> The paper is flawed by references to LCDMHC cosmology in the interpretation. Cold Dark Matter does not exist. Neither does Dark Energy. The dark matter of galaxies is planets.

APPROXIMATELY A THOUSAND ULTRA DIFFUSE GALAXIES IN THE COMA CLUSTER

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ABSTRACT

We report the discovery of 854 ultra diffuse galaxies (UDGs) in the Coma cluster using deep R band images, with partial B, i, and Hα band coverage, obtained with the Subaru telescope. Many of them (332) are Milky Way-sized with very large effective radii of $r_e > 1.5$ kpc. This study was motivated by the recent discovery of 47 UDGs by van Dokkum et al. (2015a); our discovery suggests $> 1,000$ UDGs after accounting for the smaller Subaru field (4.1 degree^2; about 1/2 of Dragonfly). The new Subaru UDGs show a distribution concentrated around the cluster center, strongly suggesting that the great majority are (likely longtime) cluster members. They are a passively evolving population, lying along the red sequence in the color-magnitude diagram with no signature of Hα emission. Star formation was, therefore, quenched in the past. They have exponential light profiles, effective radii $r_e \sim 800$ pc- 5 kpc, effective surface brightnesses $\mu_e(R) = 25\text{-}28$ mag arcsec^{-2}, and stellar masses $\sim 1 \times 10^7 M_\odot$ - $5 \times 10^8 M_\odot$. There is also a population of nucleated UDGs. Some MW-sized UDGs appear closer to the cluster center than previously reported; their survival in the strong tidal field, despite their large sizes, possibly indicates a large dark matter fraction protecting the diffuse stellar component. The indicated baryon fraction $\lesssim 1\%$ is less than the cosmic average, and thus the gas must have been removed (from the possibly massive dark halo). The UDG population is elevated in the Coma cluster compared to the field, indicating that the gas removal mechanism is related primarily to the cluster environment.

Subject headings: galaxies: clusters: individual (Coma) – galaxies: evolution – galaxies: structure

> From HGD cosmology there can be no cold dark matter or massive (CDM) halos. CHG

1. INTRODUCTION

This study is motivated by the discovery of 47 ultra diffuse galaxies (UDGs) in the Coma cluster by van Dokkum et al. (2015a) using the Dragonfly Telescope Array (Abraham & van Dokkum 2014, hereafter Dragonfly). This unexpected discovery revealed a new populatoin of low surface brightness (SB) galaxies. Indeed, their central SBs are very low 24-26 mag arcsec^{-2} in g-band and their median stellar mass is only $\sim 6 \times 10^7 M_\odot$, despite their effective radii $r_e = 1.5\text{-}4.6$ kpc being as large as those of L_* galaxies (e.g., ~ 3.6 kpc for the Milky Way (MW), calculated from Rix & Bovy 2013). van Dokkum et al. (2015a) speculated that the UDGs probably have very high dark matter fractions as they have survived in the strong tidal field of the cluster.

> No CDM!

Dragonfly is optimized to efficiently discover faint structures over a large field of view, but has relatively poor spatial resolution with seeing and pixel scales of $\sim 6''$ and $2.8''$, respectively. The above properties of the Dragonfly UDGs were derived after their discovery from archival Canada France Hawaii Telescope imaging. Follow-up studies are needed to understand their nature and origin, as well as their relationship to the cluster environment (Boselli & Gavazzi 2014, for review) and to other more studied galaxy populations, such as dwarfs

and low SBs, in clusters (e.g., Binggeli & Cameron 1991; Bothun et al. 1991; Ulmer et al. 1996, 2011; Adami et al. 2006b, 2009; Lieder et al. 2012; Ferrarese et al. 2012).

