Astron. Astrophys. 346, 778–784 (1999)

ASTRONOMY
AND
ASTROPHYSICS

A comparative study of the spatial distributions of Cepheids and star clusters in the Large Magellanic Cloud

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Received 9 December 1998 / Accepted 8 April 1999

Abstract. A new simple method for the comparison of two-dimensional distributions is elaborated and applied to the observed spatial distributions of Cepheids and open clusters in the LMC. This method is particularly suited to pick out the clusterings within non-uniform fields. The comparative study of the spatial distributions for objects with known ages provides useful hints on the dominant mode of large scale star formation. We found that only one clump, out of four evident groups of open clusters coeval with the observed Cepheids (i.e. logt$\sim$7.5$\div$8.5) coincides with a local density enhancement of Cepheids. A relation between the age range inside a clump and its size is found; this is consistent with the theory of star formation in a turbulent medium.

Key words: stars: formation – stars: variables: Cepheids – galaxies: Magellanic Clouds – galaxies: star clusters

1. Introduction

Comparative studies of the spatial distributions of different objects are of great use in investigations of galactic structure and large-scale star formation. In this regard, the LMC is certainly the most suitable target. This galaxy is quite close to us and with a low internal absorption, thus neither the distance scale nor the extinction present problems. The distributions of sufficiently bright objects can be studied throughout the whole galaxy with the same completeness. The inclination of the LMC plane to the plane of sky is small enough so that closeness of objects in the sky usually implies their space neigbourhoodness. (There exists, of course, the problem of the width of the galaxy disk, which may be some 400 pc or so, yet generally the depth of the galaxy is not essential here).

The main goal of the present paper is to study the distributions of Cepheids and star clusters over the LMC in relation to their ages. Both sets of objects have well determined ages and thus we are able to compare sub-samples of objects within the same age ranges. Since the completeness of our samples can be considered quite uniform all over the LMC, we may argue that possible differences (see eg. Efremov 1989, 1997) in the surface distributions of clusters and Cepheids within the same age range (i.e. logt$\sim$7.5$\div$8.5) could be related with different modes of star formation in different regions. Interrelations of coeval Cepheids and clusters might be thus a promising way to study the efficiency of star formation within different regions; indeed, the local star formation efficiency is a crucial parameter for the formation of bound or unbound clusters (see eg. Wilking & Lada, 1985). Density enhancements of field Cepheids (that are expected to come form dissolved clusters) may or may not be in the same regions densely populated by clusters; this could be related to a different rate of formation of bound clusters or – for those regions rich of field Cepheids and no clusters – even to the occurrence of isolated star formation mode.

We believe there is a strong need for an objective method to compare two-dimensional distributions. As nicely discussed by Hodge (1986) –and as any experienced astronomer would agree– drawing conclusions through a by-eye inspection of the distribution of stars (or other objects) in a plate is a very slippery job often biased by both the quality of the data (e.g. plate scale, limiting magnitute, colour etc.), the distance of the observed objects (physical resolution, i.e. pc/mm for plates or pc/px for CCD) and last but not least by the astronomer's scientific goal. An outstanding example of this situation is the case of the OB associations in the Andromeda galaxy. In 1964, van den Bergh (1964) inspecting Schmidt plates of the Andromeda galaxy concluded the typical size of OB associations in this galaxy was $\sim$400 pc, i.e. much larger (a factor $\sim$5) than galactic associations. Several years later Efremov et al. (1987), again through a by–eye inspection of plates but with a better plate–scale, concluded that the typical size of Andromeda associations was only $\sim$80 pc, i.e. in full agreement with the size of galactic and MC associations. These authors picked out associations of van den Bergh as well, yet they suggested that these clustering should be regarded as star complexes similar to those detected earlier in the Milky Way galaxy (Efremov 1979, 1995).

