COMBINING PHOTOMETRIC AND ASTROMETRIC DATA TO IDENTIFY STELLAR CLUSTERING AT KPC-DISTANCES

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ABSTRACT

A field of $0.5\,\deg$ x $0.5\,\deg$, at $l\sim 265\,\deg$ and $b\sim -2\,\deg$, is used as a test bed for stellar structure identification. Spectroscopic and photometric observations were used to estimate distances to the early type stars inside in the field. Positions, distances and proper motions were combined in a series of statistical analysis to identify clustering. In this way we are able to characterize stellar structures up to distances of approximately 8 Kpc, probably as far as the outer spiral arm.

Key words: OB association; spectroscopic distance; color-color diagram; proper motion.

1. INTRODUCTION

The detection of distant early type star associations is of fundamental importance to define the grand structure of the Galaxy.

The reliable identification of very distant structures (at kpc scales) is, however, a very difficult problem. At these scales, the traditional membership criteria are well beyond their inherent limitation giving place to considerable ambiguity.

This means that no single method is able to give a definitive answer and that the most solid approach is to apply several complementary criteria, from which circumstantial evidence for the eventual existence of structures can be gathered.

Based on spectroscopic, photometric and astrometric data we performed a detailed statistical study of the early type stars observed in a field of $0.5\,\deg$ x $0.5\,\deg$ ($l\sim 265\,\deg$, $b\sim -2\,\deg$) aiming to detect distant stellar clustering.

This region is particularly interesting because it contains a probable distant OB association, Bochum 7 (Moffat and Vogth, 1975) which can be used as a test bed.

2. DATA

The data used here, come from spectroscopic and photometric observations and published astrometric positions.

The spectroscopy was performed with the REOSC and Boller & Chivens spectrographs on the 2.15m telescope at CASLEO (San Juan - Argentina) giving 63 OB stars, 50 main sequence star and 13 giants and supergiants.

The photometric observations was performed in U, B and V bands with the 1.0m Curtis–Schmidt telescope of CTIO (Chile). From these observations we could detect about 2000 stars from $V\sim 8$ to $V\sim 19$.

The color-color diagram for OB main sequence stars(spectroscopically observed) shows that most of these stars ($\sim 65\%$) follows remarkably the standard extinction curve (Schmidt-Kaler, 1982). This results allowed us to use the color-color diagram to determine the spectral type for the stars that were observed only photometrically (Binney and Tremaine, 1987). In this way we additionally found about 250 photometric OB stars in the field. From the spectral type we could estimate the distances of our sample of spectroscopic and photometric OB stars.

To these data we added for our analysis, the proper motions obtained from positions found in the literature, AC2000.2 (Urban et al. 1998), Hipparcos (ESA 1997), USNO-A2.0 (Monet et al. 1998), Tycho2 (Hög et al. 2000), UCAC2 (Zacharias et al. 2003), 2MASS (Cutri et al. 2003).

3. CLUSTERING DETECTION

The errors present in our data (distances and proper motions) and the large distances of the searched structures impose a multi-technique approach combining all available information. Following this line, we develop here an anlysis of radial and angular clustering assisted by kinematical information from the determined proper motion.

3.1. Radial clustering

The magnitude of the uncertainties in distance at the large depths involved, typically $\Delta d \sim 1$ kpc at $d \sim 5$ kpc, hamper any hope of directly finding structures with radius of only some tens of pc in the radial direction. In order to analyze structuring in this direction we resort to simulations and replace each OB star with 10^3 simulated stars drawn from a gaussian distribution characterized by the average distance of original star and standard deviation equal to the inferred statistical error (Fig.1).

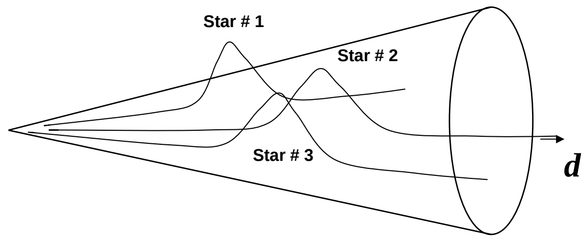

Figure 1. Simulated stars drawn from gaussian distribution around the average distance of the original star.