Optical telescopes of larger aperture are advantageous for a resolved study of this population. Yamanoi et al. (2012) used the Subaru Prime Focus Camera (Suprime-Cam; Miyazaki et al. 2002) on the Subaru telescope and derived a galaxy luminosity function down to $M_R \sim -10$ in Coma. Their three $34' \times 27'$ fields include nine Dragonfly UDGs. All of the nine were easily found in their catalog, being resolved spatially in the images. Therefore, Subaru imaging can identify this new galaxy population efficiently and permits an investigation of their internal properties. Several archival Subaru images are available for the Coma cluster (Yagi et al. 2007; Yoshida et al. 2008; Yagi et al. 2010; Okabe et al. 2010, 2014). In this Letter, we use the archival Subaru data and report the discovery of 854 UDGs, implying ~ 1000 UDGs after scaling for the Dragonfly field-of-view.

We adopted $m - M = 35.05$ (Kavelaars et al. 2000) as the distance modulus of the Coma cluster, which corresponds to an angular diameter distance of 97.5 Mpc ($1'' = 0.47$ kpc) [5]. The full catalog of the Subaru UDGs will be published in Yagi et al. (in preparation). We use the AB-magnitude system in this work.

> 2.9x10^24 m.

2. DATA

The raw R band images from the Suprime-Cam were obtained from the Subaru data archive (Baba et al. 2002). Suprime-Cam has a mosaic of ten 2048×4096 CCDs and covers a wide field of $34' \times 27'$ with a pixel scale of $0.202''$. An eighteen-pointing mosaic with Suprime-

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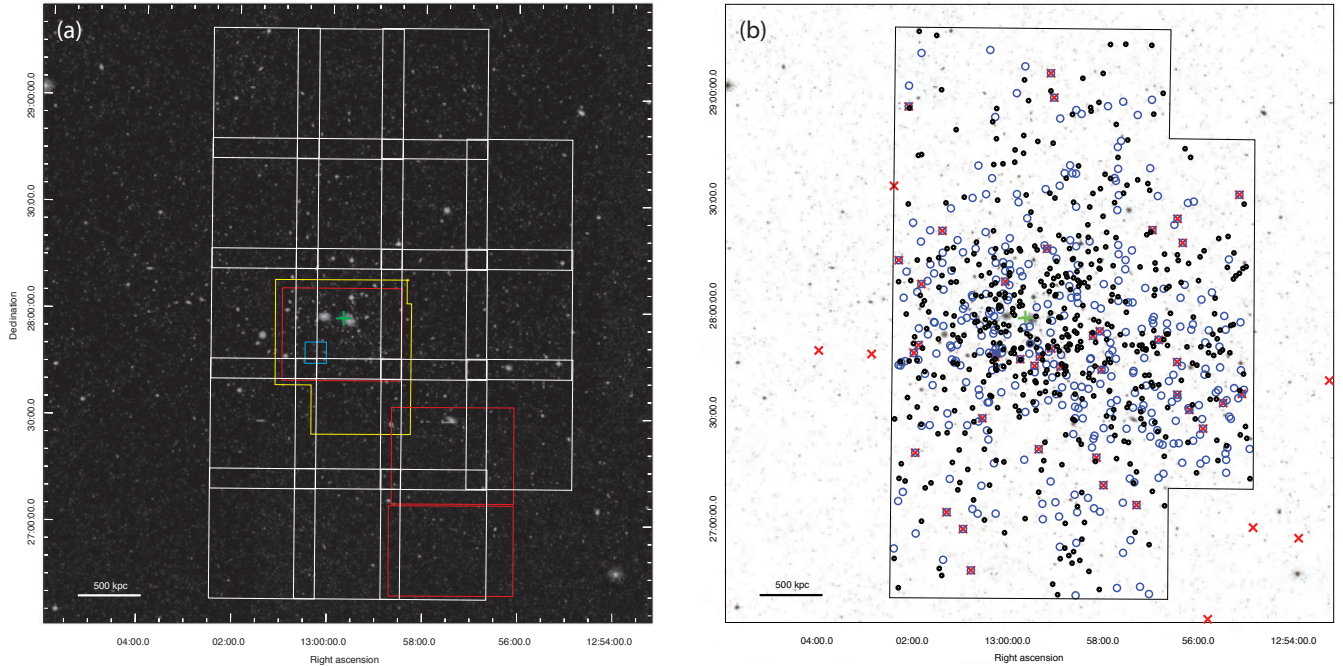[4] SOKENDAI (The Graduate University for Advanced Studies), Mitaka, Tokyo, 181-8588, Japan

[5] We adopted the Cosmological parameters of $(h_0, \Omega_M, \Omega_\lambda) = (0.71, 0.27, 0.73)$ from Larson et al. (2011).

