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Stellar clumps within the corona in the open cluster M 67

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Abstract. Several star clumps are detected inside the low-density extended corona of the open cluster M 67 with the help of the method "the distances to nearest neighbour analysis", elaborated earlier for analysis of galaxy distributions. The groups include from 5 to 11 stars and have mean sizes from 0.5 to 1.2 pc. We check the reality of their existence by statistical estimates based on kinematical data analysis. It is shown that at least one clump is not a random star density fluctuation. The question of the origin of these substructures remains open.

Key words: stars: formation – open clusters and associations: individual: M 67

1. Introduction

The idea that there are systems of stars in the galactic disk which are different from the previously known types is not new. The quest for them has continued for years. It has resulted in the discovery of large-scale structures – stellar complexes, which include several stellar associations and open clusters (see Efremov 1989). Small-scale structures intermediate between multiple systems and open clusters, according to their parameters, were distinguished with different degrees of reliability by Eggen (1970), Shatsova (1983), Orlov et al. (1995). In their latest work, Orlov et al. (1995) distinguish, with high reliability, six kinematic stellar flows within the closest solar vicinity, i. e., within the UMa cluster or its corona, and a flow within the Hyades cluster.

Agekjan & Belozerova (1979) claim that the coronae of open clusters exist for their whole life and that they lose the stars because of the action of irregular and galactical tidal forces more slowly than they get them because of dissipation of the nuclei. Thus, stellar groups or kinematic flows could arise at the beginning of the cluster evolution and, if they are stable, they could survive till the present time. On the other hand, Piskunov & Dluzhnevskaya (1989) list numerous results of observations which prove that the duration of star formation in clusters is comparable with their lifetimes. The latter contradicts neither the theory of consecutive fragmentation (see Elmegreen 1983) nor the results of calculations of the fragmentation of gaseous clouds (Di Fazio 1986). In this case, the fragments that turn into stellar groups could arise during the lifetime of a cluster.

In this study, we used the method for discovery of spatially-bounded groups of stars elaborated by Einasto et al. (1984). We distinguish several stellar clumps in the corona of M 67 with the help of this method. The reality of their existence is corroborated by the proper motion statistical study.

2. Observational data

The catalogue of Frolov & Ananyevskaya (1986) provides rectangular coordinates in a local system, relative proper motions and B, V-magnitudes for 1068 stars with limiting magnitude $B_0 = 16\overset{\text{m}}{.}5$ in the open cluster M 67. The proper motions were determined by the authors from the plates, which were obtained by the normal Pulkovo astrograph with an interval of 62 years between the two epochs. The catalogue also gives, for every star, the probability of its membership in the cluster determined by the authors and Sanders (1977) probabilities as well. The first is based on stellar proper motions and photometric data. Membership probabilities ($P_{\rm m}$) exceed zero for $n_{\rm cl} = 497$ stars. They were used in our work.

One star with $P_{\rm m}$ exceeding zero and extremely high proper motion $\mu_x = -0.3085''/\rm yr$ and $\mu_y = -0.2211''/\rm yr$ (with catalogue running number 1005) was excluded from the study.

The information about M 67 is given by Kholopov (1981). The cluster moves far above the galactic disk along a quite circular orbit and interacts little with spiral density waves, which do not influence star formation and star dissipation. The age of the cluster, equal to $4 \times 10^9 \rm yr$, is much longer than the period of star formation in it and is 180 times longer than the relaxation period. This provides evidence for the importance of dynamical evolution of the cluster. As can be seen from Fig. 1, which will be discussed later, the cluster has a dense well-marked nucleus and a large less dense corona.

