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A search of OB stars in the field of the galactic OB association Bochum 7

II. Proper Motion and IR photometry

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ABSTRACT

Aims. We plan to identify the members of the Bochum 7 association by performing simultaneous astrometric and spectrophotometric analysis, and estimate its distance and evolutionary stage.
Methods. We used our own visual spectroscopic and UBV photometric data of 30' × 30' region centered in $\alpha = 8^h44^m47.2^s$, δ = - 45°58′55.5″. This information enabled us to estimate the spectral classification and distance of all stars present in the region. The proper motion was analyzed with data of the UCAC 5 catalogue. This was used to identify the members of this association. We added JHK data from 2MASS and IRAS catalogues to check for the presence of IR excess stars
Results. We found that Bochum 7 is an OB association with at least 27 identified stellar members (l = 265°.12, b = −2°) at the distance of ≃ 5640 pc. Its proper motion is $\mu_\alpha cos\delta = -4.92 \pm 0.08$ mas yr^{-1}, $\mu_\delta = 3.26 \pm 0.08$ mas yr^{-1}. We derived an average heliocentric radial velocity of ∼ 35 km s^{-1} and were able to confirmed the binary nature of the (ALS 1135) system and detect four new binary star candidates. Massive Bo 7 star candidates point towards a young age ($\leq 3 \times 10^6$ years old) for the association, although the presence of a previous episode of star formations remains to be analyzed.

Key words. Stars: early-type – Proper motions – Catalogues – Open clusters and associations: individual: Bochum 7

1. Introduction

The need for relevant statistics, such as the determination of large scale galactic structure and the quantification of metallicity's gradients on the disk, require the knowledge of OB associations at distances of several kiloparsecs.

The study of associations located at distances greater than the kiloparsec, becomes extremely complex and the use of a single research technique yields unreliable results with large uncertainties. Bochum7 is located in the region known as the "Puppis Window" in the third quadrant of our Galaxy. The low interstellar extinction in this region, allows to obtain reliable observational data of stars that belong to the Perseus arm.

The available information can be summarized as follows:

- Stephenson & Sanduleak (1971) published the Luminous Stars in the Southern Milky Way (ALS) Catalogue.
- Moffat & Vogt (1975) performed a survey of open clusters with photoelectric photometry using the 61 cm telescope of the Bochum University at La Silla, Chile. They found that 9 members of the ALS Catalogue possibly formed an association with $\overline{E(B-V)}$ = 0.86 and $\overline{d}$ = 5.8 kpc.
- Stenholm (1984) evaluated existing data about Wolf-Rayet (WR) stars in OB associations and open clusters. They confirmed the membership of WR12 to Bochum 7, as originally proposed by Niemela (1982) and estimated a 30 pc diameter for the association.
- Sung et al. (1999) used UBV and Hα photometry and located Bo 7 at a distance of 4.8 kpc near the center of the Vela OB1 stellar association (Reed 2000). They estimated the age of the association to be about 6 Myr old.
- Dias et al. (2002) published the new catalogue of optically visible open clusters and candidates. For this, they worked with the Tycho 2 data and presented 953 members of Bochum 7 with $\mu_\alpha cos\delta$ = -0.05 mas yr^{-1} and μ_δ = 3.34 mas yr^{-1}, although no detailed breakdown of the method was presented.
- Arnal & Corti (2007) based on the analysis of the neutral hydrogen (HI) supershells carried out at the Southern Galactic Plane Survey (SGPS) proposed that the OB-association Bochum 7 was born as a consequence of the evolution of GS263-02+45.
- Corti et al. (2007) performed the first spectroscopic analysis with the OB star candidates selected from UBV aperture photometry of the 30 arc minute field centered in $\alpha = 8^h44^m47.2^s$, δ = - 45°58′55.5″(J2000.0) (hereafter Paper I).
- Michalska et al. (2013) performed a photometric investigation focused on the binary system ALS 1135 and dis-

covered 17 variable stars in the field of Vela OB1 or Bo 7 associations.

Stellar proper motions constitute a powerful tool for the identification of members of stellar groupings, open clusters or OB associations (Dias et al. 2002; de Zeeuw et al. 1999, and references therein). It is therefore necessary to have stellar catalogs containing very good proper motions and covering a large extent of the celestial sphere down to faint magnitudes. The goal of this work is to increase our knowledge of the stellar components of Bochum 7. For this, we now present an astrometric study that makes use of UCAC 5 (Zacharias et al. 2017) catalogue. With this survey we were able to derive the proper motion of stars located in the field of Bochum 7 association. The combination of the astrometric results with the analysis shown in Paper I yield the astro-spectrophotometric members of Bochum 7 association, its distance, age, radial velocities, etc. In this way, it is possible to increase our knowledge of the galactic region where Bo7 association is located.

The paper is organized as follows: Sect. 2 describes the data available, the analysis methods and results are shown in Sect. 3 and the discussion about global properties of the association and individual stars is developed in Sect. 4. Section 5 includes a brief summary of our findings. Additional material such as detailed information from radial velocity measurements for individual stars is included in an Appendix.

2. Observational Data

2.1. Astrometric data

The astrometric data used in this paper, stellar position and proper motion, are extracted from the UCAC 5 catalogue.

The UCAC 5 Catalogue presents positions over 180 million stars and 107.7 million of them with proper motions as well. The UCAC 5 positions are on the Gaia DR1 (Gaia Collaboration et al. 2016a,b) reference system. The positions have mean epochs around 1998-2000 in the south, and around 2001 to 2003 in the north. Formal position errors are about 8 mas for stars with magnitude 11 and 20 mas at magnitude 14. The UCAC 5 catalogue presents very precise proper motions combining UCAC 5 with Gaia DR1. Errors in proper motions of bright stars (R = 11 to 15 mag) lie between 1 and 2 mas yr^{-1} and can increase to 5 mas yr^{-1} for the fainter stars.

A detailed description about the construction of UCAC 5 catalogue can be found in Zacharias et al. (2017). Data extraction has been performed using the SIMBAD Astronomical Database (CDS).

