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ON THE DISC AND HALO OF THE MILKY WAY THROUGH A STUDY OF STAR CLUSTERS

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SUMMARY: The subject is the metallicity and the correlation between the metallicity and spatial distribution of star clusters of the Milky Way. The open star clusters are confirmed as good indicators for the population of the galactic disc, whereas the globular ones are confirmed as good indicators in the case of the galactic halo.

1. INTRODUCTION

The concept of stellar populations was introduced in astronomy by Baade (1944) who considered the correlation between their colour and the spatial distribution. It is well known that Baade distinguished between Population I situated in the disc of a galaxy and formed of blue objects and Population II situated in its central parts and halo, formed of red objects. Further studies have shown that Baade's ideas are basically correct, but that the population problem involves a complex correlation, in particular, according to Sandage (1986), it concerns a correlation between the geometric-and-kinematical characteristics of celestial objects and the physical ones (chemical composition, age, e. g. Majewski, 1998). The most recent studies show that the contents of different populations in the Milky Way may be identified with the objects of its subsystems, such as bulge, disc, halo, etc. (e. g. Dehnen and Binney, 1998).

The subject of the present paper is the correlation between the spatial distribution and the metallicity of star clusters. In the study of the spatial distribution two quantities are used: **surface number density** σ_{XY} (the number of clusters per area unit in projection on the galactic plane - XOY and **scale height** $|\mathbf{Z}|_e$ (the distance to the galactic plane where the line number density is $1/e$ of that in the galactic plane - e the base of natural logarithms). The metallicity is defined by means of the so-called **metallicity index [Fe/H]** (e. g. Marochnik and Suchkov, 1984 - p. 34).

The reason why star clusters are used here as probes is that they are usually thought to be good indicators of the stellar populations (or subsystems), in particular open clusters are assigned to Population I and globular ones to Population II. Besides, their distances are well determined and also the data concerning metallicity are available for many of them. Therefore, the use of star clusters of the Milky Way for the purposes of the present paper seems fully justified.

2. OBSERVATIONAL MATERIAL

The observational material consists of 100 globular clusters (data source Ninković, 1999) and of 1151 open clusters (data source Lynga, 1987. completed by most recent data by the present author using INTERNET). In the sample of globular clusters the data necessary for the present study (distance, metallicity) are available for all of them. Observing that in the Milky Way in general there are about 150 globulars, one may say that the present sample is reperesentative enough. The complete data list and the software details can be found in Nagl (2000).

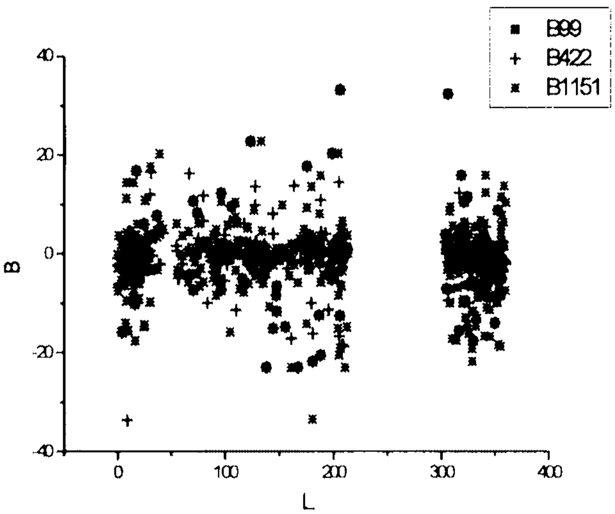

Fig. 1. *The distribution of open-cluster groups - 1151, 422 and 99 - over the celestial sphere; L, B galactic coordinates.*

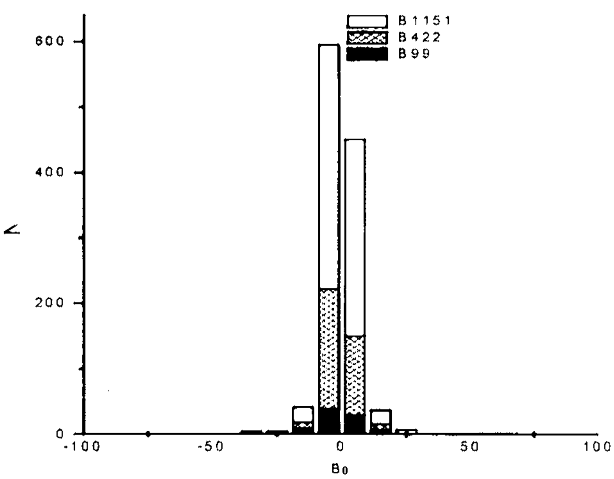

Fig. 2. *The distribution of open-cluster groups - 1151, 422 and 99 - in galactic latitude.*

As for the sample of open clusters, the distance is available for only 422, whereas only 99 of them have data on both metallicity and distance. Therefore, it is necessary to establish if this sample is representative enough. This is done by examining their distribution in directions. As seen from Fig. 1, there is, practically, no difference in this distribution for the three subsamples. Thus the subsample of 99 open clusters appears as sufficiently representative for the purposes of the present paper. The study of the distribution in galactic latitude affords an additional confirmation to this conclusion (Fig. 2).