Only recently, Magnier et al. (1993) using an *objective method* developed by Battinelli (1991) definitely settled the question basically confirming the Efremov et al. (1987) findings. Later on, using the same method, Battinelli et al. (1996) were also able to confirm the existence in M 31 of larger groups: aggregates and complexes. Furthermore, for M 31 there is hope, by identifying groups of stars of different magnitude (and pre-

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sumably different ages), to check the size–age dependence recently found by Elmegreen & Efremov (1996, 1998; see discussion below). All this makes evident the importance of a reliable technique for the clump detection.

A simple objective method to estimate the degree of correlation or anticorrelation of two two-dimensional distributions is given here. It may be used in any investigations aimed to have an objective estimate of the degree of similarity of two distributions of points over a manifold. This method is also suited to pick out clumps of objects in the non–uniform field; in this paper the method was applied mostly with this purpose.

2. Observational data: Cepheids and clusters in the LMC

The study of Cepheids and clusters in the LMC has a long history. Shapley (1930) believed that variable stars generally avoid the open clusters mostly because he noted that in the LMC open clusters and Cepheids avoid each other. However most of these clusters are simply too young to host the Cepheids and are classified now as associations. Since the fifties, Cepheids have been seen in a few clusters of the LMC (Shapley & McKibben-Neil 1951, Hodge 1961). Later, few more clusters have been found to contain Cepheids by a number of investigators. Efremov (1978, 1989) proposed the connection with clusters of a few dozen neighboring Cepheids and using the clusters' ages he obtained a new determination for the period–age relation. The typical uncertainty for ages obtained from this relation (whose intrinsic width is connected mostly with the different periods of a cepheid at different crossing of the instability strip) is roughly of the same order of the error in determination of a cluster age.

Recently, Bica et al. (1996) provided integral UBV photometry for 504 star clusters and 120 stellar associations in the LMC. As was shown earlier by many authors (e.g. Efremov 1978, Battinelli & Capuzzo-Dolcetta 1989) integral UBV photometry permits to obtain quite certain age determinations, especially for rich clusters. The last calibration of integral U-B, B-V colors of the LMC clusters in terms of age was carried out by Girardi et al. (1995) who used stellar models with mild overshooting. Ages for young clusters are about three–fold older than previous estimates, so that a possible connection of these clusters with Cepheids can be reasonably expected. Actually, Efremov (1997), using cluster ages from Girardi et al. (1995) and extending his 1978 list to a number of newly discovered Cepheids in clusters, determined the following period–age relation:

$$logt = 8.58–0.68logP \quad (1)$$

that gives ages larger than those obtained using his previous determination ($logt = 8.16–0.68logP$, Efremov 1978).

Overshooting in models of massive stars is still a somewhat controversial issue. Anyway, what is important for our present goal is that cluster and cepheid ages are homogeneous being both based on the Girardi et al. (1995) cluster age determination. Efremov & Elmegreen (1998) found as period - age relation $logt = 8.49–0.51logP$ using only the most certain Cepheids in clusters. For the bulk of Cepheids this relation gives ages quite close to those determined using Eq. (1).

Summarizing, we have used the positions of clusters from Bica et al. (1996) and their ages derived by Girardi et al. (1995). Positions and periods of Cepheids in the LMC were taken from the V volume of the GCVS and period–age relation used is that given above (see Eq. 1). In this paper we will study the spatial distributions of clusters and Cepheids in a circle of 4 degrees from the LMC center. Altogether, a sample of 1185 Cepheids and one of 536 clusters were used.

3. The Method

Let us suppose to have two sets, A and B, of objects distributed over the same physical domain F. We would like to study how B–objects are spatially located with respect to the "background" distribution A. In other words, we would like to assess whether B–objects are preferentially located in correspondence to the same specific features (like holes and/or clumps) present in the way A–objects are spatially distributed. Such kind of correspondences are often searched by astronomers in order to assess possible physical links among different classes of objects (e.g. OB associations, H II regions, star clusters etc.).

Thus, we implemented a new FORTRAN code aimed to obtain an objective and quantitative evaluation of any occurence of correspondences between the location of B–objects with overdensities (called clumps) and/or underdensities (holes) in the spatial distribution of A-objects.

