Dwarf Galaxies: From the Deep Universe to the Present
Proceedings IAU Symposium No. 344, 2019
K. B. W. McQuinn & S. Stierwalt, eds.

doi:10.1017/S1743921318006634

A New Reservoir of Dwarf Galaxy Candidates in the Centaurus A Group

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Abstract. We have searched optical $u'g'r'i'z'$ imaging of 22 deg^2 centred on the nearby giant elliptical galaxy NGC 5128 for new dwarf galaxies in the Centaurus A group. We report 45 promising new candidates, which are broadly consistent with the properties of nearby dwarf spheroidal galaxies and extend the size-luminosity relation toward fainter total luminosities and smaller sizes for known dwarf galaxies outside the Local Group (LG). Altogether, these new results show NGC 5128 to be the host of a large reservoir of low-mass dwarf galaxies that is at least as rich as that of the LG and is ripe for detailed follow-up observations.

Keywords. galaxies: star clusters, galaxies: dwarf, galaxies: elliptical, galaxies: individual (NGC5128), galaxies: interactions

1. Introduction

The last decade has seen the number of known dwarf galaxies in the Local Group (LG) explode to include dozens (e.g. Belokurov *et al.* 2010; McConnachie 2012; Bechtol *et al.* 2015; Muñoz *et al.* 2018a,b), while beyond the LG numerous dwarf satellites have been identified around nearby galaxy complexes like M81, M101, NGC 2784, M96, and others (e.g. Chiboucas *et al.* 2009; Merritt *et al.* 2014; Javanmardi *et al.* 2016; Bennet *et al.* 2017; Henkel *et al.* 2017; Müller *et al.* 2017b, 2018a; Smercina *et al.* 2017; Park *et al.* 2017), as well as in rich cluster environments like Virgo and Fornax (Sánchez-Janssen *et al.* 2016; Muñoz *et al.* 2015; Eigenthaler *et al.* 2018; Ordenes-Briceño *et al.* 2018a). Such dwarf galaxy systems are increasingly being shown to have seemingly structured distributions around their hosts, with so-called "satellite planes" detected around the LG (Ibata *et al.* 2013; Pawlowski *et al.* 2012), and 100 kpc-scale clustering for dwarfs in the Fornax cluster (Muñoz *et al.* 2015; Ordenes-Briceño *et al.* 2018a).

The nearby giant elliptical galaxy NGC 5128 is the dominant member of the Centaurus A group, and itself hosts an increasingly rich population of dwarf galaxy satellites, at least some of which are organized into a co-rotating Mpc-scale planar distribution (Müller *et al.* 2018b). The Northeast halo region hosts several dwarf galaxies and tidal features (Crnojević *et al.* 2014, 2016), which appears to lead to a satellite