2.2. Photometric and spectroscopic data

The UBV photometric data analyzed by us in order to investigate the OB association Bochum 7 are the ones presented in Sect. 2 and SubSect. 3.1 of Paper I. We selected stars with $V < 15$ mag and reddening−free parameter $Q < -0.3$ (Schmidt-Kaler Th. 1982) in the 30' × 30' photometric image centered at $\simeq \alpha = 8^h45^m$, $\delta = -45°59'$ ($l = 265.°12$, b $= -2.°0$) and found 248 probable members of this association (see Table 1). The photometric study were complemented with JHK data from the Two Micron All Sky Survey (2MASS) (Skrutskie et al. 2003)

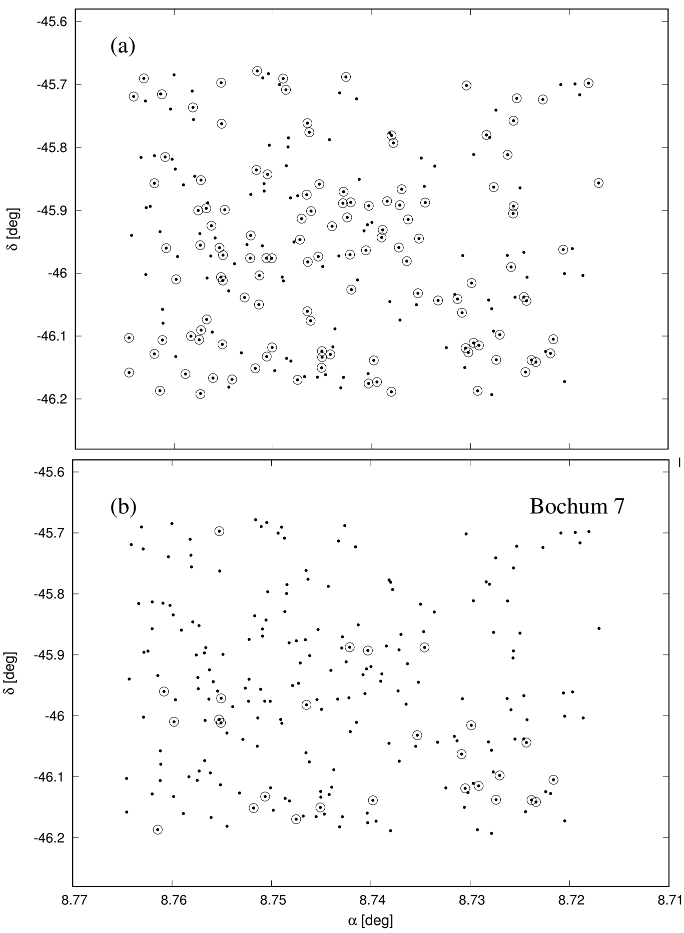

Fig. 1. Spatial distribution of the stellar association. a) Open circles around the dots represent the 123 stars with similar proper motions identified in the first analysis; the points represent the rest of the stars of the region, a total of 219 stars. b) Open circles represent the 27 astrometric and spectrophotometric Bochum 7 association members. All of them were derived using the model proposed by Orellana et al. (2010).

We also investigate the IRAS point sources present in the region under study consulting the Gator Catalog Query[1] in the IRAS Point Source Catalog v2.1 (PSC) section.

Spectral images data studied in this work are the ones presented in SubSect. 3.2.1 of Paper I.

3. Results

3.1. First astrometric analysis

Although impossible to detect by visual inspection of direct imaging, the existence of an association can be inferred from their proper motions, through the analysis of the Vector Point Diagram (VPD). In this diagram the relatively small differences of the velocities of individual stars from the association can be detected as an over-density. As a first step, we identified in UCAC 5 catalogue the 219 stars out of the 248 candidates proposed as members of Bochum 7 (Table 1). For its identification, the astrometric catalog UCAC4 was used as an intermediate catalog in the following way. From the 248 early type stars present in the field of view

[1] http://irsa.ipac.caltech.edu/missions

of Bochum 7, 226 were identified in UCAC4 from position (α, δ) and magnitudes (V, B). From the UCAC4 sample, 219 were further identified in the UCAC5 from position (α, δ) and 2MASS magnitudes (J, H, K.). Then we analyze the presence of an over-density with the model proposed by Orellana et al. (2010). In their paper, they suggested for the first time, a standardized way to identify the members of an association. To do this, the authors applied the same technique used for open clusters considering only the proper motions based upon the maximum likelihood principle (Sanders 1971).

The distribution of the proper motions will be the overlapping area of two bivariate normal frequency functions in an elliptical subregion of the VPD selected as indicated by Vasilevskis et al. (1965)

$$\Phi_i(\mu_{xi}, \mu_{yi}) = \phi_{1i}(\mu_{xi}, \mu_{yi}) + \phi_{2i}(\mu_{xi}, \mu_{yi}) \quad (1)$$

where ϕ_{1i} is a circular distribution for cluster stars, ϕ_{2i} is an elliptical distribution for field stars. The circular and elliptical distributions take the following form

$$\phi_{1i}(\mu_{xi}, \mu_{yi}) = \frac{N_a}{2\pi\sigma_a^2} \times$$
$$\times \exp\left[-\frac{(\mu_{xi}-\mu_{xa})^2 + (\mu_{yi}-\mu_{ya})^2}{2\sigma_a^2}\right] \quad (2)$$

and

$$\phi_{2i}(\mu_{xi}, \mu_{yi}) = \frac{N_f}{2\pi\sigma_{xf}\sigma_{yf}} \times$$
$$\times \exp\left[-\frac{(\mu_{xi}-\mu_{xf})^2}{2(\sigma_{xf})^2} - \frac{(\mu_{yi}-\mu_{yf})^2}{2(\sigma_{yf})^2}\right] \quad (3)$$

where the symbols σ_{xf}, σ_{yf} are the elliptical dispersions for the field stars, σ_a the circular dispersion for the association stars, μ_{xf}, μ_{yf} the field star mean proper motion, and μ_{xa}, μ_{ya} the association mean proper motion. N_a is the number of association members, and N_f the number of field stars. These parameters are found by applying the maximum likelihood principle. Once determined, the probability for the i−th star has been calculated as

$$P_i(\mu_{xi}, \mu_{yi}) = \frac{\phi_{1i}(\mu_{xi}, \mu_{yi})}{\Phi_i(\mu_{xi}, \mu_{yi})}. \quad (4)$$

A cluster member is found when $P_i \geq 0.5$.

