Improved distances to several Galactic OB associations

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Abstract

Based on $uvby\beta$ photometry we study the structure of several Galactic star-forming fields. Lac OB1 is a compact association at 520\,\pm\,20 pc spatially correlated with a region of intense H\textalpha emission in Sh2-126. Lodén 112 is a compact OB group at 1630\,\pm\,82 pc, probably connected to an extended feature of OB stars located toward the Carina tangent. The field toward Car OB1 is complex and likely contains apparent concentrations representing parts of long segments of the Carina arm projected along the line of sight. Within the classical Mon OB2 association we separate a relatively compact group at 1.26 kpc, that is spatially correlated to the Monoceros Loop SN remnant.

1 Introduction

The Galactic OB-associations offer a unique opportunity to study the influence of massive stars on the interstellar matter. A reconstruction of the star-formation history of many Galactic fields should be possible once the spatial distribution of the young stars is reliably determined. Despite the extensive efforts to improve and unify the distances to the young stellar groups in the Milky Way (MW), discrepancies still remain in the published studies for a large number of fields. Many of the present distance estimates are based to a large extent on preliminary distance calibrations, broad-band photometry, or absolute magnitudes ($M_V$) obtained via spectral and luminosity type (MK classification). On the other hand, the $uvby\beta$ photometric system provides $M_V$ and colour excess determinations for early-type stars in excellent agreement with the Hipparcos parallaxes [13].

Figure\textsuperscript{2} represents the comparison of $uvby\beta$ $M_V$ and MK-based $M_V$ to the Hipparcos-based $M_V$, pointing out to a possible over-estimation of stellar distance when relying on a MK-based determination. Since the distances to the Galactic OB associations are based
mainly on individual stellar distances and rarely on main-sequence fitting, applying \textit{uvby}_β photometry should lead to a significant improvement for many OB groups in the MW.

Our deriving of \textit{uvby}_β photometric distances utilizes the intrinsic colour calibrations of Crawford [5] and Kilkenny & Whittet [16] and the luminosity calibration of Balona & Shobbrook [1] and takes into account possible stellar emission and mis-classification [11]. The expected errors for one star are about 12\% for luminosity classes III-IV and about 18-20\% for luminosity classes I and II. Photometric \textit{uvby}_β distances derived in this way provide the same impression of the star-forming field’s structure as the improved \textit{Hipparcos} parallaxes (cf. [14]).

In this contribution we present improved distance estimates for four Galactic OB associations.

2 Lac OB1

Lac OB1 (Lac OB1b, [2]) is a nearby notable clustering of early-type stars near 10 Lacertae that initially gained attention because of the expanding motion of its members. Based on the derived \textit{uvby}_β photometric distances used in conjunction with the photometric diagrams we identify Lac OB1 as a compact group of 12 low-reddened main-sequence stars located at a distance 520±20 pc in the direction $l = 96.4^\circ, b = -16.6^\circ$ (see [9] for details). The available radial velocity and proper motion measurements support the impression that this is a real group. For these 12 stars, the recalculated \textit{Hipparcos} parallaxes [22] are in excellent agreement with the photometric \textit{uvby}_β parallaxes. The photometric distance of the O9V star 10 Lac (HD 214680) is estimated to be $715^{+107}_{-92}$ pc. Although this estimate is considerably larger than the one based on \textit{Hipparcos}, the agreement for this star is better with the recomputed \textit{Hipparcos} parallax [22] which yields a distance of $529^{+70}_{-50}$ pc in comparison to the original \textit{Hipparcos} estimate of $325^{+82}_{-55}$ pc.

Figure 2 presents the distribution of H\textsc{ii} intensity in units of Rayleighs and brightness temperature distribution of H\textsc{i} at velocity channel $-15.5$ km s$^{-1}$ toward Lac OB1, with Lac
OB1 stars superimposed. Here and on all further figures the H\textsubscript{II} data are taken from [7] via the SkyView interface [19], and the H\textsubscript{I} data are taken from Leiden/Argentine/Bonn (LAB) Survey of Galactic HI [8]. A correlation of the stars’ location with the regions of intense H\textsubscript{II} emission in Sh2-126 [21] is noticeable. On the other side, the distribution of neutral hydrogen shows a deficiency (most obvious in the selected velocity channel), also correlating with the location of the stars (see also [4]).

3 The field of Lodén 112

Lodén 112 is identified as a poor, but compact cluster candidate. Based on uvbyβ photometry we obtained true DM = 11.06±0.12(s.e.) and average color excess $E(b-y) = 0.5±0.03$(s.e.) [10]. This corresponds to a distance of 1630±82 pc, which is significantly smaller than the presently adopted 2500 pc (WEBDA). In our uvbyβ sample there are several other early B stars located at that exact distance. The photometric distances and available proper motions allowed us to identify a group of about 10 early B stars that could represent a new OB association at coordinates $282^\circ < l < 285^\circ$, $-2^\circ < b < 2^\circ$ which appears to be connected to Lodén 112 cluster candidate (see a poster by Kaltcheva & Golev at this meeting for more details).