Jin Koda

Fig. 1.— The $2.86\,\mathrm{deg} \times 2.90\,\mathrm{deg}$ ($\sim 4.87 \times 4.94\,\mathrm{Mpc}^2$) area centered on the Coma cluster, the same area as in Figure 1 of van Dokkum et al. (2015a). (a) Image from the Digitized Sky Survey. The white borders show the 18 fields covered in the Subaru R band (Okabe et al. 2014), which have the total area of $4.1\,\mathrm{degree}^2$, about 1/2 of the Dragonfly coverage. Red indicates the area analyzed by Yamanoi et al. (2012). Yellow outlines the area analyzed by Yagi et al. (2010) using the Subaru B, R, Hα, i bands. Cyan indicates the area in Figure 2. The center of the cluster (α_{J2000},δ_{J2000})=(12:59:42.8,+27:58:14) is marked with a green cross (White et al. 1993). (b) The same area as in (a), showing the distribution of the 854 Subaru UDGs (circles). The MW-sized UDGs, with large effective radii ($> 1.5\,\mathrm{kpc}$), are shown in blue. The Subaru field coverage in R is enclosed with the solid line. The 47 Dragonfly UDGs are indicated with red crosses.

Cam was taken by Okabe et al. (2014) and covered about $4.1\,\mathrm{deg}^2$ (Figure 1). The seeing was 0.6-$0.8''$, typically $0.7''$. Integration times for the 18 fields were not the same, resulting in variations in background noise, i.e., 28.3-$28.7\,\mathrm{mag\,arcsec}^{-2}$ (1σ) in a $2''$ aperture (equivalent to 30.0-$30.4\,\mathrm{mag\,arcsec}^{-2}$ in a $10''$ aperture, ~ 1 mag deeper than van Dokkum et al. 2015a). The very central field has a higher variation of $27.8\,\mathrm{mag\,arcsec}^{-2}$ since the field is contaminated by the outer envelope of bright galaxies.

The data were reduced in a standard way (Yagi et al. 2002, 2010). We used self-sky flat images, subtracted sky background locally in each small grid ($256 \times 256\,\mathrm{pixel}^2$; $51.7'' \times 51.7''$), used the WCSTools (Mink 2002) for astrometry, and applied a photometric calibration (Yagi et al. 2013) using the Sloan Digital Sky Survey (SDSS)-III DR9 catalog (Ahn et al. 2012). The grid size for the background subtraction was larger than the expected size of UDGs ($< 30'' \sim 15\,\mathrm{kpc}$). The Galactic extinction in R band varies from 0.016 to 0.031 mag across the 18-field mosaic (Schlafly & Finkbeiner 2011). We adopted the Galactic extinction value at the center of each field and neglected variation within each field. The final photometric error is $\lesssim 0.1$ mag. More details of the data reduction procedure will be presented in Yagi et al. (in preparation). In addition, we used the Suprime-Cam B, i, and Hα reduced images (see Figure 1) by Yagi et al. (2010) and Yamanoi et al. (2012).

We also analyzed a control field for comparison. The R band data of one Suprime-Cam pointing, 1/18 of the Coma field, were taken from the Subaru Deep Field

(SDF) project (Kashikawa et al. 2004). We used only a part of the raw SDF exposures taken in June 2008 to make the background noise comparable to that in the Coma fields. The 1σ background noise in a $2''$ aperture is $28.6\,\mathrm{mag\,arcsec}^{-2}$. For consistency we started from the raw data and matched data reduction parameters.

