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Globular clusters in the Fornax cluster: A report from the FDS survey

Michele Cantiello[1], A. Venhola[2], M. Paolillo[3], R. D'Abrusco[4], A. Grado[5], E. Iodice[5], R. Peletier[6], M. Capaccioli[3], M. Hilker[7], S. Mieske[8], N. Napolitano[9], G. Riccio[3], M. Spavone[5] and M. Quintini[1]

[1]INAF Astronomical Observatory of Abruzzo, via Maggini snc, 64100 Teramo, Italy
email: michele.cantiello@inaf.it

[2]University of Oulu, Finland

[3]University of Naples, Italy

[4]Center for Astrophysics, Harvard & Smithsonian, US

[5]INAF-Observatory of Naples, Italy

[6]Kapteyn Institute at the University of Groningen, Netherlands

[7]ESO, Munich, Germany

[8]ESO, Santiago, Chile

[9]Sun Yat-sen University, Guangzhou, P.R. China

Abstract. The Fornax Deep Survey (FDS) is a multi-band imaging survey of the Fornax cluster of galaxies, executed with the ESO VLT Survey Telescope (VST). The survey is designed to reach unprecedented surface brightness and point-source magnitude depth over one virial radius of the cluster. The scientific objectives of the survey are numerous: the study of the galaxy luminosity function, derivation of galaxy scaling relations, determination of the properties of compact stellar systems, an accurate determination of distances and 3-D geometry of the Fornax cluster, analysis of diffuse stellar light and galaxy interactions, etc.

In this contribute we give an overview on the interest of the survey on globular clusters (GC) populations, and present a report the status of the study of GCs also providing some preliminary results of our analysis, with particular regard to the two-dimensional distribution of GC candidates over ∼20 sq. degree area of Fornax centered on NGC 1399.

Keywords. Galaxies: star clusters – galaxies: clusters: individual (Fornax) – galaxies: photometry

1. Introduction

The study of local complexes of galaxies –clusters and groups– is crucial for our understanding of the history of formation and evolution of the Universe through its building blocks. Local galaxy systems mark the endpoint of the evolution of galaxies after billion years of more or less intense interaction with their siblings (e.g., Mo *et al.* 2010).

In the last decade – also thanks to the advent of efficient large-format imaging cameras – different observational programs have carried out intensive surveys dedicated to cover large fractions of nearby galaxy systems superseding previous optical/near-IR studies (e.g., Ferrarese *et al.* 2012; Iodice *et al.* 2017a,b). In this framework, our collaboration has obtained deep multiband (u, g, r, and i) imaging data of the Fornax cluster with the VLT Survey Telescope (VST), situated at the Paranal observatory of the European Southern Observatory (ESO).

The Fornax Deep Survey (FDS) covers the target cluster out to the virial radius (Drinkwater *et al.* 2001), an area of ∼20 square degrees around the central galaxy NGC 1399. Further 5 square degrees in the region of NGC 1316 (Fornax A) were also obtained, with only *gri* passband coverage.

The FDS provides an unprecedented dataset for studying the photometric and morphological properties of the families of objects in the Fornax cluster ranging from bright massive galaxies, down to stellar clusters. Here, we present a report on the work in progress to study globular cluster (GC) systems based on FDS data.

2. GC in FDS: overview, detection and preliminary 2-D map

Extra-galactic GCs are old, compact stellar systems, ubiquitously found in galaxies. As fossil tracers of their environment, GCs provide important and unique information to constrain the history of formation and evolution of their host galaxy and its environment (Ashman & Zepf 1998; Harris 2001; West *et al.* 2004; Brodie & Strader 2006; Misgeld & Hilker 2011; Cantiello *et al.* 2009). The systematic study of GC systems in galaxies has highlighted a wealth of properties that are used to trace the physical characteristics of the GC system itself, and of its host galaxy; these characteristics include the luminosity function of GCs, the spatial distribution, the projected surface density, the radial color profiles, the specific frequency, the kinematical properties, and the color-magnitude relations. All such properties are effective tracers of the past formation and evolution history of the galaxy, its physical distance, possible merging events, mass distribution, etc.