In this procedure we do not consider the influence of proper motions errors. Chen et al. (1997) and Orellana et al. (2015) show that the error does not change the parameters significantly and more than 80% of the members maintain their condition.

The astrometric study begins by applying the maximum likelihood method to an elliptical subregion of the VPD containing 186 stars (Fig. 2a). The parameters of the stars with similar proper motions obtained from this method are $N_a = 123$, $\mu_{xa} = -5.42 \pm 0.06$ mas yr^{-1}, $\mu_{ya} = 3.63 \pm 0.06$ mas yr^{-1}, $\sigma_a = 0.74 \pm 0.05$ mas yr^{-1}. Figs. 1a) and 2b) show the location of the 123 stars in the spatial distribution and in the VPD, respectively, with open circles around the dots. In order to identify the members stars of Bochum 7 we analyzed the distance modulus (DM) of the 123 possible members.

3.2. Spectral types and Distances

The spectral classification of stars in this study were obtained in Paper I and they are listed in Table 2.

In this paper the DM of each star was obtained using Eq. (4) of Paper I. The intrinsic $(B-V)_0$ color index and A_V visual extinction were calculated from our observational data with Eqs. 5 and 6, respectively. The latter were obtained from Schmidt-Kaler (Th. 1982), together with the absolute visual magnitude of each star according to its spectral type.

$$(B-V)_0 = 0.319 \times (U-B) - 0.23 \times (B-V) - 0.026 \quad (5)$$

$$A_V = 3.23 \times [(B-V) - (B-V)_0] \quad (6)$$

For stars with two different spectral types, we calculated the average value of M_v and interpolated linearly whenever needed. The error in the determination of the distance to each star was found to be around 30%. We obtained that value with errors propagation. For this, we considered average magnitude errors of 0.08 in V, 0.10 in B, and 0.18 in U (Paper I) and an uncertainty of 0.5 in the estimation of M_v (Walborn 1972). Although errors in individual distances derived from spectroscopic classification are large, they can still provide a first order estimation useful for removing foreground and background stars. We finally chose to consider possible Bo 7 association members to those stars whose distance matched with the average distance ($\overline{\mathrm{DM}} = 13.725$) obtained from the subset of ALS stars listed as Bo7's members by Moffat & Vogt (1975), accounting for 0.5 mag uncertainty. In this way, were considered 26 stars with $13.475 \leq \mathrm{DM} \leq 13.975$ resultant of the first astrometric analysis as probable members of Bochum 7. We also included the binary system ALS 1135 even though its photometric distance (DM = 14.1) is slightly off the range as binary pairs have larger uncertainties in their photometric distance determinations. The results obtained in the calculation of DM are shown in Table 2. The DM obtained for stars in common with Paper I, are in very good agreement.

3.3. Final astrometric analysis and association distances

In order to improve the identification of the members of Bochum 7, the maximum likelihood method was applied to a group of stars selected from the 186 stars of the elliptical subregion and DM analysis as follows.

We removed the contamination produced by 94 stars located in the foreground and background of Bochum 7 sample, i.e. those with distance modulus in the ranges 13.475 > DM > 13.975 obtained following the procedure outlined in Subsection 3.2. The Orellana et al. (2010) model was applied again to these 92 stars (186 (stars of the elliptical subregion) - 94 (stars outside the Bo 7 bin)) and the refined parameters found were $N_a = 27$, $\mu_{xa} = -4.92 \pm 0.08$ mas yr^{-1}, $\mu_{ya} = 3.26 \pm 0.08$ mas yr^{-1}, $\sigma_a = 0.42 \pm 0.07$ mas yr^{-1}. In this case 27 stars were identified as likely candidates to be members of Bochum 7. Fig 1b) and Fig. 2c) show their spatial distribution and VPD, respectively. Table 1 lists the stars found with this procedure.

After combining membership by proper motions and distances via spectrophotometry, the distance moduli of Bochum 7 association is found to be 13.7 ± 0.2 (5.6 ± 1.7 kpc).

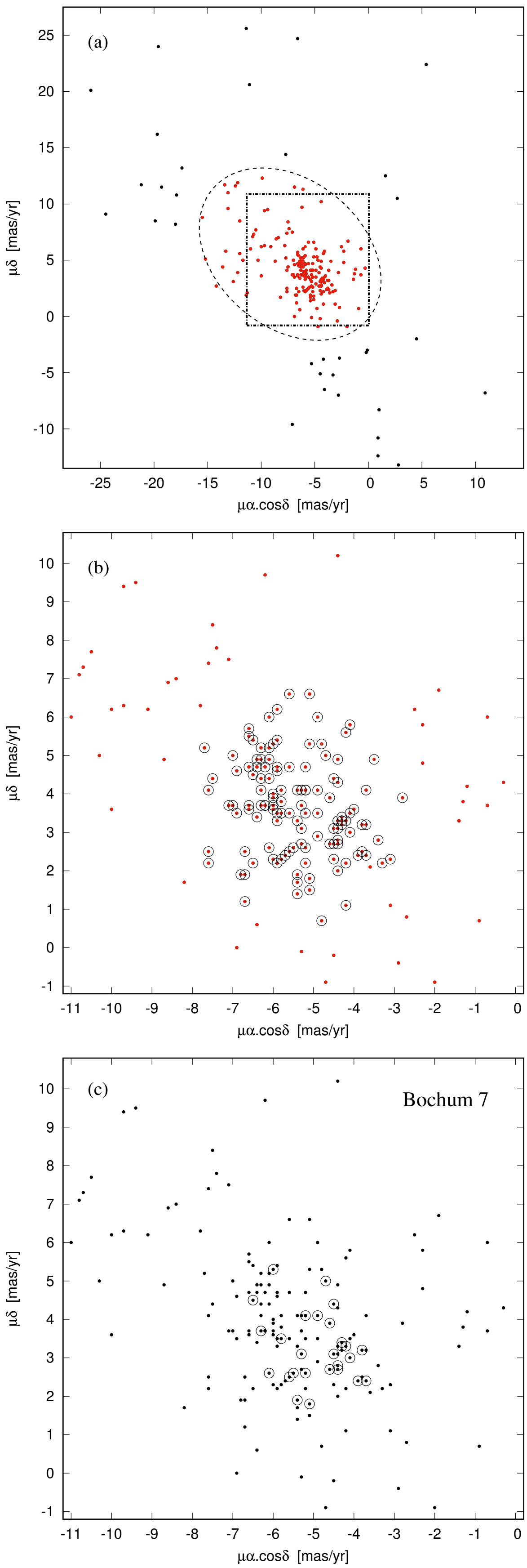

Fig. 2. VPD of the stellar association consulting UCAC5 catalogue. (a) Maximum likelihood method assigns the Gaussian distribution bivariate elliptic to the 186 field stars. Points outside ellipse represent the rest of the region's stars in the first analysis. (b) Is a zoom image of the square indicated in (a). Open circles around the dots represent the 123 astrometric members that the maximum likelihood method assigns the Gaussian circular distribution bivariate. (c) Open circles represent the 27 astrometric and spectrophotometric association Bochum 7 members. All of them were obtained using the model proposed by Orellana et al. (2010).

