Dwarf Galaxies: From the Deep Universe to the Present
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Dwarf galaxies: evidence of differential tidal effects in the Large Magellanic Cloud†

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Abstract. We built the most extended stellar density and/or surface brightness radial profiles for 13 old Large Magellanic Cloud (LMC) globular clusters (GCs). The studied GCs located farther than $\sim$ 5 kpc from the LMC center would not seem to present any hint of extended stellar structures, while those closer than $\sim$ 5 kpc do show extended structures. Such an excess of stars tightly depends on the position of the GCs, so that the closer the GC to the LMC center, the larger the excess of stars. Furthermore, the GC radii also show a remarkable trend with the position of the GC in the LMC disc. These outcomes can be fully interpreted in the light of the known GC radial velocity disc-like kinematics, from which GCs have been somehow mostly experiencing the influence of the LMC gravitational field at their respective mean distances from the LMC center.

Keywords. techniques: photometric, galaxies: star clusters, (galaxies:) Magellanic Clouds

1. Introduction

Metal-poor ancient globular clusters (GCs) in the inner halo of the Milky Way and in the Large Magellanic Cloud (LMC) are highly synchronized, in the sense that they seem to be coeval to 0.2 ± 0.4 Gyr (Wagner-Kaiser *et al.* 2017). Since their masses are also similar (Mackey & Gilmore 2003, Sollima & Baumgardt 2017), it becomes interesting to investigate whether such a synchronization has reached other astrophysical properties linked to them, such as structural parameters, relaxation times, etc.

Within the Galactic GC population, the presence of extra-tidal features is frequently seen, either as tidal tails, or extra-tidal stellar populations, or extent diffuse halo-like structures (Carballo-Bello *et al.* 2012, Navarrete *et al.* 2017, Piatti 2017). If ages and metallicities led Wagner-Kaiser *et al.* (2017) to conclude on the synchronicity of GC formation in the Milky Way and the LMC, the comparison of their structural parameters (e.g. core and tidal radii) could shed light about any synchronicity of their dynamical histories as a result of their internal dynamics and tidal interactions with their host galaxies.

2. Data handling and analysis

We downloaded from the National Optical Astronomy Observatory (NOAO) Science Data Management (SDM) Archives‡ *gi* images taken with the Dark Energy Camera

† This is an abridged version of the article published in extense in *MNRAS* (2018), 478, 2164.
‡ http://www.noao.edu/sdm/archives.php.

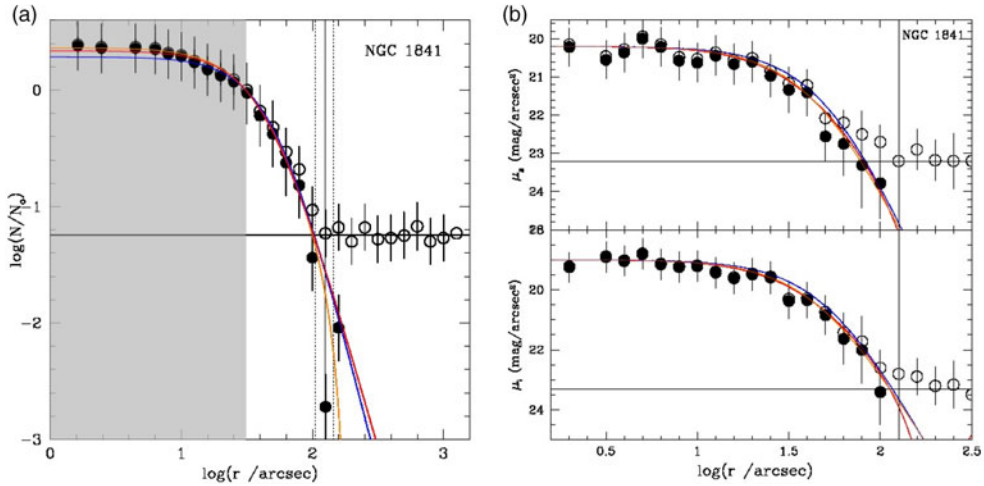

Figure 1. Stellar density (left panel) and surface brightness (right panel) profiles of NGC 1841. The shaded area was not considered to fit King (1962), Plummer (1911) and Fall, Freeman (1987) models (see text for details).

(DECam, Cerro Tololo Inter-American Observatory, Chile) by the Survey of the Magellanic Stellar History (SMASH; Niveder *et al.* 2017) in the field of 12 LMC GCs, namely, NGC 1754, 1786, 1835, 1841, 1898, 1916, 1928, 1939, 2005, 2019, 2210, and Hodge 11, and of Reticulum by the Dark Energy Survey (DES; Abbot *et al.* 2016).

A series of tasks comprising star finding and aperture photometry, PSF modeling with functions quadratically varying, and the use of the resulting PSFs to obtain instrumental magnitudes were performed iteratively three times on previously created subtracted images to find and measure magnitudes of additional fainter stars. Bona fide stellar objects were successfully isolated by using roundness values between -0.5 and 0.5 and sharpness values between 0.2 and 1.0.

We also performed extensive artificial star tests around the cluster regions in order to accurately map the completeness of our photometry in terms of photometric depth and spatial dependence with the distance from the cluster center. In doing this we repeated the PSF photometry recipes referred above – including the three passes to measure fainter stars – on a thousand created images per cluster with nearly 5 per cent added stars distributed appropriately according to the cluster stellar density profile and covered magnitude range.

