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# Tidal effects on the structure of Magellanic Cloud peripheral star clusters

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**Abstract.** The Magellanic Clouds constitute an interacting pair of galaxies in many ways overcoming the Milky Way gravitational influence. Studies linking epochs of enhanced star formation with the Clouds approximation reveal how the changing tidal field affects their stellar populations. Star clusters (SCs) are units of stellar population where this connection may be more confidently stablished due to the accurate determination of their astrophysical properties.

**Resumo.** As Nuvens de Magalhães constituem um par de galáxias cuja interação supera os efeitos da influência gravitacional da Via Láctea. Estudos relacionando épocas de formação estelar ativa com a aproximação entre as Nuvens revelam como o campo de maré variável afeta suas populações estelares. Aglomerados estelares são unidades de população estelar onde esta conexão pode ser melhor estabelecida devido à determinação precisa de suas propriedades astrofísicas.

**Keywords.** (Galaxies:) Magellanic Clouds – Galaxies: star clusters: general

## 1. Introduction

The present work aims at relating structural parameters of 56 Large Magellanic Cloud (LMC) and 34 Small Magellanic Cloud (SMC) clusters located in their outskirts with signatures of tidal effects eventually altering their evolution. To achieve our goal, SAMI@SOAR observations in *BVI* bands have been carried out for the SCs to produce a comprehensive database of homogeneous, deep and high quality photometry and derive their astrophysical and structural properties (the VISCACHA - VIsible Soar photometry of star Clusters in tApii and Coxi HuguA - project).

## 2. Observations and data reduction

The SOAR Telescope Adaptive Module (SAM) imager was employed to obtain photometric images with *BVI* filters for the SCs sample with exposure times of 3x450s (B–band), 3x375s (V-band) and 3x560s (I–band). The data were pre-reduced in a standard way, processed for bias subtraction and division by skyflats. Astrometric calibration was performed with IRAF tasks and using the 2MASS stars in the fields as astrometric references. See Fraga et al. (2013) for reduction and astrometric calibration details. The three images obtained per filter were combined and flux calibrated using Stetson or MCPS fields.

The projected spatial distribution of MCs SCs (small dots; Bica et al. 2008) is shown in Fig. 1 together with the observed SCs represented by colored symbols.

## 3. King model fittings to surface brightness profiles

The surface brightness profiles (SBPs) were built from the calibrated *V* and *I* images in annular bins divided in eight sectors for which the flux median was calculated. The SCs center were determined at the average position of the stars within the SC visual radius. The sky level, obtained from the whole image, was subtracted before the fitting procedure. Only the analysis of *V* band images is presented here.

The structural parameters central surface brigthness ($\mu_o$), core radius ($r_c$) and tidal radius ($r_t$) were estimated by fitting the King (1962) model to the clusters' SPBs. The model-fittings were performed from the SC center to the limiting radius, where the flux of cluster stars levels off with that of the field stars. From the limiting radius outward, the flux was used to compute the stellar background/foreground, which was then subtracted from the profile. Figs. 2 and 3 show King model fittings to the SBPs of selected SCs.

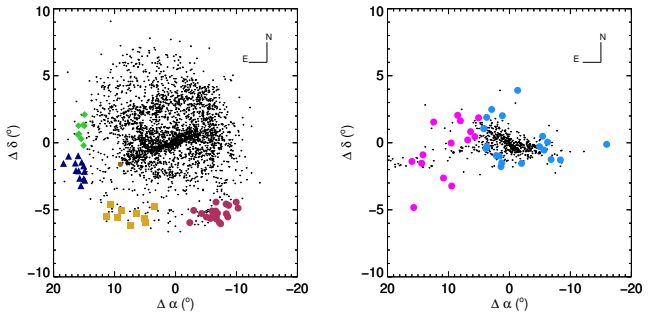


**Figure 1.** Distribution of the observed SCs.

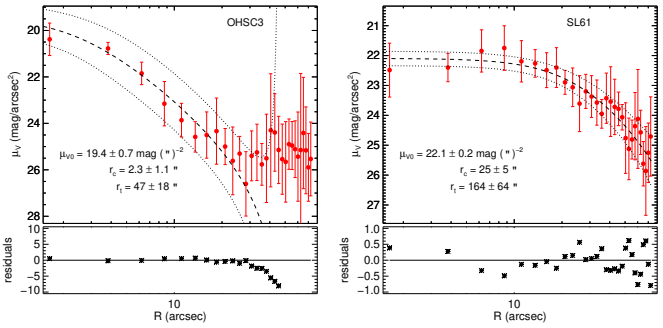


**Figure 2.** LMC clusters with the smallest core radius (left) and the largest one (right).

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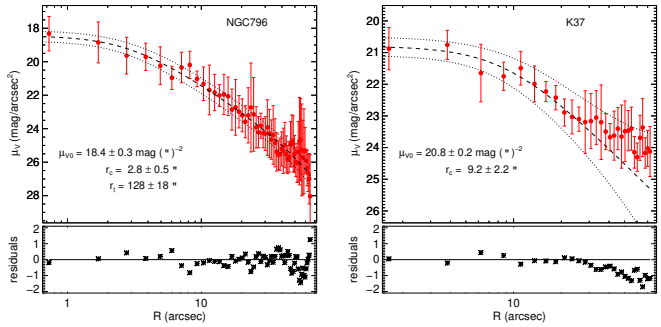