Table 1. Possible astrophotometric members of Bochum 7

ID[(1)]	$\alpha_{J2000.0}$ ($h:m:s$)	$\delta_{J2000.0}$ (o:':")	UCAC 5	$\mu_\alpha cos\delta$ (mas yr^{-1})	μ_δ (mas yr^{-1})
343	8:45:41.2	-46:11:13	532984646920682	-5.8	3.5
390	8:45:38.9	-45:57:36	532994570012623	-6.0	5.3
521	8:45:35.3	-46:00:35	532994535653243	-5.5	2.6
1031	8:45:18.9	-45:41:49	532996518209937	-6.3	3.7
1052	8:45:18.9	-46:00:22	532986340855840	-4.6	3.9
1069	8:45:18.2	-45:5817	532986358035711	-5.2	4.1
1071	8:45:18.3	-46:00:42	532986340855840	-6.5	4.5
1470	8:45:06.4	-46:09:05	532984921798650	-4.5	4.4
1607	8:45:02.2	-46:07:57	532984928670556	-5.4	1.9
1939	8:44:51.0	-46:10:11	532984873695016	-4.6	2.7
2041	8:44:47.3	-45:58:55	532986423319214	-4.4	2.8
2197	8:44:42.3	-46:09:01	532986065977889	-5.6	2.5
2511	8:44:31.6	-45:53:15	532986842508021	-5.3	3.1
2720	8:44:25.1	-45:53:35	532986859687891	-5.1	1.8
2781	8:44:23.2	-46:08:19	532985584941600	-4.3	3.3
3211	8:44:07.1	-46:01:55	532986536706341	-5.2	2.6
3273	8:44:04.5	-45:53:16	552202093686894	-4.4	2.7
3669	8:43:51.1	-46:03:46	532986014438328	-3.7	2.4
3705	8:43:49.8	-46:07:09	532985883871323	-4.2	3.3
3767	8:43:47.6	-46:00:56	532986045362086	-4.7	5.0
3829	8:43:44.9	-46:06:54	532985880435349	-4.5	3.1
3982	8:43:38.6	-46:08:16	532985729252501	-4.3	3.4
4009	8:43:37.3	-46:05:52	532985959462720	-3.9	2.4
4234	8:43:27.6	-46:02:38	552201354523083	-4.1	3.0
4288	8:43:25.7	-46:08:17	532985818587821	-4.9	4.1
4331	8:43:24.1	-46:08:29	532985815581938	-3.8	3.2
4476	8:43:17.8	-46:06:18	552201182724391	-6.1	2.6

[(1)] This paper

3.4. Stellar radial velocities

The radial velocity is another important parameter to be studied for each star member of the association. We gathered radial velocity determinations for 15 stars in Bochum 7 association (Column 9 of Table 2). A detailed breakdown of individual measurements can be found in Appendix A.

A single determination of radial velocities of massive stars must be handled with care and the uncertainties in individual distances are large likewise we perform an individual check on their velocities and those expected according to the Milky Way rotation.

Figure 3 shows the LSR radial velocity, RV$_{LSR}$, and the distance to the Sun of each star, both parameters included with their respective error bars. The fit of the Galactic rotation curve model by Brand & Blitz (1993) applied to the third quadrant of the Galaxy (see Sano et al. (2017)) is also plotted as a reference, although the *uncertainties* in the model determination at about 10 kpc from the Galactic Centre are large. Large uncertainties involved in the individual parameters reflects in the observed scatter, and only star #4288 is located farther than expected for its errors. Appendix A includes two radial velocity determinations with similar low values, making it the strongest candidate to be checked for RV anomalies in the future with better resolution spectra.

The galactic rotation model (Fig. 3) indicates that at a distance to the Sun of ∼ 5.7 kpc (∼ 13.7 mag) the Local Standard of Rest radial velocity (V$_{LSR}$) value is ∼ 40 km s^{-1} (V$_{he}$ ≃ 35 km s^{-1}). This is in good agreement with the radial velocity values with their errors shown for Bochum 7 members in Table 2.

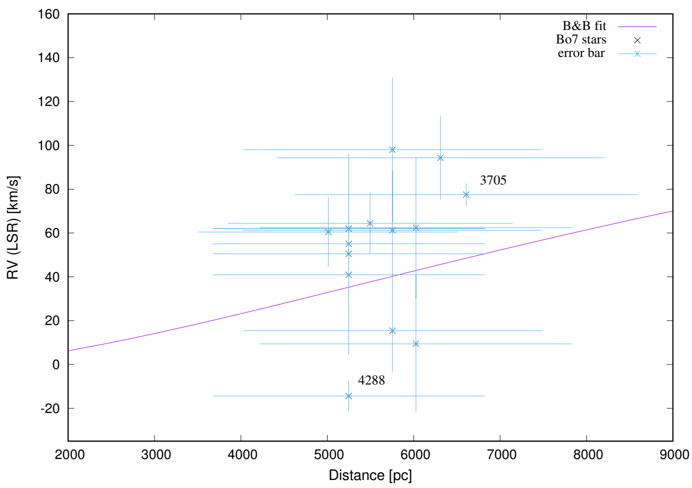

Fig. 3. LSR corrected radial velocity vs. distance of Bo 7 member candidates, plotted as blue crosses with their corresponding error bars. The pink curve displays the fit of the galactic rotation model applied to the third quadrant of our Galaxy (Brand & Blitz 1993). Star #4288 is the only more than 3σ away from its expected location and it is discussed in the text. As a reference, #3705 star is the ALS 1135 binary system.