3.1. The algorithm

In principle it is quite simple to evaluate if a point $b \in B$ lies in a region of enhanced (hereafter, for simplicity we will refer only to clumps) density of points $a \in A$: a comparison between the local (i.e. around b) density,ρ_l, with the average (over the whole manifold F) density, ρ_{av}, of points $a \in A$ is a reasonable criterion. This rises the question about how local density should be computed, or more precisely, how much large should be the area around b used to evaluate the local density. Let us r_l the radius of a circle around b over which we count the number of points $N_A(b, r_l)$ to compute the local density. For a continuous medium, the limit of $N_A(b, r_l)$ for $r_l \rightarrow 0$ is - by default - the value of density in b. Obviously, this limit is no more possible when dealing with discrete distributions. In our case the problem is: on one hand the smaller r_l the larger is the fractional sampling error $\sqrt{N_A(b, r_l)}/N_A(b, r_l)$, on the other hand increasing r_l means to smooth out small features (loss of resolution).

The opposite situation is, for the density ρ_{av}, if the spatial distribution of A shows strong large scale gradients (e.g. radial gradient, disk/halo in galaxies,...). In this case, comparing ρ_l with ρ_{av} would make out as clumps those regions that - as a result of the large scale gradient - have densities higher than the average while we are interested at local density enhancements (clumpiness). Thus, instead of computing ρ_{av} over the whole manifold F, it is wise to compute the density over a circle, $d(b, r_L)$,of a certain radius r_L ($>> r_l$). This way, ρ_{av} has the wanted meaning of average density over an area much larger than the size of the structures we are interested in. Thus, for both r_L and r_l a best value must be searched. We found it useful to define r_l as that value for which $N_A(b, r_l)$ is equal to a given number N_{loc}, i.e. r_l is the radius of the circle around b that contains N_{loc} points of A. The reason why we prefer to use such definition is that this ensures us that in all cases the local density is computed over an area that contains enough points of A. Moreover, once N_{loc} has been chosen, the percent sampling error remains constant through F.

For each $b \in B$, the main steps of the method are:

i) compute r_l as:

$$r_l = r_L \sqrt{\frac{N_{loc}}{N_A(b, r_L)}}$$

ii) for a large number of random points $x \in d(b, r_L)$ compute the average value, μ, of $N_A(x, r_l)$. The quantity μ is the right one to be compared with $N_A(b, r_l)$;

iii) compute the Poissonian probability P, to have at least $N_A(b, r_l)$ points in circle $d(x, r_l) < d(b, r_L)$:

$$P = \sum_{N_A(b,r_l)}^{\infty} \frac{\mu^k}{k!}$$

iv) Compare P with an adopted significance threshold.

3.2. Choosing N_{loc} and r_L

As discussed in the previous section, the selection of suited values for the two input parameters for our algorithm is a crucial issue. By construction of the present method, low values for r_L tend to neglect large loose clumps while large values *feel* mainly the large scale structure (in our case the LMC bar) present in the field F. The best value is - of course - the largest value for which the results are not dominated by the large scale structure. The best, *a posteriori*, choice is thus adopted. In order to check the sensitivity of the results to this choice, we also ran our code with many different values for r_L.

Our definition of r_l through N_{loc} has the advantage of ensuring us about the statistical sampling. On the other hand, this definition implies a variable r_l that - in low density regions - may lead to large r_l that do not satisfy anymore the basic condition $r_L \gg r_l$. In other word, the larger N_{loc}, the better the statistical sampling and the larger the number of points that must be discarded because $r_L \not\gg r_l$. Again an *a posteriori* balance between advantages and disadvantages is the way to properly set N_{loc}. Comparison of the results obtained with different N_{loc} is used to assess the sensitivity of the method on this parameter's choice.