3. The method of discovering spatially bounded structures

Let us examine the distribution of stars with nonzero probability of cluster membership given in Fig. 1. We give distances in linear units (mm) like coordinates in Frolov & Ananyevskaya (1986). They can be transformed into angular units by means

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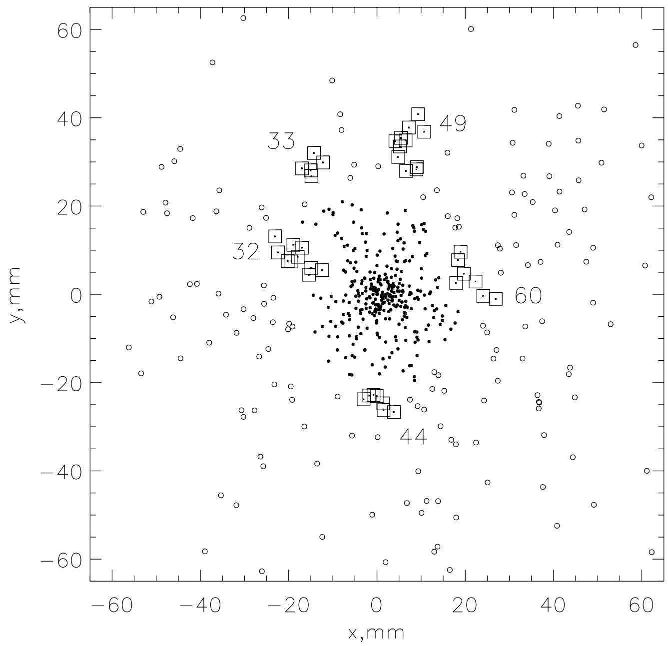

Fig. 1. Distribution of stars in the M 67 cluster in the rectangular coordinate system (x,y) centered at $\alpha = 8^{\rm h}47^{\rm m}\!\!.7, \delta = +12^\circ$. Squares show stars belonging to stellar groups with more then 5 members. Open circles – stars belonging to the corona. Numbers of groups are indicated

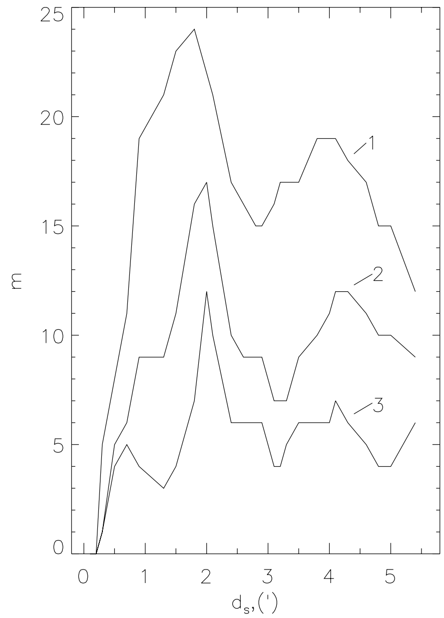

Fig. 2. Number of clumps (m) depending on the distance between the stars: 1 – clumps with more than 3 members, 2 – with more than 4 members, 3 – with more than 5 members

of the scale factor $1'/{\rm mm}$. The latter was obtained by dividing the angular diameter of the plate equal to $\varphi = 130'$ (Frolov & Ananyevskaya 1986) by the linear diameter on the plate equal to 130 mm (as can be seen from Fig. 1). A dense nucleus homogeneously filled by stars and a rarified corona are distinct. The density of the stars in the corona falls as the stars become more distant from the nucleus. The question is, are any fluctuations of the concentration of stars and, if there are some, are they accidental? Let us apply the method based on the nearest neighbour distances (Einasto et al. 1984) or NND, hereafter. This method enables to distinguish simultaneously structures with different scales and configurations. Einasto et al. (1984) used it for the local galaxies supercluster structure study. Other methods are described by Einasto et al. (1984) Orlov et al. (1995) and Battinelli (1991).

