Density profiles of populous star clusters in the Magellanic Clouds

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Abstract. The Large Magellanic Cloud (LMC) and the Small Magellanic Cloud (SMC) provide the unique opportunity to study young and populous star clusters. Some of them are elliptical in shape, or are members of a multiple systems, which are almost absent in the Milky Way. We have selected a sample of Magellanic Clouds' star clusters, some of them candidates of a multiple system components, to investigate them by means of their number density profiles. This approach allows us to determine the radial distribution of the stars of different magnitude. Since the brighter stars have larger masses than the fainter stars, the profiles can be used to trace mass-segregation in the clusters. We have fitted a theoretical model by Elson, Fall & Freeman [1987] to determine the core radius and the concentration of the stars for each magnitude range.

Key words: star clusters

Профили на плътността на населени звездни купове в Магелановите облаци

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Големият и Малкият Магеланови облаци предлагат уникалната възможност за изучаване на млади богато населени звездни купове. Някои от тях имат елиптична форма или са членове на двойни системи, каквито се срещат много рядко в Млечния път. Тук представяме извадка звездни купове от Магелановите облаци, някои от които са кандидати за членове на двойни системи. Голямото ъглово разрешение на HST/WFPC2 позволява куповете да бъдат разделени на звезди, което дава възможност да се изследват профилите на плътността на куповете и разпределението на звездите с различна яркост. Тъй като ярките зезди имат по-големи маси от слабите звезди, профилите на плътността за различните звездни величини могат да бъдат използвани като индикатор за сегрегация на масите в звездните купове. Тук използваме теоретичен модел за да определим т.нар. ядрен радиус за различни диапазони от звездни величини.

1 Observations and data reductions

In this work we use archival observations from Hubble Space Telescope WFPC2 camera. We use observations from the following HST programs: HST project 5904 for cluster NGC 1711; HST project 5475 for cluster NGC 1850; HST project 5916 for cluster NGC 1898; HST project 8134 for clusters NGC 1984 and NGC 2011 and NGC 2214. We use calibrated images that were reduced according to the standard HST pipeline, using the latest available calibrations, including bias subtraction and flat-field correction.

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The photometric reduction was done using HSTphot (Dolphin [2000]) - a photometry package especially designed for a point-spread function (PSF) fitting of WFPC2 point sources. For each image the bad and hot pixels were removed, and the cosmic rays cleaned. The images with the same pointing and rotation were combined in order to obtain a better signal to noise ratio and then were used for PSF photometry with a local determination of the background near the star. In this way we minimize the resulting error in the magnitude determination. The magnitude errors from the photometry are typically larger than 0.1^m only for the stars fainter than V 25^m.

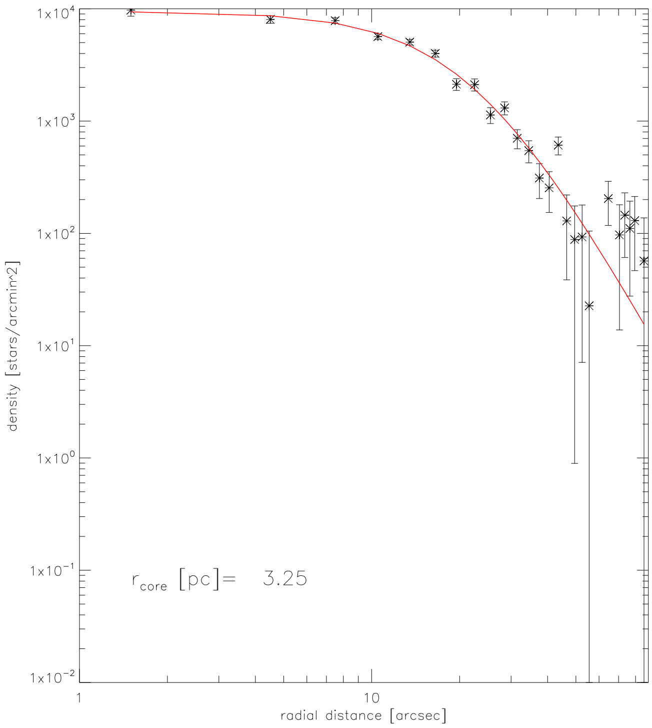

Fig. 1. The radial-density profile for NGC 2214. On the abscissa is the distance from the center of the cluster and the ordinate is stellar density in stars per square arcminute. The best-fit EFF is plotted with line and the corresponding core-radius is indicated in the lower-left corner.