3.3. The case $A = B$

A useful case is when $A = B$. In this case, the method tells us if a point $b \in A$ is located inside a clump of points of the same kind of b. Plotting all points b found in clumps is a straightforward way to identify local overdensities eventually present in the A distribution.

This method, even though presents some similarities to the Path Linkage Criterion (PLC) technique proposed by Battinelli (1991), differs from the latter in two basic points. First, in contrast to to PLC, the present method is not able to detect chains of stars or filamentary clumps (both this features are characterized by low densities if the density is computed as the ratio of the number of stars in a circle containing the feature divided by the circle area). Second (this is crucial for the aim of this paper), our method has the advantage to adapt its way to compute densities to the whole density range present in the field to analyse (r_l increases in low density regions and decreases in high density regions). This is possible with PLC only in particularly simple conditions (see e.g. Battinelli & Demers 1992).

4. Results

Even though the coincidence of clumps of Cepheids with clumps of clusters could be expected (as a typical case), we found that this is not generally true, at least in the LMC.

It must be stressed once more that the method described in the previous section determines clumps in relation to the average density of objects within a certain distance around each objects, and so it is essentially based on local quantities. This is an important difference from most of the methods based on other different implementations of cluster analysis. As a consequence, our algorithm is equally able to detect clumps both in the high-density bar and in the much looser outskirts. For this reasons, we believe to be able to reliably study the properties of the large–scale star formation.

Few examples of quite different local correlations between Cepheids and clusters are known (see Efremov 1989, 1997). Within the dense group of 7 approximately coeval clusters at the eastern border of the LMC bar many Cepheids are observed. The main members of the cluster group are the two blue globulars NCG 2058 and NGC 2065. Ages from all these clusters, as deduced from integral UBV photometry (Bica et al., 1996), are within the age–range of the two dozen Cepheids which are inside and around the clusters. It is very curious that there is another very dense clump of three dozen of Cepheids of about same age, located at 300 pc to SE from the center of the former one, which does not contain any clusters at all!

There is also a group of clusters, in the field of which only a few Cepheids are seen. This group consists of ten clusters in a region of 500×800 pc, four of which (NGC 2156, 2159, 2164 and 2172) are examples of blue globulars (Baird et al. 1974). Most of the clusters are coeval and in the surrounding field there are only 4 Cepheids, all with periods compatible with the clusters age (Efremov 1979, Welch et al. 1993). The aggregated mass of the compact (375×270 pc) quartet of the richest clusters in this complex is about 300,000 solar masses (Elson et al. 1987). These authors suggested that the quartet might be formed by a single supercloud. Thus, although this complex consists of a number of rich clusters containing Cepheids, yet outside the clusters only a few field Cepheids are observed. One may argue that most of the primeval gas content of this complex was used to form these rich clusters and not enough gas was left over to

Table 1. Clumps of clusters

id.	N_{obj}	α_{1950}	δ_{1950}	d'	⟨age(Myr)⟩	age r.m.s.
1	15	5 18 42	-69 30 06	25	179	232
2	8	5 22 15	-68 00 09	8	10	11
3	10	5 27 36	-68 53 53	15	71	111
4	13	5 07 17	-68 43 11	28	137	178
5	9	4 54 56	-69 18 26	18	50	83
6	4	4 55 33	-68 18 00	9	619	573
7	12	4 57 18	-66 30 21	15	30	42
8	13	5 32 32	-66 59 28	21	17	5
9	11	5 34 28	-67 32 09	20	17	12
10	6	5 05 46	-70 42 12	21	62	75
11	7	5 37 18	-70 13 45	9	116	16
12	11	5 37 27	-69 22 14	16	30	41
13	12	5 40 20	-69 41 54	12	15	8
14	3	5 57 52	-68 27 30	13	155	31