The essence of the NND method is the following: stars are considered as belonging to the same group only when the distance between them does not exceed certain $d_{\rm s}$. For different $d_{\rm s}$ one has different patterns of clustering. E.g., if one assumes $d_{\rm s}$ which is greater than any interstellar distance, all stars will form a group. On the other hand, if one takes the minimal possible $d_{\rm s}$, there will be only one group consisting of two stars which have that $d_{\rm s}$. Between these two extreme values of $d_{\rm s}$ there will be one which results in the maximum possible number of groups with different numbers of stars in them. It is that $d_{\rm max}$, which Battinelli (1991) suggested to consider as the "characteristic scale" for inner structures in the stellar system under study. E.g., dividing of Small Magellanic Cloud into associations according to this method (Battinelli 1991), gave results similar to ones obtained by other independent methods. An additional confirmation for this method was given in Mel'nik & Efremov (1995).

The function $m = f(d_{\rm s})$ for M 67 is shown in Fig. 2. Here m is the total number of groups of different size for given $d_{\rm s}$. The existence of two maxima in Fig. 2 is determined by the fact that, because of the greater density of the stars in the nucleus, the characteristic scale is smaller there than in the corona. The process of "clusterisation" is also different: there are many small-scale structures $(d_{\rm max} = 2\overset{\prime}{.}0)$ in the nucleus, few structures with $d_{\rm max} = 4\overset{\prime}{.}0$ in the rarefied corona, and one big group in the centre, see Fig. 1. We shall call that central group as a nucleus and the remaining outward part as a corona. The groups are also not equal in quantitative composition. There are no groups in the nucleus which differ from the multiple systems with a number of members not greater than 3–4. In the corona there are groups consisting of 5 or even more stars. Thus, the NND method gives us several tens of clumps, but we consider only clumps with five or more members. Now we can approach the study of these clumps.

4. Morphology of the corona

In Fig. 1, we show the clumps of stars that we found. We used the value $d_{\rm max} = 4\overset{\prime}{.}0$, which corresponds to the maximum number of clumps in the corona in Fig. 2. The general information about stars in clumps selected in previous section is given in Table 1. In Table 1, we list the running star number in the catalogue (No.), rectangular coordinates (x,y), photographic photometry $(V, B-V)$, proper motion components (μ_x, μ_y) and membership probability according to Frolov & Ananyevskaya (1986). In Table 2, the main charactiristics and some statistic parameters of the clumps are listed. We list them by their origial numbers