3. IDENTIFICATION

Our goal is to find UDGs in the Subaru images. Forty of the 47 UDGs discovered by Dragonfly are within the Subaru R band coverage based on their coordinates (van Dokkum et al. 2015a). All were detected significantly (with the faintest one, DF27, off by $12.5''$ from the published coordinate) and their structures were resolved in the Subaru images. The detection threshold was approximately $27.3\,\mathrm{mag\,arcsec}^{-2}$ in the R band. We describe our selection procedure for the final catalog of 854 UDGs in the Coma cluster. We found no counterparts in the control field.

We ran SExtractor (version 2.19.5; Bertin & Arnouts 1996) on individual mosaic frames with a fixed detection threshold of $27.3\,\mathrm{mag\,arcsec}^{-2}$ in R. We removed a first set of spurious detections using SExtractor's "FLAGS < 4" and "PETRO_RADIUS > 0". This initial catalog had 2,627,495 objects, including duplicates in the overlap regions of adjacent mosaic frames (~ 30 %). We used the Dragonfly UDGs as the fiducial set in adjusting parameters for selection of UDG candidates, but could not use exactly the same selection criteria as van Dokkum et al. (2015a) due to the difference in image quality. We applied constraints on R magnitude and size, "18 < MAG_AUTO < 26" and
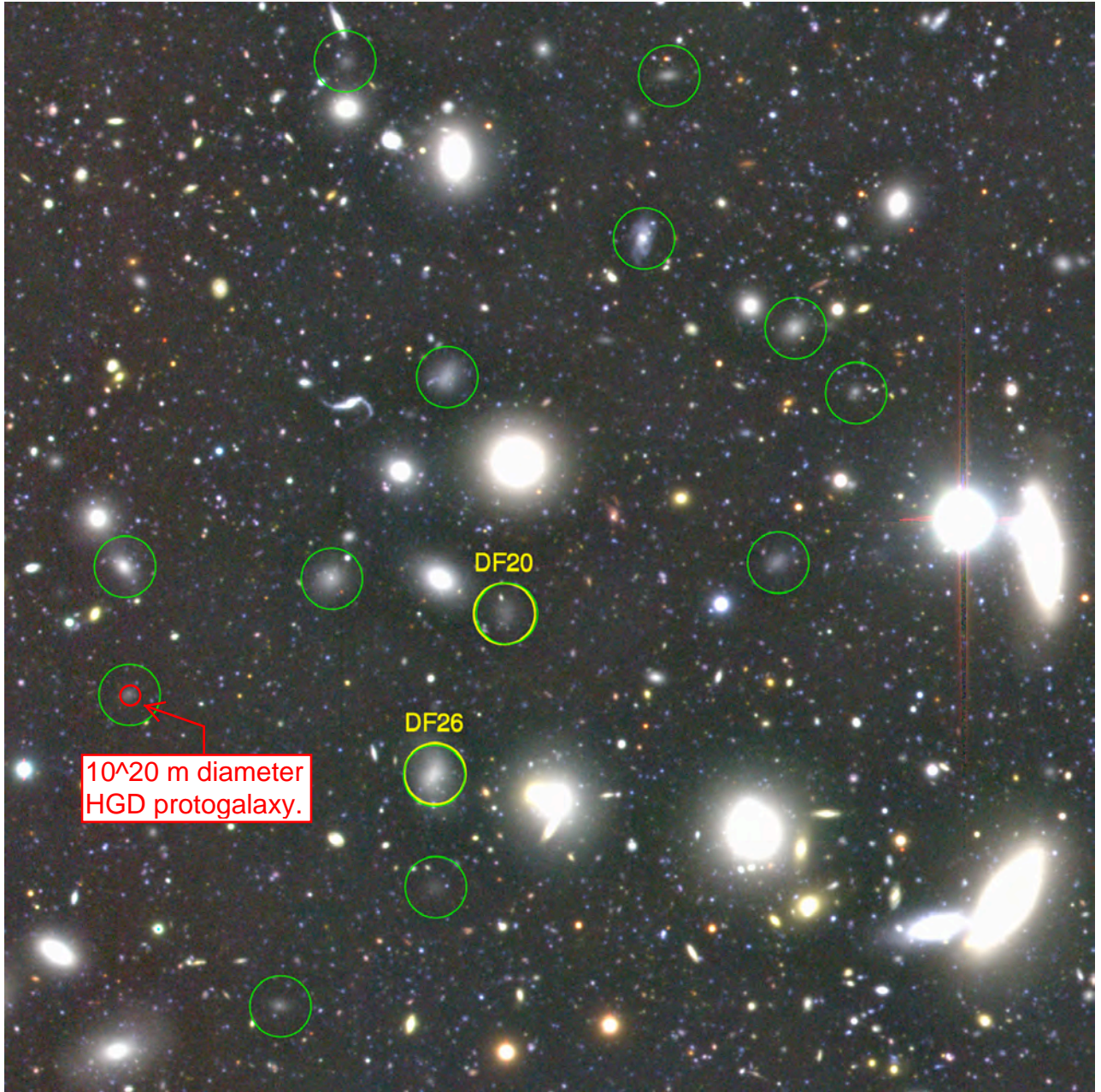
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FIG. 2.— Subaru BRi color image of the $\sim 6' \times 6'$ region ($\sim 170 \times 170 \, \text{kpc}^2$ region at $d = 97.7 \, \text{Mpc}$), shown in cyan in Figure 1a. The Dragonfly and Subaru UDGs are marked respectively with yellow and green circles with a diameter of $20''$ ($\sim 9.5 \, \text{kpc}$).