Table 2. Clumps of cepheids

id.	N_{obj}	α_{1950}	δ_{1950}	d'	⟨age (Myr)⟩	age r.m.s.
1	3	5 21 35	-66 13 58	10	141	32
2	45	5 26 47	-69 57 08	42	158	42
3	10	5 37 11	-70 10 58	11	180	29
4	23	5 40 39	-70 26 34	23	182	31
5	6	5 41 42	-67 11 33	13	173	45
6	3	5 52 22	-69 44 38	9	182	52
7	5	5 49 58	-67 13 34	19	193	36
8	9	5 09 46	-70 44 23	23	172	35
9	5	4 59 40	-69 35 08	14	193	15
10	9	4 52 19	-69 40 03	20	181	40
11	14	5 15 27	-69 11 01	25	162	33
12	4	5 15 01	-66 28 20	11	163	41
13	10	5 13 44	-65 34 26	16	212	41
14	6	5 03 48	-68 54 17	12	172	65
15	6	4 59 58	-70 18 51	27	167	45
16	5	5 03 04	-67 28 53	20	187	27
17	4	5 03 36	-66 20 03	19	183	12

Table 3. Clumps of clusters within the cepheid age-range

id.	N_{obj}	α_{1950}	δ_{1950}	d'	⟨age(Myr)⟩	age r.m.s.
1	8	5 19 32	-69 32 24	19	158	73
2	10	5 37 10	-70 09 58	23	140	61
3	4	5 57 58	-68 30 00	13	140	36
4	6	5 05 54	-68 37 36	12	105	56

form loose unbound systems from which field Cepheids may originate. A population of field Cepheids (outside clusters) can be thus considered as an indicator of such mode of star formation (in loose clusterings).

In this paper we find that the different locations for Cepheids and clusters is a typical feature. Results of our analysis of clusters' and Cepheids' spatial distributions are presented in Figs. 1, 2 and 3 as well as in Tables 1, 2 and 3. Each table contains the

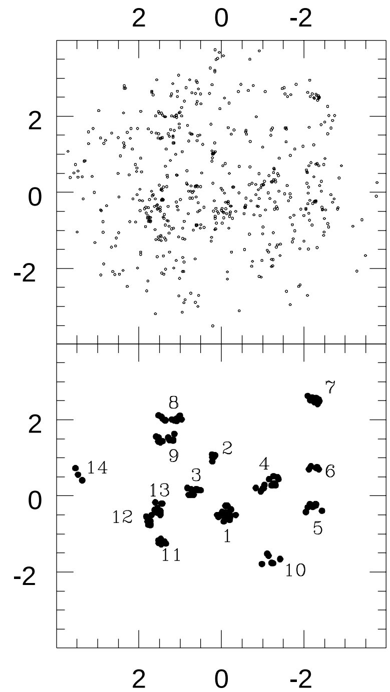

Fig. 1. *Upper panel:* the observed spatial distribution of star clusters given by Bica et al. (1996) within 4 degrees from the LMC center. *Bottom panel:* positions of clusters (black dots) found in the 14 clumps (see text). Numbers represent the identification code given in Table 1. Coordinates are RA and DEC offsets (in degrees) from the LMC center (= NGC 1928).

following data for clumps: identification number, RA, DEC, diameter, mean age, age dispersion. Diameter is defined as $0.5(d_{EW} + d_{NS})$, where d_{EW} and d_{NS} are elongations (in arcmin) along the E-W and N-S directions; age dispersion is the r.m.s. of individual ages.

We consider as a clump three or more objects which lie inside the same density enhancement of the overall distribution. We found: 14 clumps in the sample of all clusters (old globulars with ages of ∼10 Gyrs are not considered), see Fig. 1; 17 clumps of Cepheids (Fig. 2) and 4 clumps of clusters with ages in the same age–range of the cepheid sample (Fig. 3). While it is quite understandable that clumps of clusters of all ages may not concide with clumps of Cepheids, these latter are found mostly to avoid the clumps of clusters in the same age-range too (Figs. 2 and 3). Indeed, only one clump (#2) out of 4 in Fig. 3, is connected with a cepheid clump (#4 in Fig. 2). It is worth to note that this clump is just the one around NGC 2058 and NGC 2065, already known and described above. Of course, this finding is an indirect confirm of the effectiveness of our method.