4. Discussion

4.1. Recent membership identifications.

Michalska et al. (2013) performed a photometric and spectroscopic investigation focused in the ALS 1135 binary system and presented a photometric analysis of the surrounding region. They built a VI colour magnitude diagram and used additional information from spectroscopic classification found in the literature and variable stars identified from their photometry to identify six stars of this region as possible Bo 7 members. Five of these stars are included in the present work and we agree on member candidacy for stars #3705 (ALS 1135), #3669 (ALS 1137) and #3829 (CBN 84344.7-460656) although we reject CBN 84348.6-460736 and CBN 84346.7-460641 that according to our astrometric and spectrophotometric study would not be Bo 7 members by distance.

4.2. Size and evolutionary age.

Defining the boundary of the association is a non trivial issue. The lack of visible concentration of stars among the background forces us to distinguish this group kinematically, but although proper motion surveys are available, it is not possible to derive radial velocities for all the stars. Furthermore, chances of massive stars being part of a multiple system are high (Bosch et al. 2009), but it is complicated to know if the star belongs to a multiple system when there are only few spectra of it.

As was explained in Sect. 3.1 with data of proper motion is possible to do a first selection of associations members but it is not enough in order to define the size of them. At distance of $\simeq 5640$ pc adopted for Bochum 7 association, our field of view limits the surveyed area to a 50 pc wide region. This size corresponds to the typical sizes of the stellar associations (Efremov et al. 1987) although it is somewhat larger than the diameter of 30 pc found by Stenholm (1984). This association is projected onto the outer border of the HI supershell $GS263-02+45$ (Arnal & Corti 2007). Both objects have similar distances and radial velocities, so it is possible that a physical link between them is present.

Combining the photometric and spectroscopic information on member candidates we can know the evolutionary stages of the association. Figures 4 is the color-magnitude diagram (CMD) of Bochum 7. This figure shows the intrinsic visual magnitude and the intrinsic color index of each star and stars are labeled according to their luminosity class. The theoretical isochrones for solar metallicity, mass loss, and overshooting (Marigo et al. 2008) are also plotted as a reference. Figure 4 shows that main sequence and giant stars occupy a particular region of the CMD, with an unavoidable scatter, possibly due to stars from different formation events, that belong to multiple systems, stars with emission lines or fast rotators. As we are dealing with an incomplete sample of the association, we do not have enough number of stars to attempt a precise fitting of isochrones in order to discriminate different populations among them. However, it is evident that almost all massive stars lie close to the 3×10^{6} years old isochrone, pointing towards very recent episode(s) of star formation, younger than 1×10^{7} years old. The presence of WR12, a Wolf-Rayet star in the field can also be linked to recent massive star formation and was the key driver of the original spectrophotometric study. WR12 which has been identified as a single spectrum spectroscopic binary and its spectral classification (WN8h) suggests an evolutionary age of 3.5×10^{6} years (Smith & Conti 2008). van der Hucht (2001) estimates a distance of 5 kpc based on photometric data and an absolute magnitude M_v of -5.48. However, we must always keep in mind that magnitudes of WR stars are very uncertain. A very well studied star as GR290 (Polcaro et al. 2016) presents a visual magnitude that ranges from 18.3 to 18.7 in its WN8h phase. Regarding its proper motion, WR12 has a $\mu_\alpha cos\delta$ of -4.4 mas yr^{-1} and μ_δ of 2.8 mas yr^{-1}, coincident with the proper motion values of the Bochum 7 members.

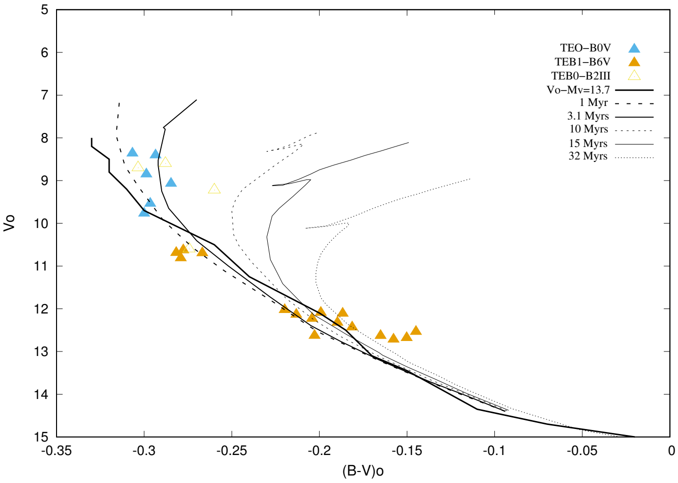

Fig. 4. CMD of member stars of Bochum 7. The main sequence stars among O6.5 and B0 are identified with light blue triangles, the main sequence stars among B1 and B6 are identified with yellow triangles, and the luminosity class III stars among B0 and B2 are identified with yellow open triangles. The thicker continuous curve is the Schmidt-Kaler (Th. 1982) HR diagram for early stars; the other curves are Marigo et al. (2008) isochrones for $z=0.02$. All the reference curves are corrected by an apparent distance modulus of 13.7

Figure 5 shows the spatial distribution of the Bochum 7 members, split in three groups according to their spectral types. One group includes the main sequence stars between O 6.5 and B 0 type (light blue triangles) which can be linked to the most recent and massive formation episode. The other group includes the main sequence stars from B 1 to B 6 (yellow triangles) and the last group includes the giant stars among B 0 and B 2 (yellow open triangles) encompassing evolved and less massive stars. The young and massive group seems more concentrated towards the southwestern region of the surveyed area. Furthermore, in the southern edge we can identify the infrared source IRAS 08426-4601 mentioned in SubSect. 2.2, which can be associated with ongoing star formation in that area. The relatively older and less massive population is more evenly spread throughout the field covered by our photometry. This scenario where different evolutionary stages seem to occupy different areas can be interpreted as a trace of sequential star formation but as Fariña et al. (2009) discussed in the N159/160 region in the LMC, a detailed and more complete study is needed before any strong claim is made. Furthermore, it is worth recalling the possible scenario described by Bastian (2011) where stars could be formed in loose filamentary groups and which will disperse in the background without the need of a large cluster with subsequent gas expulsion.