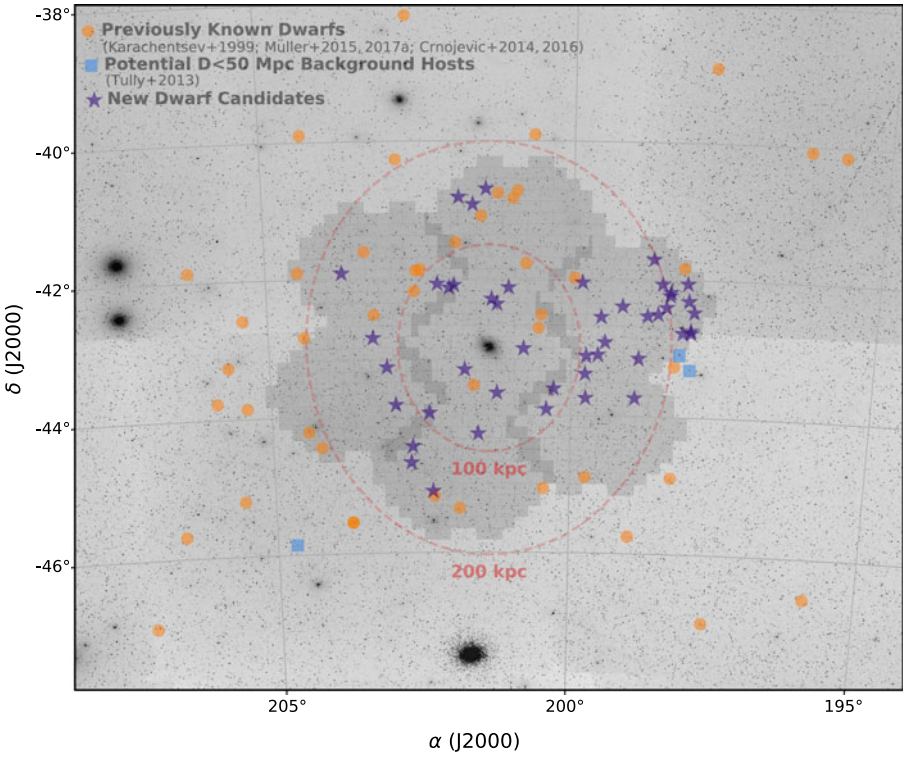

Figure 1. The spatial distribution of known and new NGC 5128 dwarf galaxies/candidates superposed on an archival DSS image. Darker grey shading indicates the current imaging footprint. New dwarf candidates are shown by purple stars, while orange dots indicate previously discovered dwarfs. Blue squares indicate potential giant hosts in the background (see § 3).

"bridge" connecting to the giant galaxy M83 (Müller *et al.* 2015, 2017a). NGC 5128 also hosts a large reservoir of $\gtrsim$3000 globular clusters extending out past 225 kpc (Taylor *et al.* 2017), with the outer halo dominated by blue—likely metal-poor—GCs that may have been deposited there during past dwarf galaxy accretion events. This intriguing system of known and hinted-at low-mass satellites provides a obvious incentive to continue the search for yet more dwarf galaxies around NGC 5128, in particular toward the North where higher numbers might be expected to form part of the bridge toward M83. Throughout this work, we adopt a NGC 5128 distance modulus of 27.88 mag (Harris *et al.* 2010), corresponding to a spatial scale of 19 pc arcsec^{-1}.

2. Dwarf Sample Selection and Light Profile Modeling

We base our analysis on ∼22 deg^2 of optical *Dark Energy Camera* (DECam) $u'g'r'i'z'$-band imaging obtained as part of the *Survey of Centaurus A's Baryonic Structures* campaign (Taylor *et al.* 2017). Basic image reduction was performed by the DECam community pipeline, and we further used the ASTROMATIC software to register frames to a common coordinate system using the 2MASS astrometric reference star catalogue and calibrate our photometry to the SDSS system.

We visually inspected full-color RGB images constructed from the $u'g'z'$ imaging, and only consider dwarfs to be robust candidates if at least three team members independently identify a given dwarf candidate to guard against spurious detections arising from personal selection biases. Fig. 1 shows the spatial locations of the dwarf candidates

https://doi.org/10.1017/S1743921318006634 Published online by Cambridge University Press