The wide-field and photometric depth of FDS are sufficient to reveal a large fraction of the GC populations in Fornax. The main properties of the FDS dataset, the data reduction and calibration, are reported in Venhola *et al.* (2018). The first analysis of GCs with FDS data, focused on the central 1 and 8.4 sq. degrees, were anticipated in Cantiello *et al.* (2018a) and in D'Abrusco *et al.* (2016), respectively. Coherently with similar existing studies, our analysis confirms the presence of a severe contamination to the sample of GC candidates by fore- and background sources. Hence, for the specific science case of GCs, to reduce the level of such contamination and for an improved photometric homogeneity, we have revised our source detection and calibration procedures with respect to the catalogs used in our previous studies.

Briefly, to improve the detection and morphological characterization of compact sources – including GC candidates – we generated master detection frames by stacking all single g, r, and i-band exposures with a given FWHM limit (typical cut: median FWHM $\leqslant 0.9$ arcsec over the OmegaCAM field of view). The detection and photometry of the sources was carried out after modeling and subtracting the brightest ($m_B^T \leqslant 18$ mag) Fornax galaxy cluster members in the frame. The master detection list, from the multiband stacked frame, was then used as input to obtain PSF photometry with DAOPhot (Stetson 1987) and aperture photometry with SExtractor (Bertin & Arnouts 1996), separately for each available passband. Furthermore, because of small residual zeropoint differences from field to field due to the different master photometric calibration frames, we also revised the FDS photometry with respect to our previous works, by matching our measurements to the photometry from APASS†. Further details will be presented in the GC catalog description paper (Cantiello *et al.*, 2020; in prep.).

The analysis of the properties of the sample of GC candidates, including an updated and extended 2-D distribution map, is in progress (see also, Riccio *et al.* 2019, in this volume). In Figure 1 we show a preliminary version of the two-dimensional map of the GC candidates in FDS, derived using the new extended *ugri* catalog, with the selection

† We acknowledge with thanks the variable star observations from the AAVSO International Database contributed by observers worldwide and used in this research.