2 Radial-density profiles (RDP)

We construct the profiles counting the number of stars in concentric rings from the center of the cluster. The number of stars in each ring is corrected for the incompleteness of the photometry. That number is then divided by the area of the ring to determine the stellar density. For the computation of the areas we take into account the shape of the WFCP2 and the gaps between the chips of the camera. To derive structural parameters from the clusters' density profiles we fit the Elson, Fall and Freeman (EFF) (Elson et al. [1987]) theoretical profile, which represents well the young LMC clusters with no tidal truncation.

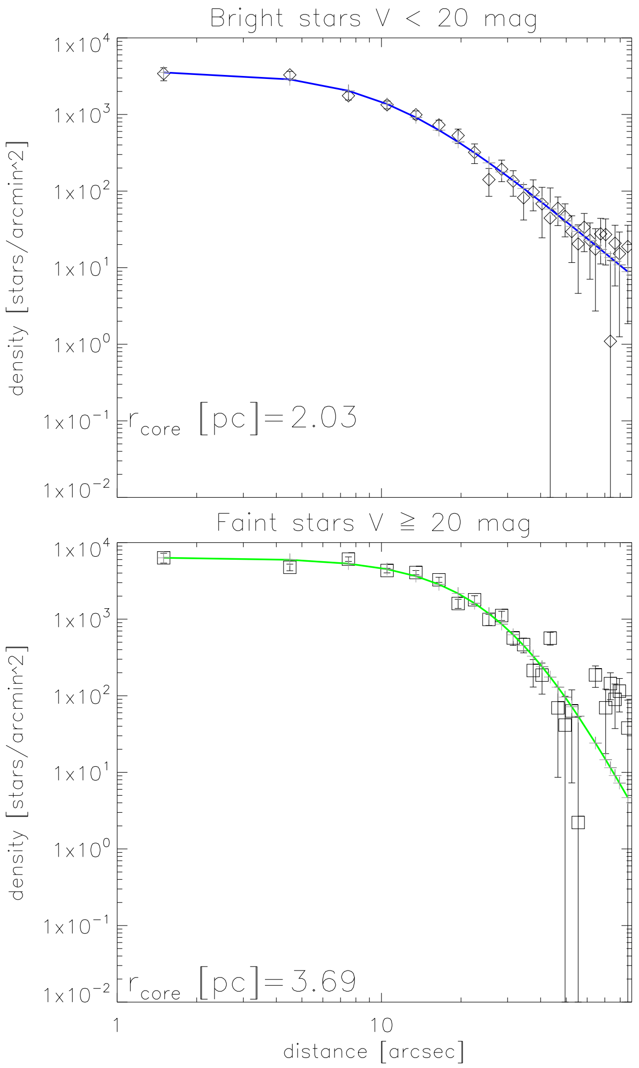

Fig. 2. The radial-density profile for stars brighter than 20^m (upper panel) and fainter than 20^m (lower panel) for NGC 2214. The best-fit EFF model is shown with line and its corresponding core-radius is indicated in the lower-left corner of each panel.

The profile is represented by the following equation

$$f(r) = f_0 \left(1 + \frac{r^2}{a^2}\right)^{-\gamma/2} \tag{1}$$

where f_0 is the central density, γ is the power-law slope, and a is a scale radius, connected to the cluster's core radius r_c as

$$r_c = a\sqrt{2^{(\gamma/2)} - 1} \tag{2}$$

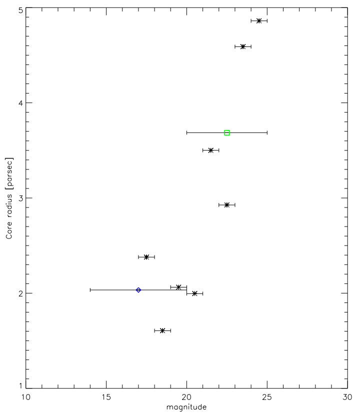

Fig. 3. Core-radius derived from the best-fit EFF model for each magnitude in the cluster NGC 2214 with its magnitude range indicated with horizontal bars. The rhomb symbol corresponds to the r_c of the combined bright stars (Fig. 2 upper) while the square symbol is the core-radius derived from the fainter stars (Fig. 2 lower).

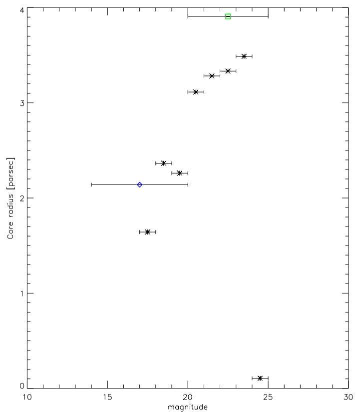

Fig. 4. The best-fit core radius vs. magnitude range for cluster NGC 1711.