"FWHM(Gaussian) $> 4''$" (i.e., all Dragonfly UDGs satisfy this condition), which left 7,362 objects.

The reported effective radius of the Dragonfly UDGs is $r_e \gtrsim 3.2''$ (using r_e from GALFIT; Peng et al. 2002). However, in the resolved Subaru images we found that an alternative constraint, SExtractor's $r_e \gtrsim 1.5''$, captures all the Dragonfly UDGs. We therefore used $r_e > 1.5''$ and a mean SB of $\langle\mu(r_e)\rangle > 24$ to choose UDG candidates. [Note that we found that r_e from SExtractor and GAL-FIT were occasionally very inconsistent; we use SExtractor's r_e for identification and GALFIT's r_e for studies of structural properties.] We excluded objects with high central concentrations (mostly high-z galaxies) by removing those whose mean SB within r_e deviates largely from the SB at r_e. This constraint, $\mu_e - \langle\mu(r_e)\rangle < 0.8$, left 1,779 candidates.

The final step was removal of spurious objects by visual inspection. Most spurious detections were due to the crowding in the cluster, such as faint tidal tails and galaxy blending, as well as distant edge-on disk galaxies, artifacts at image edges, and optical ghosts. To minimize human error, the four authors separately went through all postage stamp images. After this step and removal of duplications based on their coordinates, 854 UDG candidates were left on which at least three of us agreed. The full catalog will be published by Yagi et al. (in preparation).

4. ULTRA-DIFFUSE GALAXY CANDIDATES

The 854 UDGs candidates from Subaru are visually comparable to the Dragonfly UDGs. Figure 2 shows a sample $6' \times 6'$ field, showing the Subaru (green circles)

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The population is distinct from HGD cosmology.

and Dragonfly UDGs (yellow). Their low SBs are evident compared to the surrounding galaxies, including major galaxies in the cluster and distant background ones. Their large sizes are also clear when compared to the $20''$ diameter of the circles ($\sim 9.5\,\mathrm{kpc}$ at $d = 97.5\,\mathrm{Mpc}$). The greater number of detections, compared to Dragonfly, may be due to the superior seeing (less blending) and higher signal-to-noise ratio.