4.3. IR Photometry

The near IR two-color diagram is a good tool for the selection of IR excess stars. Figure 6 is the JHK color-color diagram obtained with 2MASS photometric of stars members of Bochum 7 association. In figure 6, the black and lilac solid curves are the unreddened and shifted according to the color excess main sequence stars, respectively (Koornneef 1983). The color excess were obtained using the Rieke & Lebofsky (1985) equations, knowing that the $E(B-V)$ is 0.77 magnitudes for Bochum 7. The dashed lines indicate

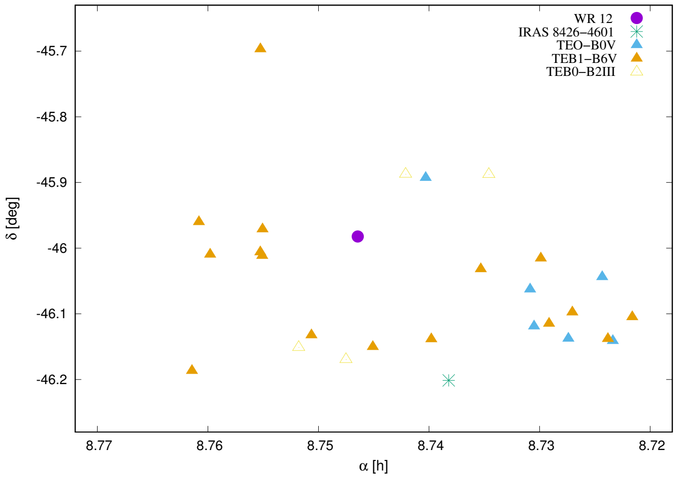

Fig. 5. Spatial distribution of the Bochum 7 members. The WR12 star is identified with a big lilac dot and the IRAS source is identified with green asterisk. The other symbols are the same as those in Fig. 4

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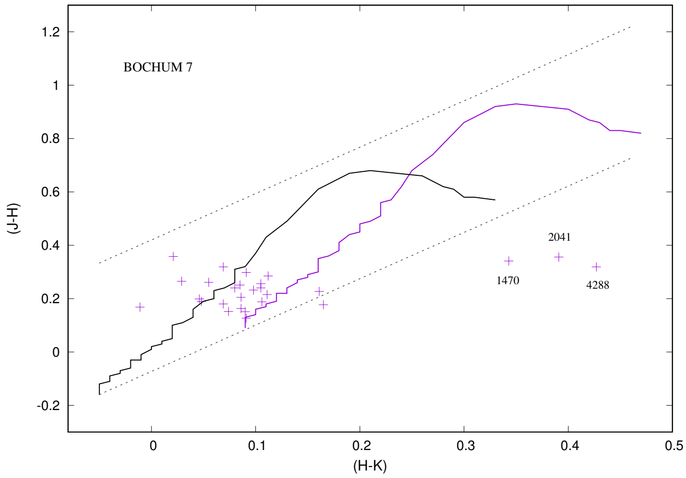

Fig. 6. Photometric diagrams for stars members of Bochum 7. Dashed lines indicate the normal reddening path (Rieke & Lebofsky 1985). The black and lilac solid curves are the unreddened and shifted according to the color excess MS, respectively (Koornneef 1983).

the normal reddening path (Rieke & Lebofsky 1985). Next to the symbols we show the stellar identification number from this paper (see Table 2).

The error of $\simeq$ 0.02 mag in the JHK color of stars observed with 2MASS telescopes, would be the reason why some stars are so distributed around the MS curve. Bochum 7 has the stars #1470, #2041 and #4288 that lie to the right of the normal reddening vector of an OB dwarf star. This apparent infrared excess can be linked to the presence of dusty disks current star formation or emission lines that enhance the observed K-band flux. Our optical spectra reveal that all these stars show emission lines (the star #1470 is classified as B0 IIIe, #2041 as WN8 and #4288 as B1-2Ve) which can be responsible for the shift to the right in their (J-H) vs. (H-K) diagram.

In the vicinity of Bo 7 is the IRAS source 8426-4601 (l, b) = (265°.3, -2°.2). In the survey of the CS (2-1) emission toward IRAS point sources in the galactic plane (Bronfman et al. 1996) this IRAS source shows an emission line at radial velocity V = 43.8 km s^{-1}. The color-color diagram obtained from the fluxes measured in the infrared (Wood & Churchwell 1989) indicates that it could be an ultra compact HII region. Molecular observations of different CO emission lines obtained with MOPRA[2] and APEX[3] radio telescopes are currently being analyzed. The main objective of these observations is to characterize the molecular cloud physics associated with the source IRAS 8426-4601 and Bochum 7 (paper in preparation).

5. Summary

Since the discovery of the Bochum 7 stellar group by Moffat & Vogt (1975), several efforts towards identification of its members have been made in the region using spectroscopic, photometric or astrometric analysis techniques. This paper is the result of the first investigation carried out in the Bo 7 region employing these astrophysics techniques simultaneously. With these we confirmed that Bochum 7 is an OB association centered at $\alpha = 8^h45^m$, $\delta = -45°59'$ (l = 265°.12, b = −2°.0) at the distance of $\simeq$ 5.7 kpc and identified 27 stellar members. The components of the proper motion are $\mu_\alpha cos\delta = -4.92{\pm}0.08$ mas yr^{-1}, $\mu_\delta = 3.26{\pm}0.08$ mas yr^{-1}. Bo 7 is located on the edge of the HI supershell $GS263-02+45$ (Arnal & Corti 2007) and perhaps the birth of the Bo 7 association may be related to the evolution of this HI supershell. The heliocentric radial velocity of Bo 7 could be $\sim$ 35 km s^{-1} (V$_{LSR}$ = 40 km s^{-1} for d = 5.7 kpc, Fig. 3), has a confirmed binary system (ALS 1135, Corti et al. (2003)) and other four stars with variable radial velocity, candidates to form part of binary systems.

