

# Structure and dynamical age of Large Magellanic Cloud star clusters surveyed by VISCACHA

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**Abstract.** Using deep photometry from the VISCACHA project, the study examines 80 peripheral clusters of the Large Magellanic Cloud (LMC) and finds that these systems undergo contraction over the course of their evolution, consistent with internal dynamics similar to Galactic open clusters. It is further verified that their structural evolution is largely independent of their distance from the LMC center, indicating that internal processes dominate over external effects arising from interaction with the Small Magellanic Cloud (SMC).

**Resumo.** Utilizando fotometria profunda do projeto VISCACHA, o estudo analisa 80 aglomerados periféricos da Grande Nuvem de Magalhães (LMC) e constata que esses sistemas sofrem contração ao longo de sua evolução, o que é consistente com uma dinâmica interna semelhante à de aglomerados abertos Galácticos. Além disso, verifica-se que sua evolução estrutural é amplamente independente da distância ao centro da LMC, indicando que os processos internos predominam sobre os efeitos externos decorrentes da interação com a Pequena Nuvem de Magalhães (SMC).

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

## 1. Introduction

The VISCACHA survey (Maia et al. 2019; <http://www.astro.iag.usp.br/~viscacha/>) provides homogeneous deep BVI photometry of peripheral MC clusters to derive astrophysical and structural parameters. In this work, masses for 80 LMC clusters with homogeneous fundamental parameters are used to estimate dynamical timescales and probe their dynamical evolution.

## 2. Methodology

Structural parameters and integrated magnitudes come from King (1962) model fits to radial density profiles (RDPs) and surface brightness profiles (SBPs). These were combined with astrophysical parameters from isochrone fitting. Total cluster mass is

estimated from age ( $t$ ) and  $M_V$  using simple stellar population (SSP) models assuming a Kroupa (2001) IMF. Relaxation time is computed from total mass, mean stellar mass, and the half-light radius, allowing determination of dynamical age ( $t/t_r$ ).

### 2.1. Isochrone fittings: astrophysical parameters

Astrophysical parameters (age, metallicity, distance, reddening, binary fraction) were derived with the SIESTA code (Ferreira et al. 2024; code available at <https://github.com/Bereira/SIESTA>), which performs a statistical match between color-magnitude diagrams of real and synthetic stellar populations. PARSEC+COLIBRI isochrones (Bressan et al. 2012, Marigo et al. 2013) were employed.

The results, for the example cluster LW 20 were:  $t = 2.01 \pm 0.06$  Gyr,  $[Fe/H] = -0.50 \pm 0.05$ ,  $d = 52.5 \pm 1.1$  kpc,  $E(B-V) = 0.14 \pm 0.01$  and binary fraction ( $m_2/m_1 \geq 0.6$ ) =  $0.54 \pm 0.07$ .

Fig. 2 (left) shows the LW 20 CMD with the best-fitting isochrone superimposed to the cluster stars and the synthetic population.

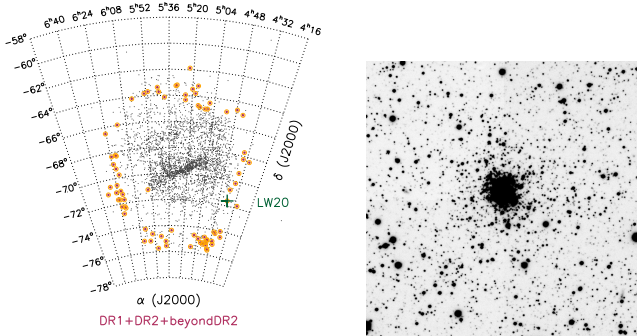
### 2.2. King model fittings to light and density profiles

Core radius ( $r_c$ ) and tidal radius ( $r_t$ ) are obtained from SBP and RDP fitting. SBP uncertainties come from annuli divided in eight sectors; RDP uncertainties follow Poisson statistics.  $r_c$  is adopted from SBP,  $r_t$  from RDP. The half-light radius and integrated V magnitude follow Santos et al. (2020).

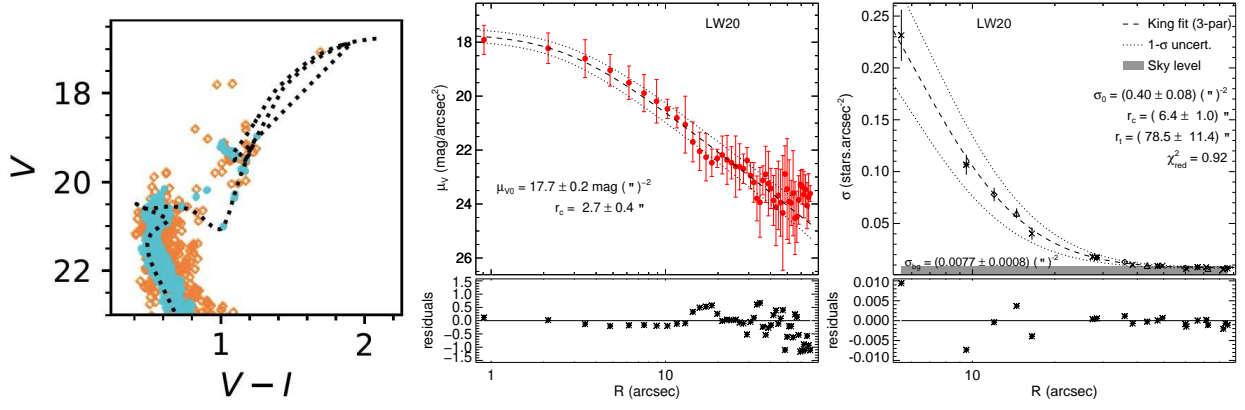
### 2.3. Determining mass from simple stellar population models