Table 1. General information about stars in the clumps

No.	x, mm	y, mm	V, mag	$B-V$, mag	μ_x, $''$/yr	μ_y, $''$/yr	P_m, %
			clump 32				
184	−23.0497	13.1210	13.59	0.53	−0.0064	0.0019	31
189	−22.3954	9.4918	13.43	0.48	−0.0019	0.0018	26
208	−20.2133	7.5251	13.34	0.54	−0.0042	0.0044	21
218	−19.3793	7.4464	13.54	0.62	−0.0004	0.0018	9
226	−18.9342	11.2128	13.45	0.53	−0.0024	−0.0023	49
230	−17.9384	8.5074	11.45	1.23	−0.0022	−0.0053	1
235	−16.9366	10.5696	13.96	0.59	−0.0015	−0.0012	67
250	−15.3603	4.4326	12.98	0.54	−0.0006	−0.0018	3
254	−14.8788	5.9978	10.08	1.09	−0.0058	−0.0049	78
280	−12.4667	5.4854	14.15	0.60	−0.0074	−0.0021	24
			clump 33				
234	−16.9509	28.5284	14.01	0.61	−0.0040	−0.0048	29
253	−14.9985	28.0823	13.36	0.60	0.0004	−0.0027	3
255	−14.8291	26.8057	14.20	0.64	−0.0060	0.0008	52
262	−14.2536	32.0201	10.60	1.26	−0.0045	0.0002	15
284	−12.1953	29.8833	12.63	0.65	−0.0079	0.0042	2
			clump 44				
414	−3.0167	−23.7758	13.52	0.57	−0.0083	0.0017	9
437	−1.7467	−22.9265	13.83	0.58	−0.0023	0.0009	47
460	−0.7660	−22.8069	13.15	0.56	−0.0081	0.0006	19
482	−0.0467	−23.0301	13.26	0.56	−0.0055	−0.0006	67
529	1.4162	−24.7030	13.30	0.62	−0.0061	0.0022	51
531	1.5041	−26.2442	13.14	0.61	−0.0074	0.0013	31
593	3.8532	−26.6788	12.72	0.62	−0.0049	0.0011	77
			clump 49				
600	4.1831	34.6893	14.46	0.56	−0.0012	−0.0060	8
620	4.8277	31.1129	13.02	0.90	−0.0068	0.0035	19
627	5.2102	33.4988	12.56	0.29	0.0004	0.0026	15
632	5.4492	35.4564	13.93	0.53	−0.0072	0.0010	28
658	6.4893	34.8697	14.12	0.40	0.0005	0.0004	21
662	6.5889	27.9476	11.46	0.91	0.0009	−0.0025	2
670	7.2285	37.7894			−0.0019	−0.0001	73
701	8.9483	28.3069	11.01	0.40	−0.0019	−0.0027	28
704	9.0308	28.8323	13.12	0.75	−0.0083	0.0008	16
712	9.3262	40.8216	13.28	0.40	−0.0087	0.0049	2
735	10.7017	36.8401	10.10	1.13	−0.0037	−0.0010	33
			clump 60				
813	17.9443	2.5847	13.74	0.58	−0.0017	0.0017	8
821	18.3680	7.7570	14.38	0.68	−0.0004	−0.0015	34
824	18.9557	9.6572	13.38	0.64	−0.0030	−0.0030	24
827	19.6801	4.6868	13.76	0.54	−0.0011	0.0010	7
845	22.3381	2.8946	13.56	0.54	−0.0033	−0.0033	41
850	24.0847	−0.3565	12.68	0.93	−0.0065	−0.0018	27
868	26.9174	−1.0381	13.71	0.52	−0.0044	−0.0013	96

Table 2. The main features of stellar groups

No.	n	$l_{\max}$, cm	$l_{\min}$, cm	d, pc	S, cm^2	$r_{\min}$, cm	$r_{\max}$, cm	$\langle\rho\rangle$, cm^{-2}	$n_{\rm unif}$	$P(n)$	$n_{\min}$	$n_{\max}$
32	10	1.6	0.6	1.2	0.96	1.3	2.8	7.6	7.3	0.08	3.3	13.8
33	5	0.6	0.4	0.5	0.24	3.0	3.7	2.3	0.6	0.0003	0.05	5.3
44	7	1.0	0.3	0.7	0.30	2.1	2.8	4.3	1.3	0.0003	0.05	5.3
49	11	1.4	0.8	1.2	1.12	2.8	4.3	2.2	2.5	0.00005	0.36	6.7
60	7	1.6	0.5	1.1	0.80	1.7	2.8	5.1	4.1	0.06	1.4	9.6

(No.), and give the number of stars in a clump (n), minimum and maximum sizes on a plate ($l_{\min}, l_{\max}$) and their area (S). The diameters (d) of groups were determined as an average of $l_{\max}$ and $l_{\min}$ group sizes, and they were first transformed into angular units and then into linear ones according to the formula: $l = r \sin\varphi$, where $r = 830$pc (Allen 1973) where l is the linear size corresponding to angular size φ and expressed in pc. Other columns of Table 2 contain statistical parameters which are necessary for discussion in the next section.

4.1. Random density fluctuations

As the stars in the cluster have residual velocities, the mathematical expectation of the number of stars in any place varies randomly and stellar density fluctuates. Let us examine these fluctuations and try to answer the question whether our groups are random fluctuations of stellar density. To solve the problems related to calculation of relatively rare, random, independent events per area or time unit, the Poisson distribution is used (see Agekjan 1974). Let us examine the regions occupied by our groups in Fig. 1 and suppose, that the number of the stars in every group changes randomly according to the Poisson law. We calculated the mathematical expectation of the numbers of stars in every region. As the stellar density in the corona rapidly falls with the distance from the nucleus, we calculated mathematical expectations of the stellar density in circular annuli which spread all over each of the groups, by the formula

$$\langle\rho\rangle = \frac{n_k}{\pi(r_{\max}^2 - r_{\min}^2)},$$

where n_k – the number of stars in the k-th circular annulus, $r_{\min}$ and $r_{\max}$ – radii passing across the nearest and the furthest from the nucleus edges of the region. The values of $r_{\min}, r_{\max}$ and $\langle\rho\rangle$ are given in Table 2.