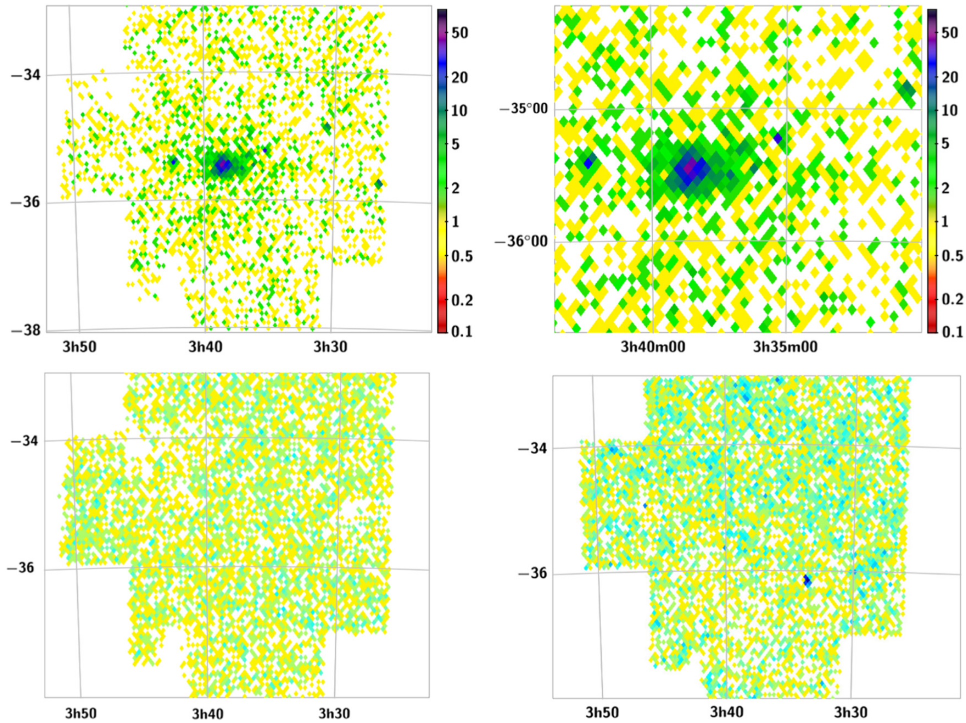

Figure 1. Upper left panel: density map of GC candidates over the ∼20 sq deg. area covered by *ugri* imaging data. The color map is shown on the right; logarithmic stretch is adopted. Upper right panel: as upper left panel, but a zoom over the central area is shown, to emphasize presence of sub-structures already presented in D'Abrusco *et al.* (2016). Lower left panel: same region as upper left panel, except that the surface density of point-like non-GC candidates sources is shown. Lower right panel: as left panel but for extended sources. The small overdensity of extended sources observed around R.A.∼$3h$ $34m$, Dec.∼$-36d$ $10m$ is due to the star forming regions detected in the bright massive spiral galaxy in Fornax NGC 1365.

procedures described in Cantiello *et al.* (2018a,b) based on morphometric and photometric characteristics of the sample, calibrated on a sample of confirmed GCs from HST data (Jordán *et al.* 2015) or from spectroscopic observations (Pota *et al.* 2018).

The upper left panel of the figure shows the density map of GC candidates over the ∼20 sq. degrees area inspected. Two known features appear quite clearly: the large overdensity of GCs around NGC 1399, and the stretched East-West direction of such distribution, extending in the eastern cluster area which is poor of bright galaxies compared to the western cluster region. As also visible in the zoomed map shown in the upper right panel of Figure 1, the revised photometry confirms the main features of the GCs overdensity already presented in D'Abrusco *et al.* (2016; see their Fig. 2).

For comparison, to highlight the high level of foreground (MW stars) and background (galaxies) contamination, the lower panels of Figure 1 show the surface density maps of non-GC point-like sources (left panel) and of extended sources (right panel) adopting the same scale as in upper panels. The lower detection rate in well-identified survey regions (e.g. R.A.∼$3h$ $43m$, Dec.∼$-37d$ $20m$) is mostly due to the presence of bright saturated stars. Further improvements to the detection of faint sources in such regions are in progress.

Despite the huge levels of contamination (only $\leqslant 0.5\%$ of sources is identified as possible GC candidate), the presence of features related to the GC system in the cluster emerges

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clearly in the figure, revealing important fossils tracers for constraining the buildup of the Fornax cluster over the megaparsec scale. Possible candidate new features are *i*) a slight GC increase in the south-east area of NGC 1399, again a region devoid of bright galaxies (R.A.∼$3h$ $41m$, Dec.∼$-36d$ $15m$), and *ii*) a *stream* bridging the cluster GCs around NGC 1399 with the Fornax A subgroup, dominated by the peculiar elliptical galaxy NGC 1316, and mostly apparent for the blue GC sub-population.

Further analysis to confirm, identify and characterize the presence of such and other "fainter" previously undetected GC-density features is in progress (D'Abrusco *et al.*, 2020, in prep.).

3. Works in progress

At less than two years from the completion of the data acquisition for the FDS survey by the VST, we have now completed process of deriving the photometry of compact and slightly-extended sources (background galaxies, small galaxies in the Fornax field, etc.) in Fornax.

The catalog of detected sources, together with their morpho- and photo-metric properties, and companion works presenting the analysis of GC properties are in progress. Any update will be made available through the FDS program web pages†, and on related pages, with publications and –as soon as public– with catalogs and imaging data.

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† Visit: http://www.na.astro.it/vegas/VEGAS/Fornax_Deep_Survey/Fornax_Deep_Survey.html

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