The distribution of these simulated stars as shown in Figure 2, pointed to an excess of 25 stars between 2.5 and 4.0 Kpc for the photometric distribution when compared to the smooth curve calculated from a Besançon simulation.

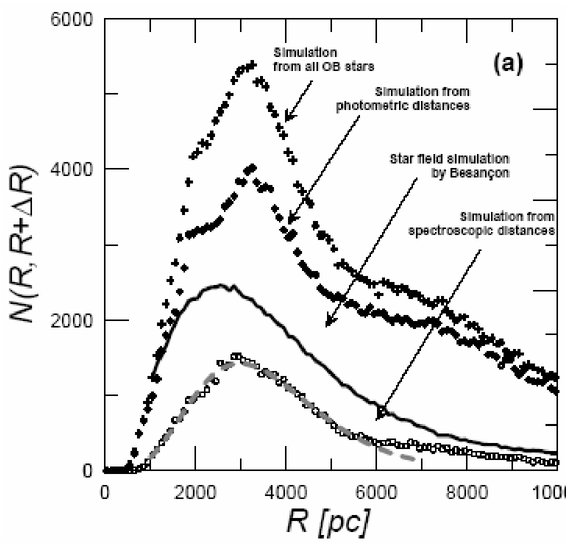

Figure 2. Distance distribution for simulated stars and for the smooth Besancon simulation.

Considering now the surface density distribution, $n(\rho)$ as function of the angular distance to the center of these stars, ρ (see, Figure 3), we see that the density is rather flat, $n(\rho) \propto \rho^{-0.3}$, up to $\rho \sim 0.1\,\mathrm{deg}$ and then cuts-off abruptly with distance, $n(\rho) \propto \rho^{-2.4}$, similar to what should be expected from a King profile (Binney and Tremaine, 1987). This analysis strongly points to the existence of a clustering at $2.5 < d < 4.0 Kpc$ not yet discussed in the literature.

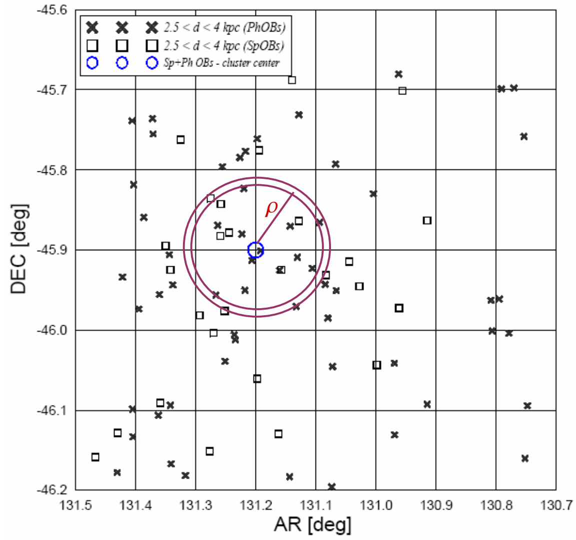

Figure 3. Spectroscopic and photometric OB stars in the interval of $2.5 < d < 4.0$ Kpc.

3.2. Angular clustering

Dividing the field in 36 cells of 5arcmin x 5arcmin we estimated what is the probability function of the expected number of cells with given number of stars for a homogeneous distribution of stars. In this case we work only with the 63 spectroscopic OB stars. The main results from this etimative (Figure 4) is that the single cell with the largest number of stars in it, i.e. 8, is higly unlikely, unless the field is non-homogeneous, that is, unless there is actually clustering.

Scanning the field where the 63 OB spectroscopic stars are distributed, with a 5arcmin x 5arcmin window we found a first structure C1 with 10 stars and chance probability of 10^{-4}. An other structure C2 with 10 or 11 stars, can be found from overlapping cells as shown in Figure 5, further strengthening the case for angular clustering.

3.3. Kinematic clustering

Here we performed an analysis looking for structures composed by neighbor stars travelling in roughly the same projected direction in the sky. We take the stars separated by at maximum 0.5Kpc and for which the differences in the direction of the residual proper motions are less than $\pm 5\,\mathrm{deg}$.

