data were reduced using standard IRAF tasks.

We also acquired high-quality, medium resolution (R = 4500) K-band (1.95-2.45 μm) spectra using the Spectrograph for Integral Field Observation in the Near Infrared (SINFONI) on the ESO VLT UT4 telescope on 2012 February 16. Data reduction was performed with the SINFONI pipeline. The IRAF task *telluric* was applied and radial velocity corrections were performed.

3. Results

We present here for the first time the spectral appearance of LHA 120-S 35 in the red part of the optical spectral range (5200-9200 Å) and in the near infrared K-band. Some preliminary results of our work in progress are reported.

Up to 5200 Å, the spectral description coincides with the one reported by Gummersbach et al. (1995). Towards the longer wavelengths, the Hα line is one of the most conspicuous features. The spectrum also shows prominent emission lines of [O I] $\lambda\lambda$ 5577, 6300, which present a single-peaked profile. The emission of the infrared triplet of Ca II $\lambda\lambda$ 8498, 8542, 8662 is clearly strong and the [Ca II] $\lambda\lambda$ 7291, 7324 emission lines are also detected. Hydrogen lines of the Paschen series are observed in emission. On the contrary, the He I $\lambda\lambda$ 5876, 6678 and 7065 lines are seen in absorption.

We determined the systemic velocity of LHA 120-S 35 from the permitted and forbidden Fe II lines to $V_{sys} = +(310 \pm 6)$ km s^{-1} in good agreement with the value of +308 km s^{-1} derived by Gummersbach et al. (1995). The FWHM of Fe II and [Fe II] lines is about 85 km s^{-1} and 25 km s^{-1}, respectively.

Figure 1 (left panel) shows the Hα line, which displays a very complex profile where the blue-shifted P Cygni absorption seems to be filled-in by emission. This profile accounts for a complex structure of the wind, which is mainly characterized by a fast component causing the blue-shifted P Cygni absorption with blue edges up to about -400 km s^{-1} and the slow component producing the -20 km s^{-1} blue-shifted central absorption.

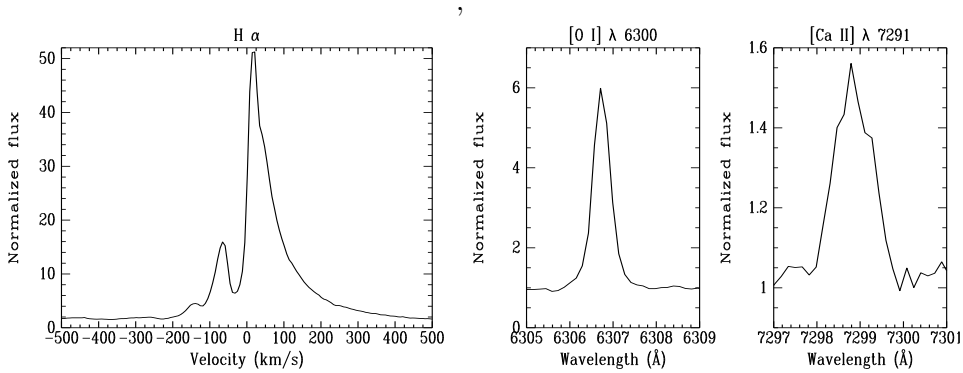

Figure 1. Left panel: Observed Hα-line profile on a velocity scale relative to V_{sys} in km s^{-1}. Center and right panels: Observed profiles of the [O I] λ 6300 and [Ca II] λ 7291 lines.

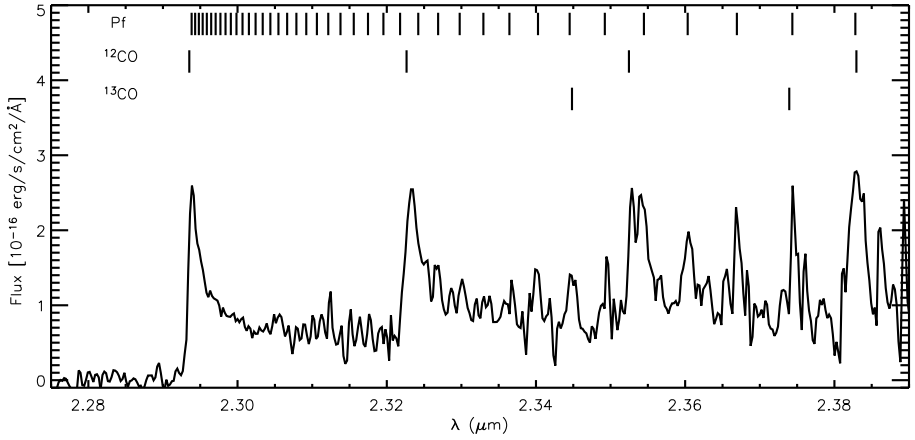

Figure 2. The first detection of CO band head emission in the flux calibrated SINFONI spectrum of LHA 120- S 35. The location of the ^{12}CO and ^{13}CO band heads and the lines of the H I Pfund series are indicated.

The K-band near infrared spectrum of LHA 120-S 35 covers the upper series of the hydrogen Pfund lines, which appear in emission. The data also reveal

strong CO band emission redwards of 2.29μm, which had not been reported earlier (see Figure 2). The band heads display similar strengths, pointing to cool molecular gas. The location of the ^{12}CO and ^{13}CO emission lines are indicated in the figure.

A future deep analysis of our spectra obtained in different wavelength regions will allow us to get valuable information on the structure and especially the kinematics within the circumstellar disk. The sets of optical forbidden lines of [O I] and [Ca II] have been recently discovered as relevant disk tracers of B[e] supergiants (Kraus et al. 2007, 2010; Aret et al. 2012). From visual inspection of the spectrum of LHA 120-S 35, the [Ca II] λ 7291 line and the [O I] λ 5577 line appear to have similar widths, both of which are broader than the [O I] λ 6300 line (see Figure 1, center and right panels). This would be in agreement with what Aret et al. (2012) found for other B[e] supergiants and might be interpreted with a Keplerian rotating disk, in which the order of location (with increasing distance from the star) of the different line forming regions (FR) would be as follows: 1) the [Ca II] λ 7291 FR, 2) the [O I] λ 5577 FR, 3) the [O I] λ 6300 FR.

Furthermore, the modeling of CO bands will provide important complementary information helping to determine the global structure of the disk of this B[e] supergiant.

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