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CPD–52 9243: Circumstellar Dust and Gas Properties Derived from Interferometric and Spectroscopic Data*

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Abstract. We present quasi-simultaneous interferometric (VLTI/MIDI) and optical and near-IR spectroscopic (CASLEO/REOSC, VLT/CRIRES, GEMINI/PHOENIX) observations of CPD–52 9243 which allow us to constrain its disk structure and kinematics. VLTI/MIDI observations provide strong support for the presence of a dusty disk-like structure around the star, with an inner angular diameter of 5 mas and an inclination angle of $\sim 50^\circ$. The dusty structure surrounds a CO gaseous Keplerian ring with a projected rotation velocity of 33 km s^{-1}. The optical line spectrum, crowded with P Cygni profiles, evidences a strong polar wind.

1. Introduction

CPD–52 9243 was classified as B8 Ia star with strong IR excess and Balmer lines with P Cygni profiles (Swings 1981). The spectrum is also crowded with emission lines of neutral and single ionized atoms, the strongest ones having also P Cygni profiles. He I appears only in absorption and the two unique forbidden lines, [O I] 6300, 6364 Å, qualitatively resemble the typical profiles for intermediate to large inclination. The presence of CO emission bands was reported by Whitelock et al. (1983) and McGregor et al.

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(1988). The star also exhibits strong polarization with $P = 5\%$ and $\theta = 36°$ (Swings 1981). McGregor et al. (1988) derived the following stellar parameters: log $T_{\rm eff} = 4.2$ and log $L = 5.4\,L_\odot$. Kozok (1985) estimated a $M_V = -6.6$ mag and a distance of 2.14 kpc, while (Swings 1981) reported a distance of about 3.1 kpc.

The non-sphericity of the circumstellar environment (CE) of several B[e] stars was confirmed by long-baseline interferometry (Domiciano de Souza et al. 2007; Meilland et al. 2010; Borges Fernandes et al. 2011). Our main goal is to study the geometry, kinematics and physical structure of the gaseous and dusty CE around B[e] supergiants in order to infer plausible mechanisms leading to the B[e] phenomenon. In what follows, we present high resolution spectroscopic and optical interferometric results on CPD–52 9243, one of the targets that are part of our observing campaign.

2. Results

We analyzed quasi-simultaneous observations of CPD–52 9243 performed, during April and May, 2010, in the optical, near-IR and mid-IR ranges using spectroscopy and long-baseline interferometry (Leinert et al. 2004).

Optical spectra: Spectroscopic observations were taken in the Hα region at CASLEO with the REOSC spectrograph ($R = 13\,000$). The obtained spectra are quite similar to those previously reported in the literature (Lopes et al. 1992; Winkler & Wolf 1989; Swings 1981). From the blueshifted absorption component of P Cygni profiles we derived an outflowing wind velocity of $\sim -200\,\mathrm{km\,s^{-1}}$ at the epoch of observation. The P Cygni absorptions of Na I lines give an outflow velocity of $-177\,\mathrm{km\,s^{-1}}$. He I and Mg II lines are observed in absorption with radial velocities of the order of $-290\,\mathrm{km\,s^{-1}}$. We also measured a mean radial velocity of $-54\,\mathrm{km\,s^{-1}}$ for the star, which was determined from the peak of the emission components of the P Cygni profiles. The study of diffuse interstellar bands (DIB), present in FEROS spectra previously obtained, suggests a color excess of $E(B-V) = 1.74$ mag (Borges Fernandes et al., in preparation).

Taking into account the radial velocity estimated for the star and that this object is located in the galactic plane: $l = 329.8°$ and $b = -0.7°$, we derived a kinematical distance assuming circular orbits for the gas and stars around the galactic center. We made use of the galactic rotation curve derived for the fourth quadrant by McClure-Griffiths & Dickey (2007) and obtained a distance of 3.4 ± 0.8 kpc from the Sun. Then, considering a mean absorption of 5.52 mag derived from the DIB components, we obtained $M_V = -7.83$ mag and log $L = 5.02\,L_\odot$. These values are in agreement with those calculated by Swings (1981) and McGregor et al. (1988).