The mathematical expectation of the number of stars within a region occupied by a clump with number i will be: $n_{\mathrm{unif}} = \langle\rho\rangle S_i$, where $S_i = l_{\min} \times l_{\max}$ is the clump area. The probability the observed star number declines from the average one only randomly, could be calculated from Poisson formula:

$$P(n) = \frac{n_{\mathrm{unif}}^n e^{-n_{\mathrm{unif}}}}{n!}.$$

We give the probabilities which we obtained in Table 2. As can be seen, they are very small. However, the values $P = 0.08$ and $P = 0.06$ (for groups 32 and 60) must not be considered to be small for Poisson distribution, as even the probability for appearance of mathematical expectation is never larger than 15% (Sachs 1972). To be sure, let us examine the confidence intervals for mathematical expectations. Their upper and lower limits ($n_{\min}$ and $n_{\max}$) are also given in Table 2. Their values were taken after Table 80 in Sachs (1972), for confidence level 95%. At last, after comparing n with corresponding confidence interval $n_{\min} - n_{\max}$, we arrive to the conclusion, that, at the given level of confidence, only two groups, 44 and 49, cannot be considered to be random fluctuations, because their values n do not fall in the correspondent $n_{\min} - n_{\max}$ intervals.

Table 3. Estimates for mean-square deviations of residual proper motions

No.	σ_{μ_x}	σ_{μ_y}	δ_μ	$\langle\delta_{\mathrm{rand}}\rangle$	σ_δ	t	$P, \%$
32	0.0025	0.0032	0.00403	0.0040	0.0005	0.06	95
33	0.0031	0.0034	0.0046	0.0038	0.0008	0.92	36
44	0.0021	0.0009	0.0023	0.0040	0.0006	2.64	0.8
49	0.0037	0.0031	0.0048	0.0041	0.0005	1.30	19
60	0.0021	0.0019	0.0028	0.0040	0.0006	1.82	7

4.2. The analysis of proper motions

Let us examine the mean-square proper motion, which if necessary can be transformed into the velocity unit. Under "velocity", we mean here only the tangential component of the spatial velocity, as radial velocities of stars are unknown.

Assuming that stellar masses in groups are equal, we denote the proper motion of the corona mass center by $\overrightarrow{\mu_0} = \langle\overrightarrow{\mu}\rangle$. Then the mean-square residual motion will be:

$$\langle\mu_{\mathrm{res}}^2\rangle = \langle(\overrightarrow{\mu} - \overrightarrow{\mu_0})^2\rangle = \langle\overrightarrow{\mu}^2\rangle - \langle\overrightarrow{\mu}\rangle^2. \quad (1)$$

Putting expressions for $\langle\overrightarrow{\mu}^2\rangle = \langle\mu_x^2 + \mu_y^2\rangle$ and $\langle\overrightarrow{\mu}\rangle^2 = \langle\mu_x\rangle^2 + \langle\mu_y\rangle^2$ into (1) and using the usual definition for dispersion we get an expression for the mean-square residual proper motion

$$\langle\mu_{\mathrm{res}}^2\rangle = \langle\mu_x^2\rangle - \langle\mu_x\rangle^2 + \langle\mu_y^2\rangle - \langle\mu_y\rangle^2 = = (\sigma_{\mu_x}^2 + \sigma_{\mu_y}^2)\frac{n-1}{n}. \quad (2)$$

Now the expression (1) has transformed into a dispersion the sum of proper motion components. The factor $\frac{n-1}{n}$ appears because "sigma" is usually used to denote the so-called "undisplaced" dispersion (see Agekjan 1974).