3. RESULTS

The metallicity distribution of all globular clusters and 99 open clusters is presented in Fig. 3. It is seen that the distribution of the former ones is bimodal so that a limit of approximately **[Fe/H]=-1** appears, dividing the sample into two subsamples containing 76 "metal-poor" clusters and 24 "metal-rich" ones. This fact (bimodal distribution) is well known from the literature (e. g. Zinn, 1985). In addition, Zinn's standpoint was that the metal-rich globular clusters have the properties of a disc system. This standpoint is to be verified in the rest of the present paper. In the case of the two groups of globular clusters the metallicity distribution is symmetric with respect to the maximum, whereas that concerning the open clusters is not. The maxima lie at -1.6 for the 76 metal-poor globular clusters, at -0.55 for the 24 metal-rich globular clusters and at -0.04 for the open clusters. It is also seen that the open clusters are on the average more metal rich than the globular ones since there is no open cluster with metallicity under -1 whereas the most metal rich among them have metallicities somewhat exceeding the solar one.

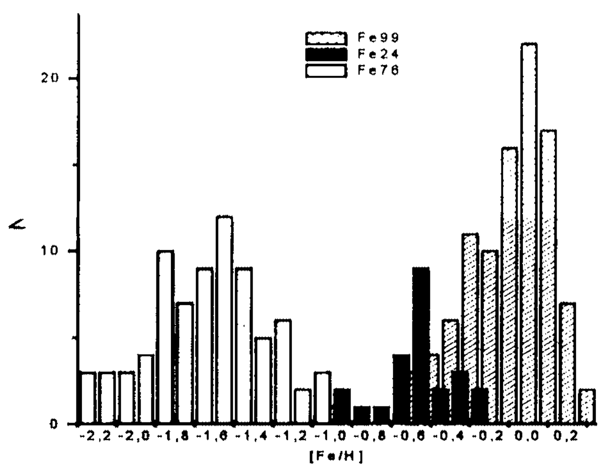

Fig. 3. *The metallicity distribution for the two globular-cluster groups - G76 and G24 and for 99 open clusters.*

Now a question arises whether all globular clusters belong to the halo or, perhaps, a part of their population may be assigned to another subsystem (disc or bulge). For this purpose the subsample of metal-rich globulars, here called G24 due to their total number, is studied. As the first step its members are examined individually. However, more metal rich clusters among them do not appear to be closer to the galactic centre. Therefore, an identification of any of them with the galactic bulge is not possible. The second step involves a comparison yielding a set of 49 metal-poor globular clusters. These globular clusters are within 8 kpc from the galactic centre, the distance within which are all G24 clusters. Now one studies the spatial distribution of all groups of star clusters including the newly formed one G49, as

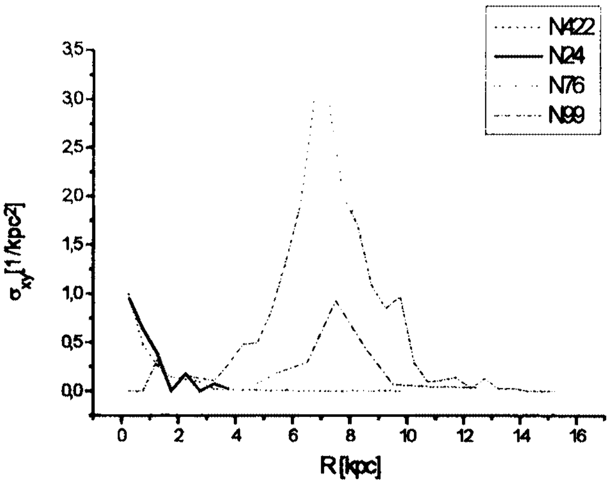

Fig. 4. *The plot of the surface number density σ_{XY} for different star-cluster groups.*

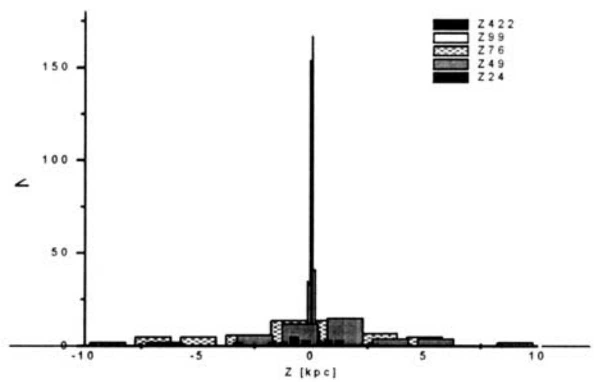

Fig. 5. *The plot of the line number density for different star-cluster groups.*

well. The results are presented in Figs. 4-5. In calculating the galactocentric distances of all star clusters the value of 8 kpc is used for the galactocentric distance of the Sun. It is based on Mermilliod's (1999) recommendation.