3 Discussion and conclusions

Figures – 5 show in detail as an example the LMC cluster NGC 2214 whereas Figures 6 – 10 show the derived core-radii vs. magnitude range of the stars in the clusters NGC 1711, NGC 1850, NGC 1898, NGC 1984 and NGC 2011.

NGC 2214 is a young LMC cluster, possibly in a process of merging (Bhatia & MacGillivray [1988]). In our photometry we cover a magnitude range of more than 10^m. Figure 1 shows the radial-density profile of the cluster and the best EFF fit is shown with line. Figure 2 shows the representative density profiles for stars brighter than 20^m with the best-fit model with line in the upper panel. The RDP of stars fainter than 20^m best-fit model is shown with line in the lower panel. The reason why we separate the stars in two groups – brighter and fainter than 20^m, is because in this way we get much better statistics for the stellar density than in magnitude bins of 1^m. On Figure 3 we show the derived core-radius from fitting the profile for each magnitude bin. It can be seen that the derived core-radius tends to become larger with increasing magnitude, giving indication of mass segregation.

The LMC cluster NGC 1711 is known to be mass-segregated (Subramaniam et al. [1993]) and here (Fig. 4) we confirm that there is an evident trend for our best-fit core-radius to increase with magnitude – the faint stars are more wide spread than the cluster's bright stars.

NGC 1850 is a well-known binary cluster candidate of LMC. The main cluster is very populous while the companion is a small bright clump of ∼50 blue stars. In our RDP the contribution of the small companion is not evident, because of averaging the number of stars in each concentric ring. Figure 5 shows the derived core-radius vs. magnitude for the main cluster.

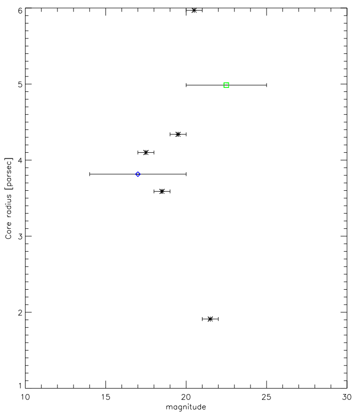

Fig. 5. The best-fit core radius vs. magnitude range for cluster NGC 1850.

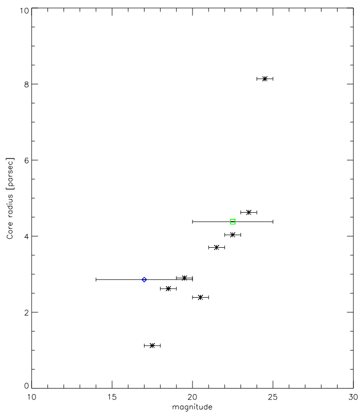

Fig. 6. The best-fit core radius vs. magnitude range for cluster NGC 1898.

The core-radius for NGC 1898 follows the same trend as NGC 1711 - the bright stars are more concentrated and the fainter stars are more wide spread (Fig. 6).The cluster NGC 1984 is located in a very dense star field in a LMC star forming region. The field stars probably influence our density profiles for the stars fainter fainter than 20^m (Fig. 7).

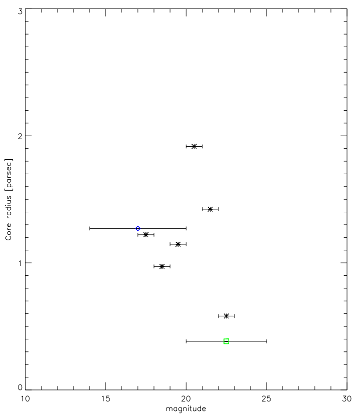

Fig. 7. The best-fit core radius vs. magnitude range for cluster NGC 1984.

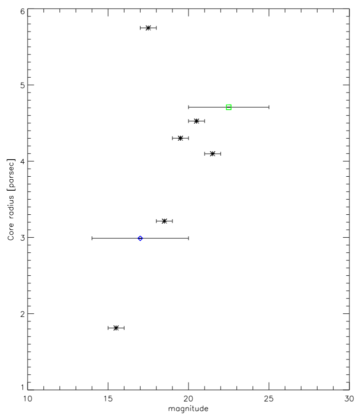

Fig. 8. The best-fit core radius vs. magnitude range for cluster NGC 2011.

NGC 2011 is a young LMC cluster located in the OB association region LH 75.This cluster also shows an indication of stellar stratification (Fig. 8).

From the above investigation we can conclude that the core-radius at various magnitudes may be used as an indicator for mass-segregation in star clusters.

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