The mutual avoiding of clumps of Cepheids and clusters rises an important new problem. Could the factors leading to the preferred formation of bound clusters be altered in region of about 0.5 kpc in size? Another important consideration about the distribution of clumps is that clumps seem to show a quasi-regular spacing, especially prominent along the bar, with a scale of about 1 kpc. Clump sizes span within the rather narrow range, 100÷400 pc with the only exception of the large cepheid clump

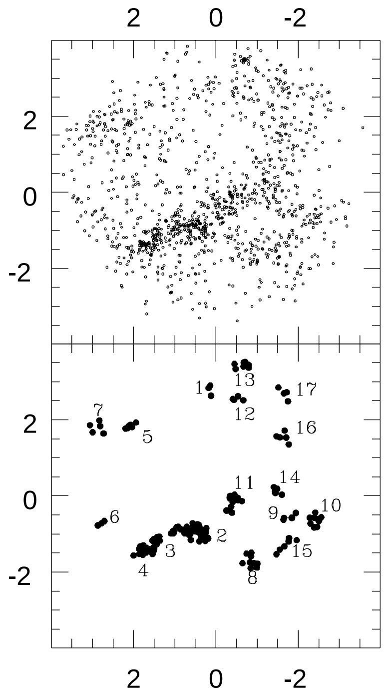

Fig. 2. *Upper panel:* the observed spatial distribution of Cepheids (from V volume of GCVS, Artyukhina et al. 1996) within 4 degrees from the LMC center. *Bottom panel:* positions of Cepheids (black dots) found in the 17 clumps (see text). Numbers represent the identification code given in Table 2. Coordinates as in Fig. 1.

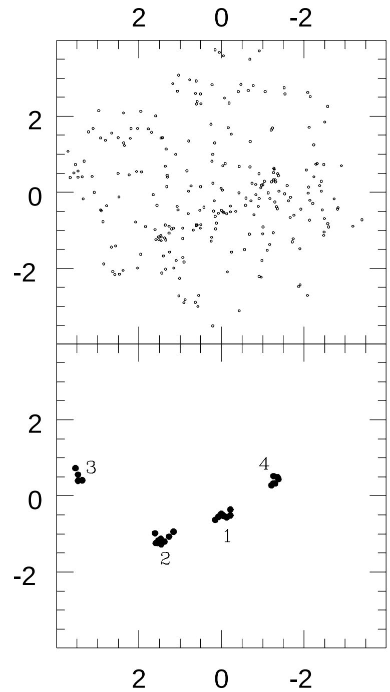

Fig. 3. *Upper panel:* the observed spatial distribution of star clusters given by Bica et al. (1996) within 4 degrees from the LMC center and coeval with the cepheid sample of Fig. 2. *Bottom panel:* positions of clusters (black dots) found in the 4 clumps (see text). Numbers represent the identification code given in Table 3. Coordinates as in Fig. 1.

#2 (whose diameter is ~600 pc). However, Fig. 2 suggests that this clump might consist of three smaller ones. We note that these sizes are essentially smaller than those observed for complexes of Cepheids, clusters and blue stars in the MW and M 31 (see Efremov 1995; Battinelli et al., 1996). A possible explanation of the smaller sizes found for the LMC clumps could be, as discussed below, the smaller size of the LMC itself (Elmegreen et al. 1996).

The parameters adopted for our statistical analysis of the surface distributions of Cepheids, clusters and clusters coeval with Cepheids are (R_L,N_{loc}): (0.7°,6), (0.7°,4) and (0.7°,3), respectively. The adopted significance threshold for the probability P is the usual 90%. As we mentioned in Sect. 3.2 an a posteriori check of the dependence of our results on the adopted parameters is needed. We performed this check with particular attention to the case of Cepheids, being this dataset the furthermost abundant and thus allowing the largest variation of the parameters. We found that our results are only marginally dependant on the chosen parameters in a range $R_L \in [0.5, 0.9]$ and $N_{loc} \in [3, 9]$. Indeed, most of the difference found among the various runs regards statistically ill-defined clumps that are anyway cancelled out by the significance threshold of 90%. If all groups with less than three objects are rejected the only difference left among the runs regards a few objects that may/may not belong to some clumps shown in Figs. 1–3; this difference of course does not involve the reality of such clumps.

