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Possible mass loss from red giants in old open clusters

A. Antov, M. Popova

In the Department of Astronomy of Bulgarian Academy of Sciences the mass segregation effect in old open clusters was studied extensively. The photometric data for stars up to 20^m in the regions containing the core and corona of the clusters, as well as the galactic field around them were used. The photometry was based on the measuring of the diameters of the stellar images on the blue prints of the Palomar Sky Survey. Star counts in concentric rings were carried out and the distribution of the stars with different mass was obtained.

Segregation effects were found to be present in M 67 (Popova, 1975), NGC 1245 (Popova, Tsvetkov, 1973; Popova, Tsvetkova, 1981), NGC 6939 (Popova, Antov, 1976), and NGC 6866 (Popova, Rogalski). These results are consistent with evaluations of the relaxation theory and digital model computations by Wielen (1967) and by Henon (1971) for the time scale of mass segregation in open clusters as all these clusters are older than 10^8 years.

The mass segregation effect may be used also for study of the possible mass loss in the red giant stage, through comparison of the radial distribution of upper main sequence stars and that of giants branch clump stars in open clusters older than 3.10^8 years. As Cannon (1970) has suggested for these clusters, the clump giants have passed through very luminous red giant tip, their helium cores are degenerate and they are an analogue of the globular cluster's horisontal branch. Theoretical evolutionary calculations of Iben and Faulkner (1966) and Faulkner and Cannon (1973) support this identification and constancy of the absolute magnitude of the clump was interpreted as observational evidence of the occurrence of electron degeneracy in the cores of low-mass red giants. The correlation between the position of the clump on the C-M diagramm and the age found by Vassilevski (1972) for open clusters older than 3.10^8 years is not confirmed, as it has been shown by Popova, Dluzsnevskaya, Antov and Piskunov (1977).

The estimate of the duration of the clump giant stage $\sim 2.10^8$ years points out that the effect of mass segregation may be expected to be observable. For some individual open clusters this was confirmed by Hawarden (1975) who found that stars of the giant branch clump in at least five of a sample of

six open clusters older than Hyades are less concentrated toward the cluster center than the stars of the upper main sequence. He mentioned also the similar results of Arp and Cuffey (1962) for NGC 2158 and of Eggen and Stoy (1961) for NGC 2477. Therefore, for individual clusters the sam-

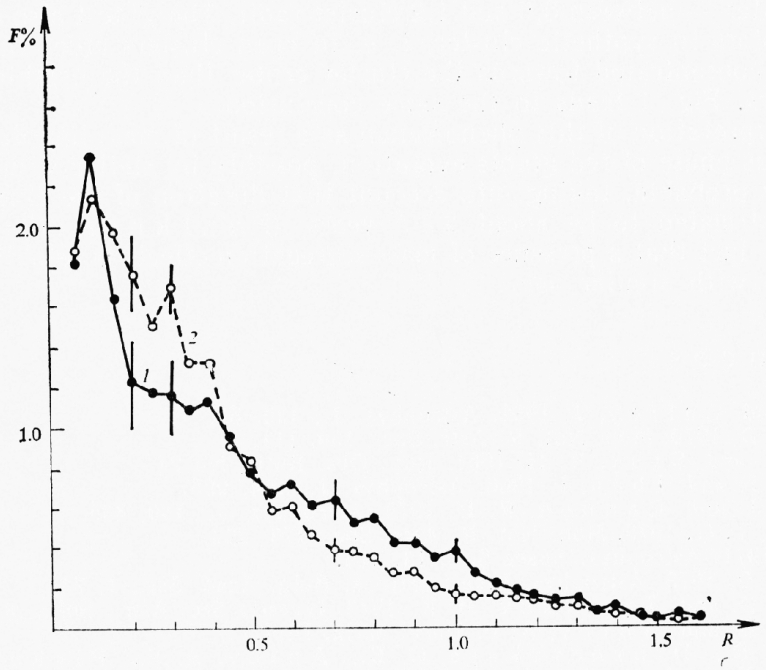

Fig. 1. Radial distribution of clump giants (*1*) and distribution of the stars from the upper main sequence (*2*)

ple of clump giants is small. The results may be influenced by the division in the zones for counts, from the radial differences of the reddening in the cluster and some other factors.

For the diminishing of this influneces we compiled a synthetic cluster using the data for 39 open clusters older than 3.10^8 years for which we have found published C-M diagrams and identification charts. The apparent radius of each cluster was taken as unity. For each star in the rectangular areas on the C-M diagram containing the clump and the brightest part of the main sequence the distance from the cluster's center in units of cluster's radius was determined. The total number of clump stars in synthetic cluster is 369 and the stars in the upper part of the main sequence are 964. The influence of some field stars is impossible to be removed.

To verify if the mass segregation is a general property of the old open clusters we obtained the radial distribution of clump giants and that of the stars in the brightest part of the main sequence in the synthetic open cluster. They are presented on Fig. 1. The bars represent the standard deviations.

The method applied by Hawarden (1972) for individual clusters was used for synthetic cluster. The clump concentration parameter

$$C=\frac{c(i)\,.\,m(o)}{c(o)\,.\,m(i)}$$

was obtained. Here c and m are respectively the number of the clump and main sequence stars in inner zone (i) and the outer (o) zone of the cluster, so if $C>1$, the clump stars are more concentrated to the center than the stars of the upper part of the main sequence. For synthetic cluster $C<1$ ($C_{synth}=0{,}60$). In the inner zone are included the stars with distance less than 0,6 cluster radii, in the outer — between 0,6 and 1,2 cluster radii. The χ^2 test also confirms that clump stars in synthetic cluster, i. e. in open clusters older than 3.10^8 yrs, are less concentrated towards the cluster center than the brightest main sequence stars. Fig. 1 leads to the same conclusion.

The interpretation of this phenomenon as a result of mass loss during the most luminous phase of red giants evolution, possibly by stellar wind mechanism, is very probable, taking into account that duration of the clump-giant phase was estimated to be about 2.10^8 years (Faulkner, Cannon, 1973) and the fact that a presence of mass segregation effect is established for open clusters with similar age.

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О возможной потере массы красных гигантов в старых рассеянных скоплениях

А. Антов, М. Попова

(Резюме)

Исследован эффект массовой сегрегации для проверки возможной потери массы в стадии красных гигантов. Изучено распределение гигантов, членов концентрации на диаграмме цвет—величина и звезд верхней части главной последовательности на основе синтетического скопления, составленного из 39 рассеянных скоплений старше 3.10^9 лет. Установлено, что звезды верхней части главной последовательности концентрируются больше к центру скопления, чем гиганты в концентрациях. Этот факт интерпретируется как указание на потерю массы звезд в стадии красных гигантов. Приложение χ^2-критерия подтверждает полученные результаты.

Department of Astronomy with
National Astronomical Laboratory,
Bulgarian Academy of Sciences

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