As expected, the distribution in projection is radial one, i. e. the surface number density depends solely on R, the distance to the axis of galactic rotation. The points are fitted with exponential curves following Freeman (1970; 1987). The corresponding formulae are:

$$\sigma_{XY422}(R) = 0.7exp(-R/10.5);$$
$$\sigma_{XY99}(R) = 0.7exp(-R/8.5);$$
$$\sigma_{XY76}(R) = 1.4exp(-R/3);$$
$$\sigma_{XY24}(R) = 1.4exp(-R/2);$$
$$\sigma_{XY49}(R) = 2exp(-R/2.5)\ .$$

The additional subscripts 422, 99, etc. indicate the corresponding group of star clusters.

As already said above, the study of the line number density yields the quantity $|Z|_e$. Its values for the given cluster groups are:

$$|Z|_{e422} = 0.15;\ |Z|_{e99} = 0.15;$$
$$|Z|_{e76} = 5;\ |Z|_{e24} = 3;$$
$$|Z|_{e49} = 4\ .$$

As in the case of the surface number density, the numbers in the subscripts indicate the cluster groups, whereas the values for $|Z|_e$ are expressed in kpc just as the scales in the exponential formulae.

3. DISCUSSION AND CONCLUSIONS

In the case of the Milky-Way open clusters the most recent data are analysed. It is confirmed that they represent the Milky-Way disc. Their distribution in projection upon galactic plane is exponential although the scales found in the present paper do not follow exactly the values usually proposed for the disc. However, one should not forget the strong influence of the observational selection due to which there is an evident paucity of these clusters towards the galactic centre. Therefore, the distribution in projection on the axis of galactic rotation plays a very important role. It reveals a very strong concentration of the open clusters towards the galactic plane (Fig. 5). As seen, the plot resembles a delta function. It should be mentioned once again that the two samples G422 and G99 exhibit practically no difference concerning the spatial distribution. Hence the group of open clusters for which both distance and metallicity are available is a representative sample of these objects.

The metallicity distribution for the open clusters is also specific (Fig. 3). A vast majority is concentrated near 0 (the solar value), all of them having metallicity over -1 and the histogram is asymmetric with respect to the maximum. The asymmetry may be a consequence of the chemical evolution since very young open clusters are expected to have metallicity exceeding that of the Sun.

A rather different situation is found in the case of the globular clusters. It is found here, just as by Zinn (1985), that their metallicity distribution is bimodal. However, unlike Zinn, who assigned the "metal-rich" globular clusters (here G24) to the disc, the present author's standpoint is that these objects belong to the Milky-Way halo. This is seen from their spatial distribution; the scales concerning both distribution in projection on the galactic plane and that in projection on the axis of rotation are similar for the two groups of globular clusters- G76 and G24. This similarity is enhanced after introducing the new group G49. In the present author's opinion the similarity between G24 and G76, resp. the difference between G24 and say G99, in the spatial distribution is most strongly illustrated in Fig. 5 presenting the distribution in projection on the axis of galactic rotation.

The identification of some members of G24 with the galactic bulge appears as unsuccessful. On the other hand, the small number of clusters in this group may cause the maximum in the metallicity distribution (Fig. 3) being accidental. In such a case the metallicity distribution for the Milky-Way globular clusters in general could have only one maximum at about -1.6 with metallicities approaching almost the solar one, just as in the case of individual halo stars (e. g. McWilliam, 1997). Such a picture would mean that the metallicity distributions of various Milky-Way subsystems are continuous, approximately gaussian, where an overlapping between different subsystems takes place. This is a point of view at variance with the idea of discrete metallicity distributions of different Milky-Way subsystems where no such overlapping would exist (e. g. Marsakov and Suchkov, 1982).

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ДИСК И ХАЛО МЛЕЧНОГ ПУТА НА ОСНОВИ ПРОУЧАВАЊА ЗВЕЗДАНИХ ЈАТА

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Испитују се металичност и корелација између металичности и просторне расподеле за звездана јата Млечног пута. Потврђује се да су развејана звездана јата добри индикатори за популацију галактичког диска, док се за збијена јата потврђује да су добри индикатори за случај галактичког халоа.