Infrared spectra: High resolution ($R = 50\,000$) near-IR observations were carried out on April 3, 2010 with Gemini/PHOENIX and April 6 2010 with VLT/CRIRES, covering a wavelength range of 2.291 – 2.301 μm and 2.276 – 2.326 μm, respectively. The CO band emissions observed are clearly double-peaked (see Fig. 1, left), indicating either rotation in a quasi-Keplerian disk or an outflow confined within some solid angle around the equatorial plane, resulting in a slow, high-density disk. The peak separation of the vibro-rotational lines of the $2 \rightarrow 0$ band indicates a maximum radial velocity, projected to the line of sight, of about 25 – 26 $\mathrm{km\,s^{-1}}$.

A theoretical spectrum of CO bandheads was computed in the LTE approximation with the disk code of Kraus et al. (2000), considering models with different kinematical properties (Keplerian rotation or constant velocity outflow). Then, taking into account the disk inclination from the interferometric data, $i \simeq 50°$, we found that the model

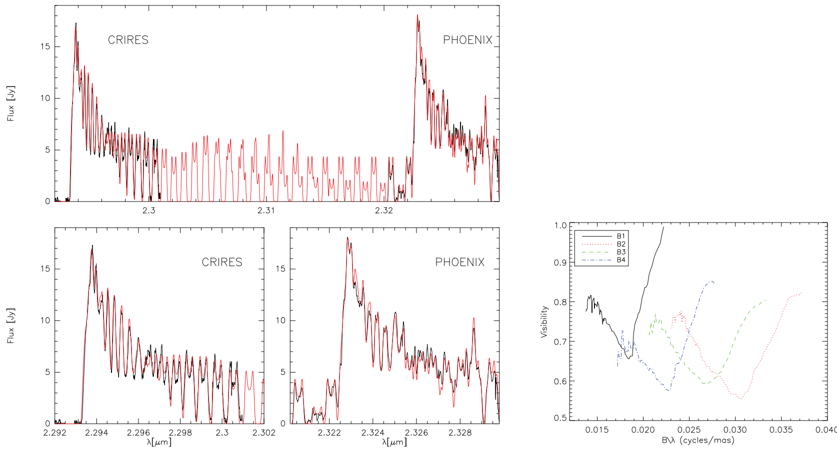

Figure 1. *Left:* Best-fitting rotating disk model (solid line/red) to the observed flux-calibrated CO bands (dotted line/black). A zoom of each CO bandhead fitting is shown in the bottom panels *Right:* VLTI/MIDI calibrated visibility curves of CPD–52 9243 as a function of the spatial frequency B/λ. Each color corresponds to a different orientation of the projected baselines.

that best reproduces the shape (width and peak-separation) of the resolved lines at the short-wavelength end of the Phoenix spectrum corresponds to a rotating model with a velocity of $33 - 34\,\mathrm{km\,s^{-1}}$ (see Fig. 1, left). From the modelling we also determine a disk temperature of 2400 K and CO column densities of $4 \times 10^{22}\,\mathrm{cm^{-2}}$.

On the other hand, we note a radial velocity shift of the CO spectra of about $-55\,\mathrm{km\,s^{-1}}$, which is in good agreement with the systemic velocity of the star obtained from the optical emission components of single ionized atoms and Balmer lines, and can therefore be ascribed to the star's radial velocity. This value leads to a kinematical distance of 3.4 ± 0.8 kpc.

Interferometric observations: *N*-band calibrated visibility curves of CPD–52 9243 were obtained from VLTI/MIDI data for different baselines and at different position angles (Fig. 1, right). The star is clearly resolved in all baselines and there is evidence of the presence of a non-spherical symmetric structure, probably a disk-like environment around the star. In all the observations the minimum visibility is observed around $10\,\mu$m which indicates a higher opacity due to the presence of silicate dust.