[2] https://www.narrabri.atnf.csiro.au/mopra/
[3] http://www.eso.org/public/teles-instr/apex/

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Table 2. Spectrophotometric information of stars in Bochum 7, including distance modulus determination and measured radial velocities

ID	V	J	H	K	(B-V)	SpT	V_o - M_v	RV (km s^{-1})	Cross ref. CBN.........../2MASS..........
343	14.8	13.5	13.3	13.1	0.59	b4 V	13.8	–	84541.2-461113/J08454120-4611127
390	14.4	13.4	13.2	13.2	0.40	b5 V	13.8	–	84538.9-455736/J08453890-4557364
521	14.8	12.8	12.5	12.5	0.66	b5 V	13.6	–	84535.3-460035/J08453526-4600351
1031	14.8	13.3	13.0	12.9	0.57	B5 V	13.5	49(16) (II)	84518.8-454147/J08451888-4541494
1052	14.6	12.7	12.5	12.4	0.56	b3 V	13.7	–	84519.0-460022/J08451895-4600221
1069	13.6	12.0	11.8	11.7	0.65	B1 V	13.8	88(33)(II)	84518.2-455816/J08451822-4558166
1071	14.8	13.4	13.2	13.1	0.55	b5 V	13.6	–	84518.3-460042/J08451829-4600418
1470	11.5	9.6	9.3	8.9	0.55	B0 IIIe	13.8	var (Tab. A.5)	84506.4-460905/ALS 1147
1607	15.0	13.4	13.0	13.0	0.70	b3 V	13.6	–	84502.2-460757/J08450226-4607572
1939	11.6	10.3	10.1	10.1	0.47	B1 III	13.6	var (Tab. A.4)	84450.9-461012/ALS 1146
2041	10.8	8.6	8.3	7.9	0.51	WN8	13.8	–	84447.2-455856/ALS 1145
2197	14.8	13.3	13.1	13.0	0.48	b4V	14.0	–	84442.2-460900/J08444228-4609013
2511	13.5	11.8	11.6	11.5	0.61	B2 III	14.0	85(19) (II)	84431.5-455314/J08443163-4553148
2720	11.3	9.8	9.6	9.4	0.61	O7.5 V	13.6	var (Tab. A.3)	84424.9-455334/ALS 1144
2781	13.7	11.8	11.6	11.4	0.65	B1-2/V-III	13.9	55(32) (II)	84423.1-460821/J08442325-4608192
3211	14.9	13.3	13.1	13.0	0.58	b6 V	13.6	–	84407.2-460155/J08440715-4601548
3273	11.7	9.8	9.5	9.5	0.68	B0 III	13.7	var (Tab A.6)	84404.5-455316/ALS 1140
3669	11.4	10.2	10.0	10.0	0.45	O9-9.5 V	13.6	var (Tab A.6)	84350.9-460348/ALS 1137
3705	10.9	9.9	9.7	9.6	0.34	O6.5((f)) V	14.1	71(1)⋆	84349.6-460711/ALS 1135
3767	15.0	13.2	13.0	13.0	0.56	b6V	13.7	–	84347.5-460029/J08434760-4600562
3829	12.9	11.7	11.5	11.4	0.43	B1 V	13.9	3(31) (II)	84344.7-460656/J08434493-4606537
3982	12.0	10.7	10.5	10.5	0.45	O9.5 V	13.6	56(17) (II)	84338.5-460817/J08433863-4608157
4009	14.2	12.7	12.5	12.4	0.47	b4 V	13.6	–	84334.4-460553/J08433734-4605520
4234	12.6	11.2	11.0	10.9	0.56	B0 V	13.8	55(27) (II)	84327.4-460240/J08432763-4602382
4288	13.7	12.0	11.7	11.3	0.62	B1-2 Ve	13.6	var (Tab A.6)	84325.6-460820/J08432574-4608174
4331	10.8	9.8	9.7	9.6	0.46	O7.5 V	13.6	var (Tab. A.2)	84324.0-460831/ALS 1131
4476	14.5	13.1	12.9	12.8	0.38	b6 V	13.9	–	84317.8-460618/J08431784-4606180

⋆ Corti et al. (2003)

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Table A.1. Instrumental configurations used

ID	Epoch(s)	Spectrog.	Rec.disp. (Å px^{-1})	$\Delta\lambda$ (Å)	S/N
I	1999 (Jan., Feb.)	B&C	2.30	3800-5000	120-200
II	2000 (Jan.)	REOSC	1.65	3700-5200	150-200
I	2001 (Jan.)	B&C	2.30	3800-5000	120-200
II	2001 (Feb.)	REOSC	1.65	3700-5200	150-200
II	2002 (Jan., Feb.)	REOSC	1.65	3700-5200	150-200

Appendix A: Individual stellar radial velocities

For the determination of the radial velocities (Subsection 3.4) we analyzed digital spectra obtained by us for some stars present in the Bochum 7 region. The data about the instrumental configuration employed to obtained the spectra were developed in SubSect. 2.2 of Paper I. Table A.1 of this paper lists some characteristics of the CASLEO [4] runs.

The radial velocity of each star was obtained measuring the absorption lines of Hγ, HeI 4471Å , Hβ and HeI 4922Å found in its spectra. The result about the probable members of Bochum 7 is shown in Table 2. In this, we present the heliocentric radial velocity with the standard deviation of radial velocity average and the instrumental configuration in two pairs of parentheses. There are several stars in which it was not possible to obtain a good estimate of radial velocity in its spectra. The ALS Catalogue's stars 1135 (CBN 84349.6-460711), 1131 (CBN 84324.0-460831), 1144 (CBN 84424.9-455334), 1146 (CBN 84450.9-461012) and 1147 (CBN 84506.3-460906) show variations in radial velocity in its spectra.

[4] Visiting Astronomer, Complejo Astronómico El Leoncito operated under agreement between the Consejo Nacional de Investigaciones Científicas y Técnicas de la República Argentina and the National Universities of La Plata, Córdoba and San Juan.