First of all, we tested the consistency of calculated proper motion used in this analysis. For this, we compare them with Hipparcos results. A direct comparison is impossible because the corresponding interval in magnitude for Hipparcos and our sample of OB stars is not the same.

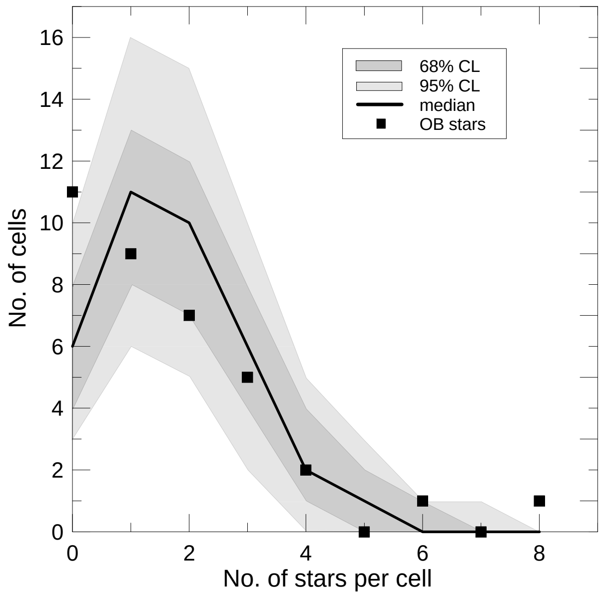

Figure 4. 68% and 95% confidence level for the number of cells as a function of the number of stars per cell. The thick line is the median and the points are the values actually found in the field.

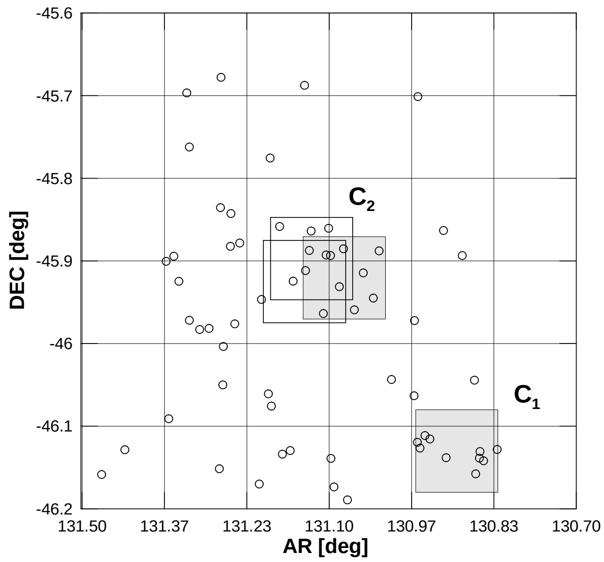

Figure 5. Clustering with the smallest chance probability ($< 10^{-4}$).

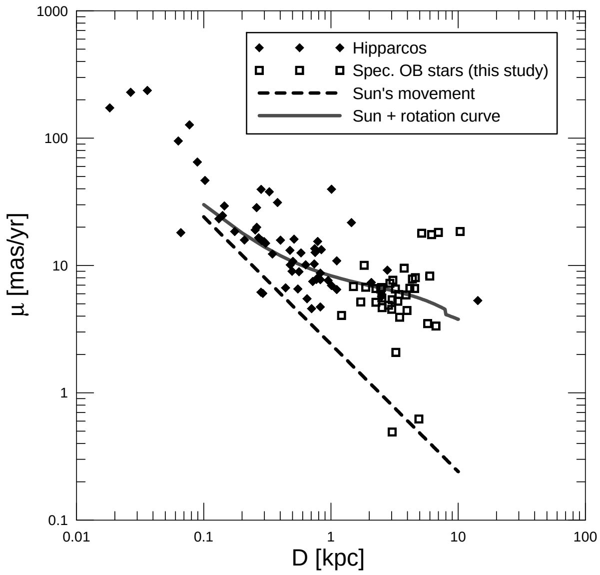

Figure 6. Hipparcos and our determination proper motions for the spectroscopic OB stars.