In Table 3, we give the values of mean-square components of the proper motions and mean residual proper motion $\delta_\mu = \langle\mu_{\mathrm{res}}^2\rangle^{1/2}$. As can be seen from Table 3, they differ by more than a factor two. Is this difference of any importance or is it random? To answer these questions, we extracted from the corona of M 67 a thousand random samples with equal numbers of stars in every group. We calculated the mean-square residual proper motions $\langle\delta_{\mathrm{rand}}\rangle$ and their dispersions σ_δ, which helped us to estimate t-statistics (Sachs 1972) in the form:

$$t = \frac{|\delta_\mu - \langle\delta_{\mathrm{rand}}\rangle|}{\sigma_\delta},$$

also given in Table 3.

In the last column of Table 3, we give probabilities found with the help of t-statistics (Sachs 1972) for events the meaning of which is that statistically δ_μ and $\langle\delta_{\mathrm{rand}}\rangle$ are equal. It must be noted that group 44 has dispersion obviously different from random (of about 0.8%). Another extreme case is clump 32, which has dispersion equal to the random value.

4.3. Clump star contents

Let us consider the stellar composition of the clumps. For this purpose, we used the V, $(B-V)$ data contained in the catalogue Frolov & Ananyevskaya (1986). With the help of the

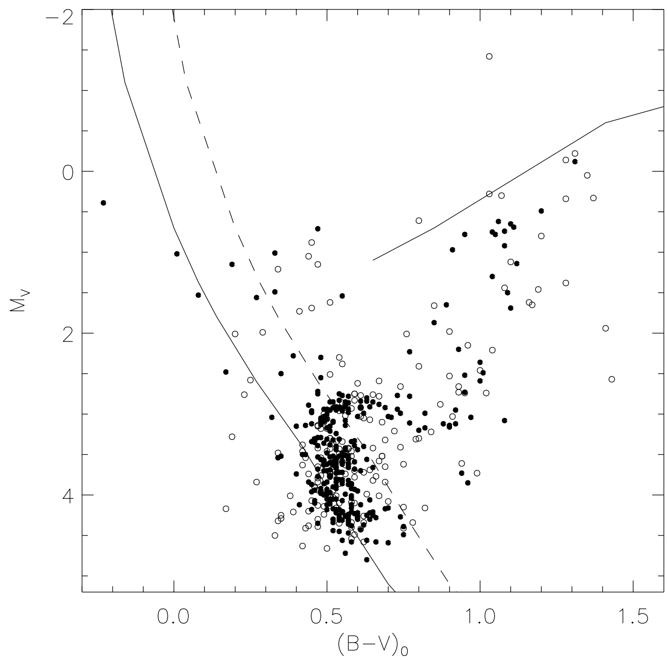

Fig. 3. Color–magnitude diagram for M 67: corona stars – open circles and central part – filled circles