Masses are obtained using the SSP-based function from Maia et al. (2014):

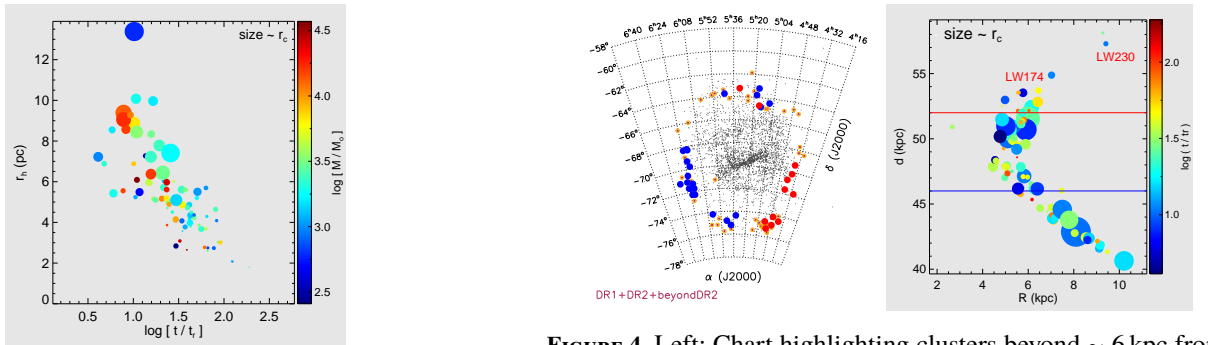
$$\log(M/M_\odot) = a + b \log [t(\text{yr})] - 0.4(M_V - M_{V,\odot}) \quad (1)$$



**FIGURE 1.** Left: Projected spatial distribution of LMC star clusters (grey dots from Bica et al. 2008). The LMC clusters in our sample are represented by orange symbols and the green cross (LW 20). Right: LW 20 V band image as observed with SAMI 3' × 3' FoV. North is up and east to the right.



**FIGURE 2.** Left: LW 20 CMD and the best-fitting isochrone (dots) to the cluster (orange, open symbols) and synthetic (cyan, filled symbols) populations. Center: Best-fitting King model to LW 20 surface brightness profile. Right: Best-fitting King model to LW 20 radial density profile.



**FIGURE 3.** Half-light radius vs dynamical age. The color bar indicates the clusters' mass and symbol sizes represent their relative core radii.

where  $M_{V,\odot} = 4.83$ ,  $a = -6.11 \pm 0.08$  and  $b = 0.64 \pm 0.01$  for a LMC average  $[Fe/H] = -0.40$  (Maia et al. 2014).

Average stellar mass decreases with SSP age from 0.6 to 0.28  $M_{\odot}$ .

#### 2.4. Half-mass relaxation time and the dynamical age

Assuming a radially uniform mass-to-light ratio, the half-light radius is taken as a direct proxy for the half-mass radius. The relaxation time is then computed at  $r_h$  following the formulation given in Heggie & Hut (2003):

$$t_r = 2.1 \times 10^5 \frac{\sqrt{M(M_{\odot})} r_h(\text{pc})^3}{\langle m(M_{\odot}) \rangle \ln(0.11M/\langle m \rangle)} \text{ yr} \quad (2)$$

### 3. Results

Fig. 3 shows the contraction of the half-light radius for more evolved clusters, as measured by the dynamical age.

Fig. 4 suggests that clusters farther than  $\sim 6$  kpc from the LMC center are mostly beyond 52 kpc (red) or before 46 kpc (blue) from us. All clusters beyond 52 kpc, except LW 174 and LW 230 (red circles towards North), are associated with the beginning of the LMC disk warp observed in the west (towards the SMC).

In summary, the half-light radii decrease with increasing dynamical age, indicating progressive internal contraction. The spatial analysis reveals distinct line-of-sight distances for clusters be-

**FIGURE 4.** Left: Chart highlighting clusters beyond  $\sim 6$  kpc from the LMC center that are closer to us (blue) and farther away (red). Right: Dynamical age (symbol colors) and core radius (symbol sizes) in a heliocentric vs galactocentric distance plane; clusters at the average LMC disk distance are between the red and blue lines.

yond  $\sim 6$  kpc, including groups related to the onset of the LMC disk warp.

### 4. Conclusion

Based on these results, peripheral LMC clusters may experience orbital perturbations due to interactions with the SMC; however, variations in the external gravitational potential appear to have little impact on their structural evolution, which is predominantly governed by internal dynamical processes, as indicated by the correlation between  $r_h$  and dynamical age.

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