For resolved LMC GCs, we built stellar density radial profiles by employing a kernel density estimator routine over a subsample of stars with i magnitudes brighter than those for the 90 per cent completeness level. Additionally, we produced gi surface brightness radial profiles for all the GC sample. Fig. 1 illustrates the measured and background subtracted stellar density and surface brightness profiles with open and filled circles, respectively. The background level is represented by the horizontal solid line, while the vertical solid and dotted lines represent the GC's radius and its uncertainty. We fitted King (1962), Plummer (1911) and Fall, Freeman (1987) models to derive core (r_c), half-light (r_h), and tidal (r_t) radii and the power-law slope at large radii (γ).

Fig. 2 would seem to suggest that γ, r_{cls} and the concentration parameter (c) show a trend with the position of the GCs in the galaxy. As can be seen, the smaller the γ value, the smaller the deprojected distance (d_{deproj}), and hence the stronger the LMC tidal field, suggesting that the LMC gravitational field has been acting differently on the GCs. Bearing in mind that the orbital motions of LMC GCs are satisfactorily described by a

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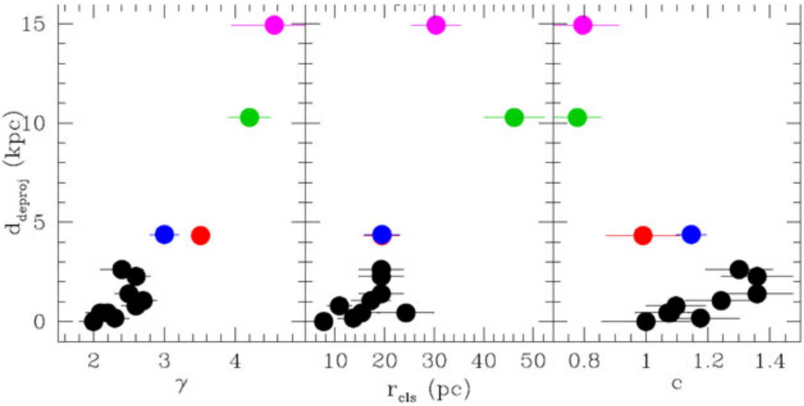

Figure 2. Relationships of different structural parameters with the deprojected distance.

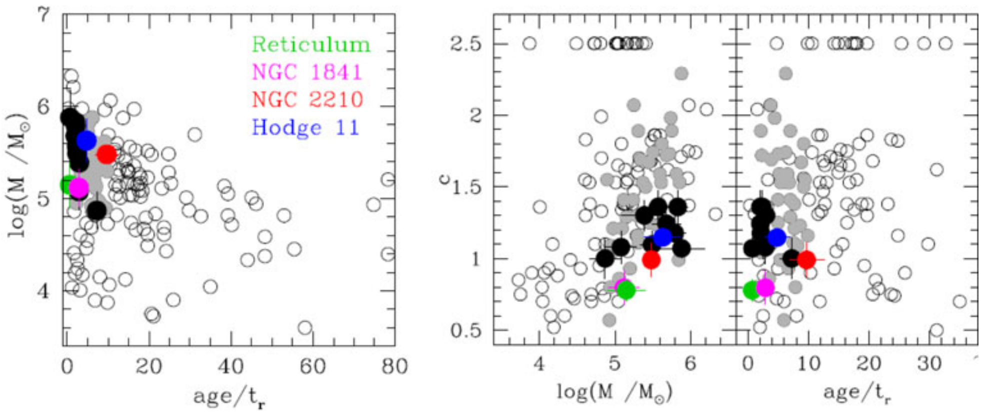

Figure 3. Dynamics evolution diagnostic diagrams. Black and gray filled circles represent LMC GCs at d_{deproj}< 5 kpc and GGCs with masses similar to the LMC GCs, respectively. Open circles represent all the Galactic GCs.

disc-like rotation with no GCs appearing to have halo kinematics (Schommer *et al.* 1992, Grocholski *et al.* 2006, Sharma *et al.* 2006), so that it is expected that they do not cross the LMC disc, the above result could be somehow expected, and it is now confirmed by the observations. Similarly, the innermost GCs are smaller than the outermost ones. The variation in cluster size is not due to systematically different masses: GCs with d_{deproj} smaller or larger than $\sim$ 5 kpc span comparable mass ranges (see Fig. 3). Furthermore, even having similar masses, they have dynamically evolved differently: the innermost ones have in average larger median relaxation times than their more remote counterparts (see Fig. 3). This finding suggests that the LMC gravitational field has played an important role in accelerating the dynamical evolution of the innermost GCs.

We compared LMC GC dynamics/structural parameters with those of Galactic GCs. As the concentration parameter c is concerned, the larger its values, the more dynamically evolved a cluster. As can be seen in Fig. 3, more massive Galactic GCs have dynamically evolved faster; while the LMC GCs have the lowest c values, thus implying that they are the least evolved, in comparison to their counterpart Galactic GCs. This is an unexpected result because both GC populations have lived similar number of times their

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relaxation times t_r (similar age/t_r ratios), as is shown in Fig. 3, and are highly synchronized (Wagner-Kaiser *et al.* 2017). Under the assumption that isolated GCs of similar masses should dynamically evolve similarly, the present outcome poses the idea that other conditions, for instance, the gravitational potential of the host galaxy, the features of the GC orbital motions (halo- or disc- like orbits), could also affect differentially the relationships between different structural parameters.

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