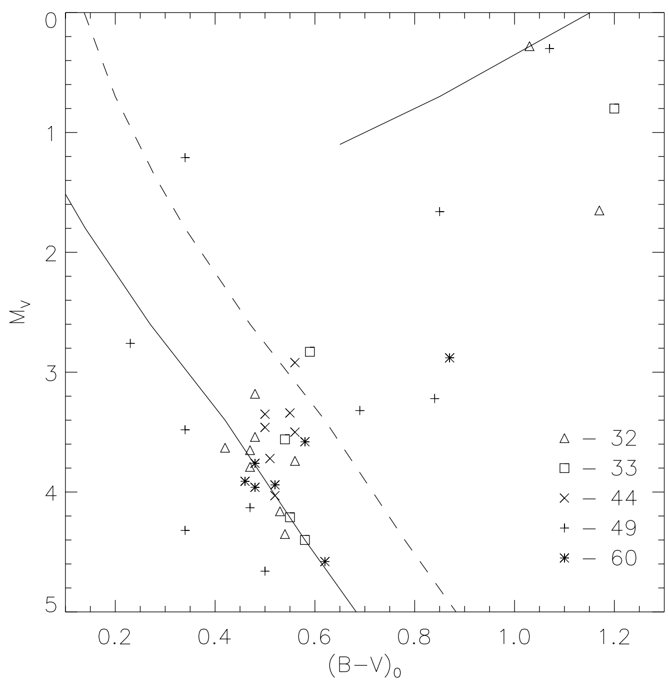

Fig. 4. Color–magnitude diagram for clumps. Different symbols show stars from different clumps

color excess $E_{B-V} = 0.06$, the cluster distance from the Sun $r = 830\text{pc}$ and absorption $A_V = 0^{\rm m}.2$ from Allen (1973), we determined normal colors $(B-V)_0 = (B-V) - E_{B-V}$ and absolute magnitude $M_V = V - A_V + 5 - 5\lg r$ for all members of M 67.

The color–magnitude diagram for the M 67 cluster is shown in Fig. 3. Stars from the corona and nucleus are shown by different symbols. Corona stars were selected in Sec.3 by the NND method and are shown in Fig. 1. The M 67 color–magnitude diagram has features typical for old clusters: it demonstrates giant and subgiant branches and some "blue strugglers" residing above the main sequence turnoff point. Main sequence and giant branch (Allen, 1973) are schematically shown by continuous lines. We have cut Fig. 3 into two parts by a broken line: main sequence stars are to the left of this line and giants and subgiants are to the right. In Table 4, we display the percentages of giants and subgiants in our clumps($\pi_{\rm clump}$) shown in Fig. 4. For the corona, this value is equal to $\pi_{\rm corona} = 44\%$.

Table 4. The contents of giants and subgiants in the clumps and probability of accepting or refusing the H_0-hypothesis : $\pi_{\rm corona} = \pi_{\rm clump}$

No.	$\pi_{\rm clump}, \%$	P_π	H_0
32	20	0.11	no
33	40	0.35	yes
44	14	0.12	no
49	46	0.21	yes
60	14	0.12	no

For the decision of whether the percentages coincide, we have used the following technique from Sachs (1972). Consider the statistical zero-hypothetis $H_0 : \pi_{\rm corona} = \pi_{\rm clump}$ and alternative $H_A : \pi_{\rm corona} \neq \pi_{\rm clump}$ for each clump. In Table 4, we give the corresponding probability (P_π). That value was determined by means of a hypergeometrical distribution used for different populations study

$$P_\pi = \frac{C_{N_{\rm g}}^{n_{\rm g}} C_{N_{\rm d}}^{n_{\rm d}}}{C_{N_{\rm d}+N_{\rm g}}^{n_{\rm d}+n_{\rm g}}},$$

where $N_{\rm g}, n_{\rm g}$ – the number of giants and subgiants, $N_{\rm d}, n_{\rm d}$ – the number of dwarfs in the corona and in a clump correspondingly.

As seen from Table 4, at the confidence level of 13% H_0 is accepted for clumps 33 and 49. For these clumps, $\pi_{\rm clump}$ differs from $\pi_{\rm corona}$ only randomly. On the other hand, for clumps 32, 44 and 60, H_0 should be refused and the alternative hypothesis H_A should be accepted. This means that in these three clumps giants and subgiants are significantly less abundant then in the corona. Note that the clump 44 does not contain either giants or subgiants.