**Figure 3.** SMC clusters of different ages: ∼ 70 Myr (left) and ∼ 2 Gyr (right).

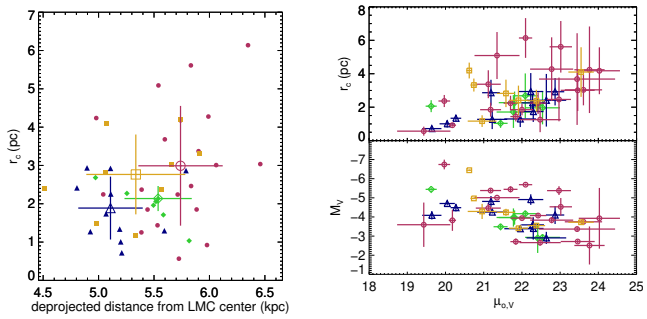


**Figure 4.** Relationships among LMC SCs structural parameters.

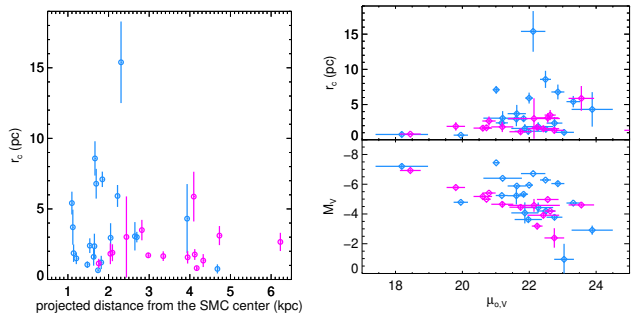


**Figure 5.** Relationships among SMC SCs structural parameters.

## 4. Literature connections

The existence of tidal-dynamical effects in SCs is closely related to their structural parameters (Miholics et al. 2014). Werchan & Zaritsky (2011) found that the LMC lacks SCs that are as large as those in the SMC, and suggested that this result could be a signature of stronger tidal stresses in the LMC. However, since they did cover the central part of the galaxy, they could not explore such effects in the LMC outer disk.

Using field red clump stars from the SMASH survey, Choi et al. (2018) constrained the 3D structure of the LMC, showing a warp towards the southwest of the outer disc, probably associated to the interaction with the SMC. A simulation by Besla et al. (2012), involving three encounters between the Clouds including a direct collision, evidences this warp and indicates that the Clouds themselves, not the Milky Way, are responsible for the distorted features observed in the LMC, such as this warp, a tilted bar and low density stellar arcs ∼ 15 kpc from the LMC centre towards the north (Mackey et al. 2016).

## 5. Results on the LMC

The outer LMC SCs have deprojected distances to the LMC center that do not differ by more than 2 kpc (assuming that the SCs lie in a disk), but are distributed azimuthally from east to southwest throughout ≈ 130°, making different dynamical effects expected among them (Fig. 4). We found that the westernmost LMC SCs (red dots), the nearest ones to the SMC, have a larger spread of core radius than the SCs located elsewhere. This group of SCs is also in the far side of the LMC from us and contains the lowest surface brightness members of our sample.

Interestingly, this result may be compared to recent simulations of the LMC/SMC interaction and analyses of the low surface brightness general field, that reveal asymmetric stellar structures in the LMC outskirts, among them a warp towards the southwest of the outer LMC disc, which is probably associated to the interaction with the SMC. It will be interesting to compare the properties of the SCs located at these regions with the results by Choi et al. (2018). Does the spread in core radius that we noticed for SCs located at ∼ 6 kpc and towards the southwest is associated to the beginning of the warp?

## 6. Results on the SMC

The SMC SC sample cover a larger distance range from the SMC center than that for the LMC sample, but the $r_c$ seems not to be affected by such differential tidal field. Since we used at this time an overall SMC distance to us of 60 kpc and the large SMC depth is well stablished, only when individual SC distances are obtained from isochronal fittings is that it will be possible to make a better account of this issue.

The behavior of the SCs' core radius $r_c$ and integrated magnitude $M_v$ as a function of the central surface brightness $\mu_{\circ,v}$ is similar to that obtained for the LMC (Fig. 5). They reflect the expected relation among the parameters: (i) more luminous SCs have higher central surface brightness than less luminous SCs and (ii) SCs with low central surface brightness (less luminous) have a spread of core radius, while high central surface brightness SCs have small core radius.

## 7. Perspectives

In the near future, we will obtain distance, age and metallicity for the sample and study their gradients in connection with the structural parameters. Such investigation shall provide new findings on the Clouds SC population more strongly affected by the galaxies' interaction and may reveal interesting aspects of their evolution.

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