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1 Globular clusters in the Fornax cluster: 2 A report from the FDS survey

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16 **Abstract.** The Fornax Deep Survey (FDS) is a multi-band imaging survey of the Fornax cluster of
17 galaxies, executed with the ESO VLT Survey Telescope (VST). The survey is designed to reach
18 unprecedented surface brightness and point-source magnitude depth over one virial radius of the
19 cluster. The scientific objectives of the survey are numerous: the study of the galaxy luminosity
20 function, derivation of galaxy scaling relations, determination of the properties of compact stellar
21 systems, an accurate determination of distances and 3-D geometry of the Fornax cluster, analysis
22 of diffuse stellar light and galaxy interactions, etc.
23

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

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

30 1. Introduction

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

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

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

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

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

51 Extra-galactic GCs are old, compact stellar systems, ubiquitously found in galaxies.
 52 As fossil tracers of their environment, GCs provide important and unique information to
 53 constrain the history of formation and evolution of their host galaxy and its environment
 54 (Ashman & Zepf 1998; Harris 2001; West *et al.* 2004; Brodie & Strader 2006; Misgeld & **Q3**
 55 Hilker 2011). The systematic study of GC systems in galaxies has highlighted a wealth of
 56 properties that are used to trace the physical characteristics of the GC system itself, and
 57 of its host galaxy; these characteristics include the luminosity function of GCs, the spatial
 58 distribution, the projected surface density, the radial color profiles, the specific frequency,
 59 the kinematical properties, and the color-magnitude relations. All such properties are
 60 effective tracers of the past formation and evolution history of the galaxy, its physical
 61 distance, possible merging events, mass distribution, etc.

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

72 Briefly, to improve the detection and morphological characterization of compact
 73 sources – including GC candidates – we generated master detection frames by stack-
 74 ing all single *g*, *r*, and *i*-band exposures with a given FWHM limit (typical cut: median
 75 FWHM ≤ 0.9 arcsec over the OmegaCAM field of view). The detection and photometry of
 76 the sources was carried out after modeling and subtracting the brightest ($m_B^T \leq 18$ mag)
 77 Fornax galaxy cluster members in the frame. The master detection list, from the multi-
 78 band stacked frame, was then used as input to obtain PSF photometry with DAOPhot
 79 (Stetson 1987) and aperture photometry with SExtractor (Bertin & Arnouts 1996),
 80 separately for each available passband. Furthermore, because of small residual zeropoint
 81 differences from field to field due to the different master photometric calibration frames,
 82 we also revised the FDS photometry with respect to our previous works, by matching
 83 our measurements to the photometry from APASS[†]. Further details will be presented in
 84 the GC catalog description paper (Cantiello *et al.*, 2019; in prep.).

85 The analysis of the properties of the sample of GC candidates, including an updated
 86 and extended 2-D distribution map, is in progress (see also, Riccio *et al.*, 2019, in this
 87 volume). In Figure 1 we show a preliminary version of the two-dimensional map of the
 88 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.

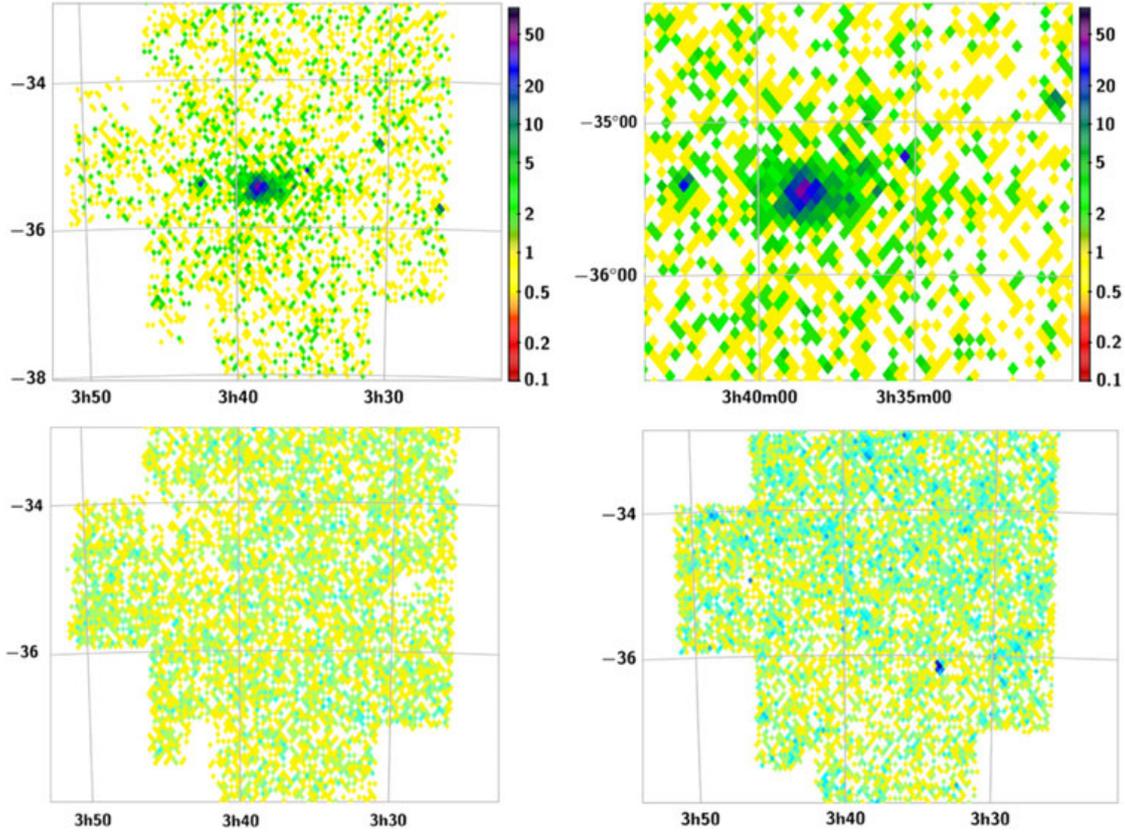


Figure 1. Upper left panel: density map of GC candidates over the ~ 20 sq deg. area covered by *ugri* imaging data. The color map is shown on the right; logarithmic stretch is adopted. Upper right panel: as upper left panel, but a zoom over the central area is shown, to emphasize presence of sub-structures 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. $\sim 3h\ 34m$, Dec. $\sim -36d\ 10m$ is due to the star forming regions detected in the bright massive spiral galaxy in Fornax NGC 1365.

89 procedures described in [Cantiello *et al.* \(2018a,b\)](#) based on morphometric and photo-
 90 metric characteristics of the sample, calibrated on a sample of confirmed GCs from HST
 91 data ([Jordán *et al.* 2015](#)) or from spectroscopic observations ([Pota *et al.* 2018](#)).

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

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

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

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

114 Further analysis to confirm, identify and characterize the presence of such and other
 115 “fainter” previously undetected GC-density features is in progress (D’Abrusco *et al.*,
 116 2019, in prep.).

117 3. Works in progress

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

122 The catalog of detected sources, together with their morpho- and photo-metric prop-
 123 erties, and companion works presenting the analysis of GC properties are in progress.
 124 Any update will be made available through the FDS program web pages†, and on related
 125 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