4.4. *Influence of errors*

The average errors of the measurements of the proper motion are equal to $\varepsilon = 0.0020''/\text{yr}$ (see Frolov & Ananyevskaya 1986). The number of measurements used for ε determination is $n_{\rm cat} = 1068$. For M 67, we have $\sigma_{\mu_x} = 0.0026$ and $\sigma_{\mu_y} = 0.0025$ and according to (2) $\delta_\mu = 0.0036$. It is a distant cluster with small proper motions and δ_μ^2 for this cluster is comparable with ε^2. Does this mean that proper motion precision is not good enough for computing residuals? Or in other words, are the residuals reflecting only the Poisson error of measurements rather than internal dispersions? Which of the two hypotheses $H_0 : \delta_\mu^2 = \varepsilon^2$ or $H_A : \delta_\mu^2 \neq \varepsilon^2$ is true? For comparing dispersions and

Table 5. F-statistics needed for accepting or refusing the H_0-hypothesis : $\delta_\mu^2 = \varepsilon^2$ for the clumps in the corona and all of M 67

No.	$F(\delta_\mu, \varepsilon)$	H_0
32	4.06	no
33	5.30	no
44	1.32	yes
49	5.76	no
60	1.96	yes
M 67	12.3	no

deciding whether their difference is meaningful, we calculated the Fisher–Snedecor statistics for large samples ($n > 100$)

$$F = \frac{|\delta_\mu - \varepsilon|}{\left(\frac{\delta_\mu^2}{2n_{\rm cl}} + \frac{\varepsilon^2}{2n_{\rm cat}}\right)^{1/2}}. \quad (3)$$

Using Eq. (3), we found $F = 12.3$. This value clearly designates (with a level of confidence equal to 0.1%, Sachs 1972) that δ_μ^2 and ε^2 are different, so we have a reason to accept the H_A. Thus the residuals are present in the whole cluster. What can we say about clumps?

Now we examine the statistical zero-hypothesis $H_0 : \delta_\mu^2 = \varepsilon^2$ and alternative $H_A : \delta_\mu^2 \neq \varepsilon^2$ for each clump, as we do above for the whole cluster. In Table 5, we give the Fisher–Snedecor statistics according to the formula $F = \delta_\mu^2/\varepsilon^2$ (Sachs, 1972) calculated with confidence level equal 10%. Eq. (3) cannot be used in this case, since the number of stars in the clumps is not large. As seen from Table 5, H_0 cannot be refused for clumps 44 and 60. In these cases, the residuals reflect only errors of measurements rather then internal dispersion. For these clumps, the difference $\delta_\mu^2 - \varepsilon^2$ is practically equal to zero: the velocities of stars inside these clumps are within the measurement errors. For other clumps, H_0 is refused and H_A must be taken into consideration. We use ε as a more precise error estimate for the clumps, applyed on whole cluster. The error of individual measurement for one star is less than ε, with probability equal to 68.3% (Agekjan 1974). This value characterises the precision of the conclusions in column 3 of Table 5.

5. Conclusions

In this paper, we applied the method of selecting internal stellar structures to the cluster M 67. As a result, five stellar groups were found in the corona of M 67. The groups include 5 to 11 stars and have average sizes from 0.5 to 1.2 pc.

The question of reliability of the clumps was examined:

1. It was proved that groups 44 and 49 are not random number fluctuations at the confidence level equal to 95%.
2. The mean-square velocity for one of the groups (No. 44), at the level of confidence equal to 95%, differs from the velocities of random samples of stars from the corona of M 67. This proves that this group is kinematically distinguished.
3. After examining the mean-square star velocities in the groups, we have shown that, taking into consideration the errors in the measurements of proper motion components, clumps number 44 and 60 include stars with identical velocities within the errors of measurements.
4. As seen from the last column of Table 1, when the threshold for membership is introduced, clumps in the corona lose some of their members. On the $P_{\rm m}$ level approximately equal to 50%, all of the clumps became indistinguishable. The maximum members (4 from 7) remain in clump No. 44.
5. The clumps 32, 44 and 60 have significantly lower percentage of giants and subgiants if compared to surrounding corona and other clumps.

We can state that at least one group (No. 44) in the corona of M 67 is a real stellar substructure with members sharing a position in space, common motions and star content.

There is one point that remains unclear. When were these clumps formed: at the beginning of the cluster evolution, during the evolution or within the corona itself after stars dissipated from the core.

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