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# INDICATION OF STELLAR STRATIFICATION IN 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 elliptical in shape, or members of a multiple system, 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 and Freeman 1987 to determine the core radius and the concentration of the stars for each magnitude range.

## 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. 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 $V\ 25^m$.

## 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. 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, $\gamma$ is the power-law slope, and $a$ is a scale radius, connected to the cluster's core radius $r_c$ as

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

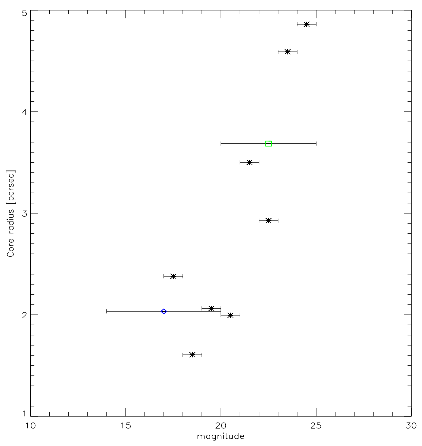


Figure 1: Core-radius derived from the best-fit EFF model for each magnitude in the cluster NGC 2214 with its magnitude range indicated with horizontal bars. The rhomb symbol corresponds to the $r_c$ of the combined bright stars while the square symbol is the core-radius derived from the fainter stars.

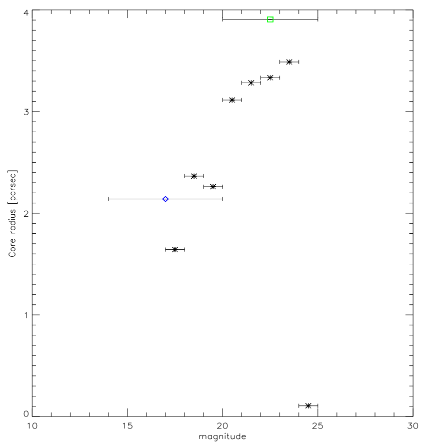


Figure 2: The best-fit core radius vs. magnitude range for cluster NGC 1711

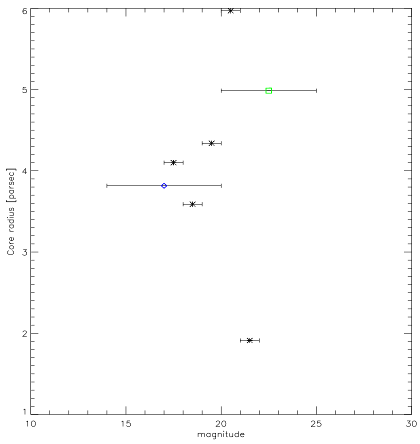


Figure 3: The best-fit core radius vs. magnitude range for cluster NGC 1850

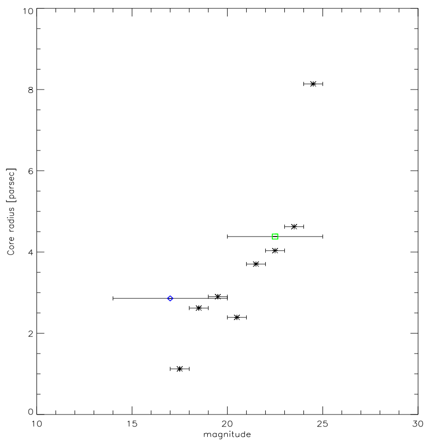


Figure 4: The best-fit core radius vs. magnitude range for cluster NGC 1898

## 3. DISCUSSION AND CONCLUSIONS

The LMC cluster NGC 1711 is known to be mass-segregated (Subramaniam et al.1993) and here (Fig. 2) 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. Fig. 3 shows the derived core-radius vs. magnitude for the main cluster. 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. 4). 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. 5). 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. 6). NGC 2214 is a young LMC cluster, possibly in a process of merging (Bhatia and MacGillivray 1988). On Fig. 1 we show the derived core-radius from fitting the profile for each magnitude bin, indicated by horizontal bars. It can be seen that the derived core-radius tends to become larger with increasing magnitude.

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

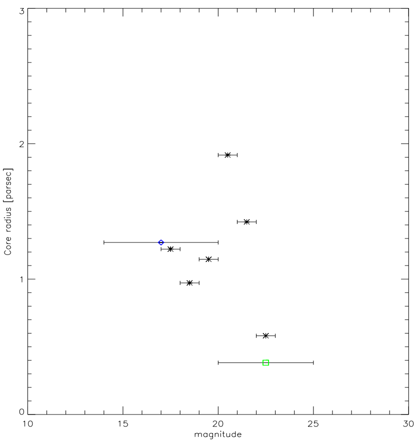


Figure 5: The best-fit core radius vs. magnitude range for cluster NGC 1984

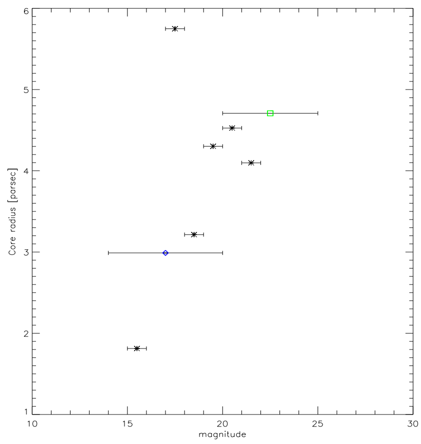


Figure 6: The best-fit core radius vs. magnitude range for cluster NGC 2011

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## References

Bhatia, R. K. and MacGillivray, H. T.: 1988, *Astron. Astrophys.*, **203**, L5.
Dolphin, A. E.: 2000, *PASP*, **112**, 1383.
Elson, R. A. W., Fall, S. M. and Freeman, K. C.: 1987, *Astrophys. J.*, **323**, 54.
Subramaniam, A., Sagar, R. and Bhatt, H. C.: 1993, *Astron. Astrophys.*, **273**, 100.