ALS 1135 is a binary system presented by Corti et al. (2003), Fernández Lajús & Niemela (2006) and Michalska et al. (2013). The radial velocity measured in the other stars are presented from Table A.2 to Table A.5, respectively. They list Heliocentric Julian Day, Instrumental Configuration, heliocentric radial velocity (with the number of measured lines to average in parentheses) and in the last column, standard deviation of radial velocity average. The presence of systematic differences between the lines of spectra obtained from night to night could be due to a binary effect. ALS 1131 is the star showing the greatest radial velocity dispersion with -45 $\mathrm{km\,s^{-1}} \leq$ Vr $\leq$ 160 $\mathrm{km\,s^{-1}}$. This star presents an additional characteristic typical of binary systems, the variation of the intensity ratio of HeI 4471 / HeII 4541, known as Struve-Sahade effect (Bagnuolo et al. 1999). The intensity ratios obtained between the lines of HeI 4471 and HeII 4541 vary between 1.6 and 2.4. These data make this star a highly probable binary system, although more data with better resolution are needed. ALS 1144 is another star showing a large radial velocity dispersion with -26 $\mathrm{km\,s^{-1}} \leq$ Vr $\leq$ 100 $\mathrm{km\,s^{-1}}$. ALS 1146 shows radial velocity dispersion values somewhat smaller than the other binary star candidates (80 $\mathrm{km\,s^{-1}}$), so it could be a longer period binary system. ALS 1147 is a star with hydrogen Balmer lines in emission in its spectra and we found a large dispersion in their radial velocity values, flagging it as another probable binary system.

The stars ALS 1137 (CBN 84350.9-460348), ALS 1140 (CBN 84404.4-455316), CBN 84325.6-460820 and CBN 84438.9-460746 also show variations in their radial velocity, and they are listed in Table A.6. For these four stars it will be necessary to obtain more spectral data to confirm that the stellar radial velocity is indeed variable.

Table A.2. CBN84324.0-460831 (*ALS* 1131): heliocentric radial velocities.

HJD (2450000+)	*IC*	V_r ($\mathrm{km\,s^{-1}}$)	σ ($\mathrm{km\,s^{-1}}$)
202.832	I	16(4)	±26
1204.850	I	43(4)	±10
1219.586	I	52(4)	±15
1555.641	II	18(4)	±16
1556.733	II	47(4)	±29
1557.773	II	-21(4)	±04
1558.649	II	71(4)	±21
1559.641	II	51(4)	±11
1560.671	II	49(4)	±08
1561.636	II	48(4)	±05
1565.707	II	121(4)	±10
1572.809	II	20(4)	±08
1573.750	II	51(4)	±10
1574.782	II	15(4)	±23
1924.712	I	160(4)	±44
1927.845	I	-23(4)	±34
1945.806	II	25(4)	±33
1946.575	II	106(4)	±16
2293.774	II	-45(4)	±16
2296.861	II	28(4)	±39
2298.726	II	38(4)	±19
2299.725	II	130(4)	±25
2300.699	II	30(4)	±24
2301.674	II	60(4)	±34
2302.671	II	33(4)	±28
2322.733	II	-16(4)	±07
2323.614	II	87(4)	±04
2324.538	II	74(4)	±09

Table A.3. CBN84424.9-455334 (*ALS* 1144): heliocentric radial velocities.

HJD (2450000+)	*IC*	V_r ($\mathrm{km\,s^{-1}}$)	σ ($\mathrm{km\,s^{-1}}$)
1203.793	I	48(4)	±15
1219.604	I	26(4)	±04
1221.834	I	82(4)	±15
1555.834	II	60(4)	±14
1556.720	II	29(4)	±13
1557.818	II	19(4)	±16
1558.671	II	46(4)	±19
1559.666	II	66(4)	±15
1560.711	II	64(4)	±10
1561.647	II	18(4)	±09
1565.658	II	37(4)	±05
1566.781	II	00(4)	±18
1573.761	II	56(4)	±03
1574.767	II	26(3)	±07
1575.853	II	-26(4)	±22
1924.867	I	87(4)	±14
1925.807	I	55(4)	±19
1927.863	I	42(4)	±15
1945.824	II	62(4)	±15
1946.560	II	39(4)	±12
2293.672	II	100(4)	±10
2296.687	II	23(4)	±16
2323.594	II	60(4)	±04
2324.556	II	77(4)	±13

Table A.4. CBN84450.9-461012 (*ALS* 1146): heliocentric radial velocities.

HJD (2450000+)	IC	V_r ($km\,s^{-1}$)	σ ($km\,s^{-1}$)
1203.729	I	16(4)	±11
1205.772	I	-04(4)	±05
1220.841	I	47(4)	±32
1555.755	II	36(4)	±11
1556.745	II	48(4)	±12
1557.761	II	49(4)	±19
1558.625	II	27(4)	±24
1559.628	II	37(4)	±27
1560.658	II	38(4)	±15
1561.624	II	39(4)	±38
1565.689	II	26(4)	±15
1570.853	II	23(4)	±24
1572.800	II	12(4)	±19
1574.687	II	26(4)	±20
1924.785	I	41(4)	±23
1926.756	I	37(3)	±23
1946.591	II	76(4)	±25

Table A.5. CBN84506.3-460906 (*ALS* 1147): heliocentric radial velocities.

HJD (2450000+)	IC	V_r ($km\,s^{-1}$)	σ ($km\,s^{-1}$)
1203.752	I	-32(3)	±30
1205.788	I	03(3)	±19
1219.654	I	-04(3)	±07
1220.857	I	26(3)	±10
1221.848	I	-02(4)	±21
1555.770	II	12(3)	±25
1556.757	II	15(3)	±24
1557.750	II	25(3)	±03
1558.636	II	57(3)	±34
1559.617	II	11(3)	±07
1560.623	II	11(3)	±29
1561.613	II	19(3)	±17
1565.670	II	-21(3)	±33
1566.792	II	00(3)	±20
1572.790	II	15(3)	±21
1575.865	II	02(3)	±48
1924.760	I	-18(3)	±11
1926.735	I	14(3)	±28
1946.606	II	14(4)	±37

Table A.6. Heliocentric radial velocities.

ID	HJD (2450000+)	IC	V_r ($km\,s^{-1}$)	σ ($km\,s^{-1}$)
CBN84438.9-460746	1558.779	II	49(4)	±18
	1946.654	II	73(4)	±22
CBN84325.6-460820	925.730	I	-13(4)	±36
	2293.774	II	-27(4)	±32
CBN84350.9-460348	1202.814	I	57(4)	±16
	1204.835	I	37(4)	±24
	1558.660	II	72(4)	±09
CBN84404.5-455316	203.773	I	40(4)	±10
	1219.826	I	53(4)	±21
	1558.682	II	74(4)	±17