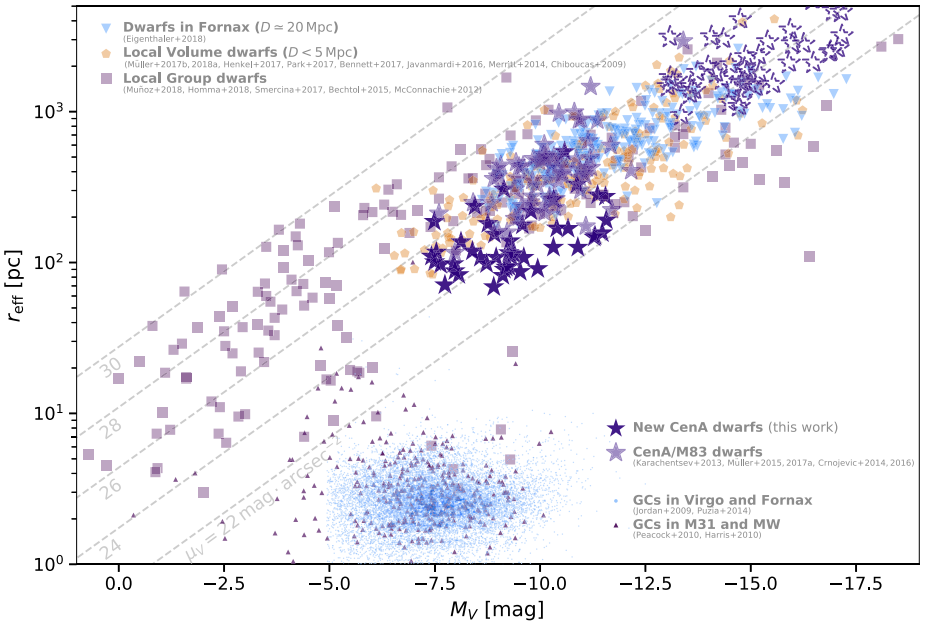

Figure 2. The size-luminosity diagram including the present dwarf candidates, and others in the LG and nearby universe. We differentiate those already known in the Centaurus A/M83 complex for easier comparison to the candidates presented in this work (dark vs. light stars). Empty dashed stars show the sample from this work shifted to the distance of a background group at a distance of 50 Mpc.

presented here (purple stars) in relation to dwarfs previously reported in the literature (orange dots Karachentsev *et al.* 2013; Müller *et al.* 2015, 2017a; Crnojević *et al.* 2014, 2016). We point out an intriguing overdensity of new dwarf candidates toward the west of NGC 5128 itself, which may represent a dwarf group coherently falling into NGC 5128's halo. We refrain from making a strong commentary on this feature, as its significance is still unconstrained as this region of the imaging has undergone the deepest scrutiny compared to the rest of the field. Hence, more faint dwarfs may yet be found throughout the region, lowering the significance of this particular feature.

We use the GALFIT software (Peng *et al.* 2010) to estimate structural and photometric properties for the dwarfs. We model them with Sérsic profiles (Sérsic 1963) using an iterative strategy to mask non-dwarf sources by using model-subtracted residual images to improve the masking until the model parameters converge to stable solutions (e.g. Eigenthaler *et al.* 2018). We convert g'- and r'-band magnitudes to V using the conversion of Jester *et al.* (2005) and, assuming distances concurrent with NGC 5128, find dwarf magnitudes in the range $-11.6 \lesssim M_V \lesssim -7.4$, effective radii $70 \lesssim r_{\rm eff}/{\rm pc} \lesssim 500$, and Sérsic shape parameters $0.14 \lesssim n \lesssim 2.5$; properties that are broadly consistent with dSph's found throughout the LG.

3. Size-luminosity Relation and Centaurus A Group Membership

Fig. 2 shows the $r_{\rm eff}$ vs. M_V relation for the new dwarf candidates (dark purple stars), previously known dwarfs in the Centaurus A/M83 complex (lighter purple stars), as well as other low-mass stellar systems compiled from the literature with symbols and sources as indicated in the figure legends. Where possible M_V is shown, converted from g'- and r'-band photometry where necessary, although we simply show $M_{g'}$ or $M_{r'}$ where only a single band is available. The $r_{\rm eff}$ vs. M_V relation of the new candidates shows a similar

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slope as other nearby dwarfs, though our selection technique is somewhat biased toward higher average surface brightness. The faintest of the new candidates populate a region of Fig. 2 mostly devoid of LG analogues, with the most compact of these having few known comparables in the nearby universe. We thus consider the possibility of them being members of more distant galaxy systems. We show by the open dashed purple stars in Fig. 2 the locations of the new candidates if they were hosted by a background giant galaxy at a distance of 50 Mpc, where the bulk of the sample would be pushed the the high-luminosity threshold of the $r_{\rm eff}$ vs. M_V relation. This value thus represents a reasonable limit for the distance to any potential background hosts. Querying the Cosmicflows-2 catalogue (Tully *et al.* 2013) for galaxies near the SCABS survey region results in three potential hosts, with only two lying within 1° of the survey footprint (blue squares; Fig. 1). Given this, we consider that at a few candidates in the Western region of the survey could be associated with background galaxies, but conclude that the vast majority of the sample are very likely to be true members of the Centaurus A group.

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