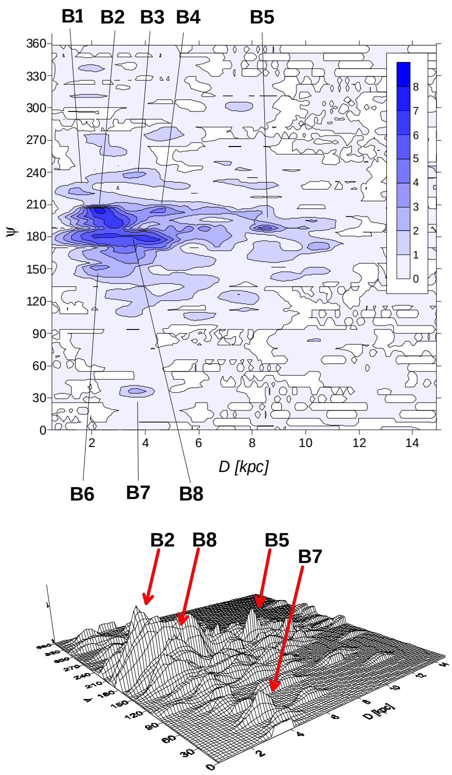

Figure 7. Countour map and wire frame for the number of of OB stars as function of distance D that have proper motions pointing at $\pm 5\,\deg$ from direction Ψ.

Therefore, we compare instead the proper motions as function of distance as shown in Figure 6. The Hipparcos stars are taken in a area of $2\deg$ centered in the same direction of our field. As we can see in this figure both sets of proper motions match smoothly over distances running from ~ 0.1 to ~ 10 Kpc.

The followed figure (Figure 7) show the possible physical structures found in this way when applied to all (spectroscopic and photometric) OB population.

4. DISCUSSION

Figure 8 compares the possible OB association at $\sim 5 Kpc$, Bochum7 as proposed in the literature (Moffat and

Vogt, 1975) with some of the clusterings found here. As we can see, our results are compatible with the existence of the Bochum7 OB association, but go one step further in the unbiased search for structures in the field at scales of kiloparsecs.

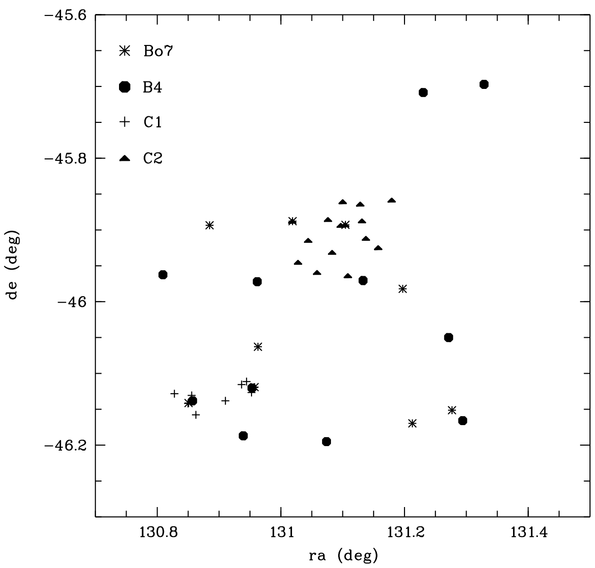

Figure 8. Bochum 7 (Bo7) OB association and some structures found in this work: Bo7(131.09, -45.94, 5.8Kpc); B4 (131.08, -46.02, 4.3Kpc); C1(130.09, -46.13, 5.2Kpc); C2 (131.10, -45.91, 4.5Kpc).

5. CONCLUSION

We use photometric, spectroscopic and astrometric data of a $0.5\,\mathrm{deg} \times 0.5\,\mathrm{deg}$ region of the sky, in order to perform radial, angular and kinematic statistical analysis of the OB stars identified in that line of sight.

Based on these analysis we demonstrate the possible existence of several structures covering a range of distances where previous authors had only envisioned the existence of a single loosely defined association.

Correspondingly, we believe that the multi-technique approach is the safest one for dealing with structure determination and characterization at kpc scales.

Although spectroscopic data was used for a sub-sample of objects in the analysis, our results would be mostly unchanged if only photometric and astrometric data were available. Analysis of this type would be greatly boosted by high quality data as GAIA will be able to provide.

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