5. Discussion and conclusions

Let's consider first some possible explanations for the difference found in the spatial distribution among coeval cluster and cepheid overdensities. This issue is strictly connected with the more general question why there are isolated young stars, especially massive stars (as seen in the LMC by Massey et al. 1995).

Such isolated stars might form either alone since the very beginning (but this seems to be difficult from the present theory's point of view) or in small unstable associations that quickly dissolve into the field. Of course, in this view, the probability for a protocluster to end-up as a bound or unbound stellar system (after formation of the hot stars and SNe) plays a crucial role in producing isolated stars.

As discussed in Efremov (1995) metal abundance of the paternal gas cloud may influence the probability to form bound or unbound stellar groups. Low metallicity is expected to increase the probability to form bound clusters, because it makes it more difficult for the radiation pressure to disrupt the paternal cloud (Elmegreen 1983) and/or because it relatively slows down the thermal instabilities thus delaying the appearance of massive stars (Richtler 1993). There is indeed evidence that the abundances of some populous clusters, such as NGC 330 and NGC 1818, are considerably lower than those of field supergiants (see Richtler 1993, Mateo 1992 and references in Efremov 1991). However, more recent observations (Jasniewicz & Thevenin,

1994) do not confirm this result and lead to more uncertain conclusions (Hilker et al., 1995).

Another possible cause for the formation of bound/unbound clusters may be the differences in the surrounding pressure. Recently, Elmegreen & Efremov (1997) argued that high pressure conditions are favorable to the formation of bound clusters even from massive clouds which are able to form many hot stars, whereas clusters forming in moderate-to-low pressure environments are likely to end-up as unbound systems.

Only if the mass of a cloud is so low ($< 10,000 M_{\odot}$) that no O star is likely to form (because of the small total number of stars formed and of the relatively rareness of O stars) a newly formed clusters may remain bound. In the galactic disk, in its present day conditions, massive clouds usually form unbound associations. On the other hand, young globular clusters form now from similar clouds in interacting galaxies, as the HST data recently proved, and they also form in the LMC probably as a result of its interactions with the SMC.

It is so natural to ask whether local differences in the pressure conditions may explain why we observe, on one hand, almost no Cepheids (as indicators of field stars) around the quartet of massive clusters (NGC 2156 and others, which is the clump #3 in Fig. 3) and, on the other hand, the high–density clump of Cepheids (#4 in Fig. 2) with no clusters in it.

The only clear connection of Cepheids and clusters is in NGC 2058-2065 region (cepheid clump #3 and cluster clump #11 (in Fig. 1) = #2 (in Fig. 2).

The relevant question is whether the mutual avoiding of clusters and Cepheids is a general rule (event though with some local exceptions) and – if so – if this can be explained by the alternating pattern of high– and low–pressure cells in a galaxy. From the present study no final conclusions can be drawn and, certainly, more detailed data and further studies are needed to address this issue.

The density of Cepheids in clumps #3 and #4 is very high whereas the range of their periods (ages) is quite small. Within the region of $12' \times 25'$ which encompasses the clump #4 there are 32 Cepheids listed in the Volume V of the GCVS (Arthyuhina et al. 1995). The local density of Cepheids in this region is 470 stars per square kpc, whereas the average density of Cepheids in the LMC is 28 kpc$^{-}2$, and in the arm S4 of M 31 and around the Sun is 10–15 kpc$^{-}2$ (see Efremov 1989, p. 167). About 80% of Cepheids in clump #4 have periods in the range 2–5 days which, according formula (1), implies $130 \div 240$ Myr ages.