4 Car OB1

According to [6] the Car OB1 association is located at 2.5 kpc toward $284^\circ < l < 288^\circ$, $-2.2^\circ < b < 0.9^\circ$ and has an average radial velocity of $-5$ km s$^{-1}$ (see [17]). In their revision of the list of Galactic OB associations Melnik & Efremov [18] break down Car OB1 into five groups at distances between 2.2 and 2.8 kpc. Figure 3 presents the H\textsubscript{I} velocity channel image.
at $v = -5$ km s$^{-1}$ and the distribution of H\textsc{ii} toward Car OB1. Only stars intrinsically brighter than $-3$ mag with $uvby\beta$ distances available are shown. Different symbols are used to denote the apparent groups that could be separated based on our sample. The group marked with white dots (23 stars) is located at average coordinates $l = 287.56^\circ$, $b = -0.67^\circ$ in direction of the Car 1E group from the list of [18], in the vicinity of $\eta$ Car. According to the distances obtained here, these stars are spread out between 2204 and 6404 pc, with an average of $3728 \pm 956$ pc. Another apparent concentration (small black plus-symbols, six stars) is found at $l = 287.01^\circ$, $b = -0.41^\circ$ and an average distance of $3308 \pm 2090$ pc. The significant spread in distance suggests that these are not physical groups. The third apparent grouping, marked with black dots (16 stars), is found at $l = 285.83^\circ$, $b = 0.071^\circ$ (this is Car 1B of [18]). These stars are well grouped at $2583 \pm 70$ (s.e.) pc (see [15] for more details). It seems that these apparent groups are located along the edge of the Carina arm. The apparent field stars along the edge of the arm are marked with large star-symbols whereas the other field stars are marked with large circles.

This region has a complex structure and does not harbour just one stellar association. It is highly likely that some of the apparent concentrations represent parts of long segments of the Carina arm projected along the line of sight near the Carina tangent.

5 Mon OB2

In light of the growing importance of Northern Monoceros in the study of star-formation, precise distance estimates to the apparent structures of young stars in the field are most
important for a variety of reasons. Northern Monoceros is dominated by the Rosette Nebula, thought to be spatially correlated to the young open cluster NGC 2244 and the large Mon OB2 association [20]. Precise $uvby\beta$ stellar distances and reddening are derived for a sample of more than 200 O-B9 stars in a $12^\circ \times 12^\circ$ field centered on NGC 2244 [12]. According to this sample, the classical Mon OB2 association, previously thought to be at 1.6 kpc, is represented by a relatively compact group at 1.26 kpc in the vicinity of NGC 2244 and a layer of massive stars between 1.5 and 3 kpc spread across the entire field.

Figure 4 presents the distribution of H$\text{II}$ toward the group at 1.26 kpc and the H$\text{I}$ velocity channel image at $v = 15.5$ km s$^{-1}$ (at which the lack of H$\text{I}$ in the vicinity of this group is more obvious). New estimations of the temperature, brightness, spectral index, and distance to the Monoceros Loop SN remnant were recently reported by Borka Jovanović & Urošević [3]. They stressed the influence of molecular cloud on Monoceros SN remnant and calculated a distance of $1250 \pm 190$ pc to the Loop. This new distance estimate is in excellent agreement with the distance to the group at 1.26 kpc.

6 Concluding Remarks

As already mentioned, a better understanding of the phenomena associated with the interaction between young massive stars and their surrounding ISM in the fields of the Galactic OB associations should be possible once their structure is reliably established. A multi-wavelength approach analyzing the distribution of the massive OB stars, ionized and neutral material, and that of the interstellar dust would allow us to better understand the different components of the ISM and the interactions among them.
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References

[1] Balona, L. A., & Shobbrook, R. R. 1984, MNRAS, 210, 375
[2] Blaauw, A. 1958, AJ, 63, 187
[3] Borka Jovanovi´c, V, & Uroˇsevi´c, D. 2009, AN, 330, 741
[4] Cappa De Nicolau, C. E., & Olano C. A. 1990, Rev. Mexicana Astron. Astrof., 21, 269
[5] Crawford, D. L. 1978, AJ, 83, 48
[6] Humphreys, R. M. 1978, AJSS, 38, 309
[7] Finkbeiner, D. P. 2003, ApJS, 146, 407
[8] Kalberla P.M.W., Burton W.B., Hartmann D., Arnal E.M., Bajaja E., Morras R., Poeppel W.G.L. 2005, A&A, 440, 775
[9] Kaltcheva, N. 2009, PASP,121, 1045
[10] Kaltcheva, N., & Golev, V. 2011, in preparation
[11] Kaltcheva, N., & Hilditch, R. 2000, MNRAS, 312, 753
[12] Kaltcheva, N., Kuchera, A., Hathaway, C. 2010, AN 331, 384
[13] Kaltcheva, N., & Knude, J., 1998, A&A, 337, 178
[14] Kaltcheva, N., & Makarov, V. 2007, ApJ, 667L, 155
[15] Kaltcheva, N., & Scorcio, M. 2010, A&A, 514, A59
[16] Kilkenny, D., & Whittet, D. C. B. 1985, MNRAS, 216, 127
[17] Melnik, A. M., & Dambis, A. K. 2009, MNRAS, 400, 518
[18] Melnik, A. M., & Efremov, Yu. N. 1995, AstL, 21, 10
[19] McGlynn, T., Scollick, K., White, N. 1998, in New Horizons from Multi-Wavelength Sky Surveys, Proc. of the 179th Symp. of the IAU, held in Baltimore, USA Aug 26-30, 1996, Kluwer Academic Publishers, edited by B. J. McLean, D. A. Golombek, J. J. E. Hayes, & H. E. Payne, p. 465
[20] Ruprecht, J. 1966, Trans. IAU 12B, 350
[21] Sharpless, S. 1959, ApJS, 4, 257
[22] van Leeuwen, F. 2007, Hipparcos, the new reduction of the raw data (Dordrecht:Springer)