The observed visibilities were fitted with a single elliptical Gaussian, defined by the FWHM of the major axis (a_1) and of the minor axis (b_1), and the orientation of the major axis into the plane of the sky (θ_1). Since the CE extension varies within the *N*-band, we assumed that the free-parameters were wavelength dependent. We calculated the global χ^2 for all wavelengths and obtained the best-fitting model. The ratio of the FWHM axes gave us the inclination of the polar axis *i*, where $\cos\, i = b_1/a_1 = 0.625$. We found that there was a clear indication of a disk observed at intermediate to high inclination, in average around 50°, with the major axis oriented at $\sim 35°$ with respect to the plane of the sky. This result is consistent with the direction of the large polarization source reported by Swings (1981). In addition, from a Gaussian disk model, we estimate an upper limit for the inner edge and a lower limit for the outer edge of the dusty disk of ~ 5 and 20 mas, respectively.

3. Conclusions

High angular resolution interferometry measurements obtained with VLTI/MIDI provide strong support for the presence of a dusty disk-like structure around CPD–52 4392, with inner and outer angular diameters of 5 and 20 mas (radii of ∼ 8 and 35 AU), respectively. The disk presents an inclination angle with respect to the line of sight of ∼ 50°. Unfortunately, the detailed spatial resolution modelling of the CE structure is still not possible, since our data (based on only four sets of visibilities) do not have a good u, v-plane coverage. This dusty structure surrounds a CO gaseous ring in Keplerian rotation. On the other hand, the optical line spectrum evidences a strong and rapid wind outflow of about 280 km s^{-1}. Therefore, the existence of regions with quite different kinematical structures is consistent with a CE with two different components: a Keplerian disk and a polar wind.

We would also like to call the attention to the fact that the hottest ring of the CO emitting region has a temperature of only 2400 ± 100 K which turns out to be rather cold compared to the dissociation temperature of CO which is of the order of 5000 K. Similarly, cold CO rings have recently been found to surround two B[e] supergiants in the Large Magellanic Cloud (Liermann et al. 2010). Liermann et al. (2010) interpreted the lack of hot CO gas around these luminous stars as the result of a detached ring surrounding the stars rather than a disk reaching to much smaller distances from the star. The presence of a detached ring rather than a disk was also recently suggested by Kraus et al. (2010). Hence, such an interpretation might also hold for the disk/ring of CPD–52 9243 due to the absence of hot CO gas close to the star.

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References

Borges Fernandes, M., Meilland, A., Bendjoya, P., et al. 2011, A&A, 528, A20
Domiciano de Souza, A., Driebe, T., Chesneau, O., et al. 2007, A&A, 464, 81
Kozok, J. R. 1985, A&AS, 62, 7
Kraus, M., Borges Fernandes, M., & de Araújo, F. X. 2010, A&A, 517, A30
Kraus, M., Krügel, E., Thum, C., et al. 2000, A&A, 362, 158
Leinert, C., van Boekel, R., Waters, L. B. F. M., et al. 2004, A&A, 423, 537
Liermann, A., Kraus, M., Schnurr, O., et al. 2010, MNRAS, 408, L6
Lopes, D. F., Damineli Neto, A., & de Freitas Pacheco, J. A. 1992, A&A, 261, 482
McClure-Griffiths, N. M., & Dickey, J. M. 2007, ApJ, 671, 427
McGregor, P. J., Hyland, A. R., & Hillier, D. J. 1988, ApJ, 324, 1071
Meilland, A., Kanaan, S., Borges Fernandes, M., et al. 2010, A&A, 512, A73
Swings, J. P. 1981, A&A, 98, 112
Whitelock, P. A., Feast, M. W., Roberts, G., et al. 1983, MNRAS, 205, 1207
Winkler, H., & Wolf, B. 1989, A&A, 219, 151