Such a region may be considered the fossil bursts of star formation. From the total number of Cepheids observed in these regions we evaluate that, some fifty millions years ago, such regions contained dozens of OB- stars. These regions are located at the easter border of the LMC bar where large dynamical perturbations are expected. Such disturbances might be connected with frequent appearance of burst-like regions of star formation (e.g. 30 Dor) seen at the bars' extremities of many Magellanic-type galaxies (Elmegreen & Elmegreen, 1980).

High density, small sizes and small age range of these clumps fit well in the framework of the theory of star formation in turbulent ISM. According to this theory, the smaller the star-forming region, the shorter the duration of star formation and, therefore, the smaller the age range within it (Elmegreen & Efremov, 1996; Efremov & Elmegreen 1998). The generally small size of the clumps of stars and clusters in the LMC compared with those observed in large spiral galaxies is in agreement with the correlation, found by Elmegreen & Efremov (1996), between the size of the star complexes and the size of the host galaxy. In smaller galaxies, where the star formation duration is generally shorter than in large galaxies even the largest regions of star formation can form so quickly that there are still many OB stars, and then they appear very bright, like 30 Dor (see review in Elmegreen & Efremov 1998). The small duration of star formation implies the small range of periods of Cepheids at the later stage of evolution, which is just what we observed in cepheid clumps #3 and #4.

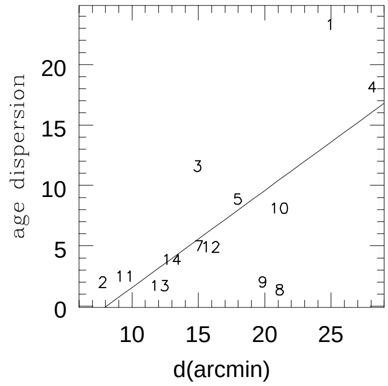

Fig. 4. Observed size – age-dispersion scatter plot for the clumps of Fig. 1. Numbers correspond to the numbering given in Fig. 1.

The evidences for the relation betwen size and duration of star formation in a region were recently found by Efremov & Elmegreen (1998) in the LMC from the mutual distances and age difference of clusters. We found a similar relation within individual clumps of clusters. The smaller the clump, the smaller is the range of ages of the clusters in it (Fig. 4).

The relation between the size of a region and the duration of the star forming process suggests that OB associations are probably only part of a large hierarchy of structures. The identification of associations is entirely based on the presence of OB-stars, i.e. objects with a specific age that in turn implies a selection of one particular scale out of a continuum of scales for the star–formation process. This was implicitly the case in Efremov et al. (1987) and Battinelli et al. (1996), where OB associations were identified from the distribution of blue bright objects in the field of M 31, with certain limits to stellar magnitudes. As Efremov & Elmegreen (1998) concluded, OB associations should not be considered as representative of the star formation process in general; they are only one level in a continuous hierarchy of self-similar processes that extends from parsec to kiloparsec scales. In other words, OB associations have their observed sizes and masses only because O stars typically last for 10 Myr and these sizes are just what the size-age relation predicts for 10 Myr.

Stellar complexes are the largest members of the hierachical sequence which still maintain the round shape and whose dimensions are probably determined by the size of the host–galaxy. Larger structures in the hierarchy of star-formation regions exist and their shapes result from the shearing due to the differential rotation; these very large complexes usually appear as short segments of spiral arms (Elmegreen & Efremov 1996, 1998).

The evidence of the relation we found between the duration of cluster formation and the clump size points to the same direction.

Even though the present study refers only to one galaxy we can conclude that our results represent a first observational support to theory of star formation in the turbulent hierarchical gas clouds. Obviously, strengthening these results and accepting this scenario as a general occurence will require a similar study for a significant large sample of nearby galaxies.

Acknowledgements. We are indebted to T. Richtler whose comments allowed us to substantially improve the original manuscript. Yu.E. acknowledges the support from the Russian Foundation for Basic Researches, grant 97-02-17358.

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