The majority of the 854 candidates are most likely UDGs in the Coma cluster. One of them has been spectroscopically confirmed as a cluster member (van Dokkum et al. 2015b). The control SDF field has virtually no counterparts – only thirteen were left after the SExtractor-based selection, twelve of which were obvious image artifacts or tails of bright galaxies. The last one appeared to be a blend of multiple objects. Hence, contamination by non-cluster members is rare and negligible. Note, however, that some negligible number of contaminations might still exist. For example, the third object from the top in Figure 2 may be a background spiral galaxy. Despite this significantly increased sample, the UDGs are still a minor population in the Coma cluster (Yamanoi et al. 2012).

In the literature, we found that many of the Subaru UDGs had been cataloged albeit as more compact objects; Adami et al. (2006a) found 248 of 309 that lay within their coverage, and Yamanoi et al. (2012) 232 of 240. Among them, only 17 were classified as low SB galaxies (Adami et al. 2006b). Their large extents and low SBs were revealed for the first time in this study. We note that eleven out of the 12 Dragonfly UDGs within their field were also cataloged in Adami et al. (2006a), but none were classified as low SB (Adami et al. 2006b).

5. STRUCTURAL PARAMETERS

The GALFIT package was used to measure the structural parameters of the Subaru UDGs. The fits were made with a single Sersic profile (Sersic 1968) with sky background fixed. We used SExtractor's segmentation images to mask surrounding objects. Seventy-nine of the 854 required additional manual masks to exclude a bright compact object(s) within their boundaries – interestingly, sixty-seven of these appear to have compact nuclei at their centers. We judged the fits acceptable based on the goodness-of-fit ($\chi^2_\nu < 1$; 75 objects were thus excluded) and consistency between GALFIT and SExtractor measurements (r_e from GALFIT and SExtractor consistent within a factor of 3; 11 removed). In this section, we use the sample of 768 objects with good GALFIT results, out of which 332 have GALFIT's $r_e > 1.5\,\mathrm{kpc}$ (i.e., MW-sized UDGs as defined in van Dokkum et al. 2015a). We refer to the former full set of galaxies as UDGs, and the latter as MW-sized UDGs. Figure 3 shows some examples of GALFIT results for the UDGs of lowest SB, of largest-size, and with a compact nucleus.

Figure 4(a), (b), and (c) show histograms of Sersic index (n), axis ratio (b/a), and central SB ($\mu_0(\mathrm{R})$). For both UDGs and MW-sized UDGs, their average Sersic indices $\langle n \rangle = 0.9\text{-}1.0$ indicate an exponential profile. The distributions of axis ratio, as well as its average $\langle b/a \rangle = 0.7\text{-}0.8$, are skewed toward a large value; therefore, this UDG sample does not consist of randomly-oriented thin-disk galaxies in a statistical sense (which would skew their distribution toward a low b/a). The

$\mu_0(\mathrm{R})$ ranges around $23\text{-}26\,\mathrm{mag\,arcsec^{-2}}$. These results are consistent with van Dokkum et al. (2015a) when the difference in the adopted bands, SDSS g and Subaru R, is taken into account (roughly $g - R \sim 0.8$ mag for the red-sequence in Coma).

The Subaru UDGs are likely an extension of normal and dwarf galaxy populations and are not, on their own, a distinct population. Figure 4(d) shows the properties of the UDGs (crosses) with respect to normal galaxies in Coma (circles; from Komiyama et al. 2002). The apparent R magnitude of the UDGs is 18 to 24 mag, indicating an absolute magnitude of about -12 to -16 mag at the Coma distance. The smallest and faintest UDGs (e.g., $r_e < 1\,\mathrm{kpc}$ and $M_R < -12$ in Figure 4c) overlap with the largest and brightest dwarf galaxies and share some properties in common with them (e.g., the exponential profile, nucleated population; see Tolstoy et al. 2009; McConnachie 2012; Boselli & Gavazzi 2014). Dotted lines represent constant SBs (μ_es) from 23 to 29 $\mathrm{mag\,arcsec^{-2}}$ with a $1\,\mathrm{mag\,arcsec^{-2}}$ interval, assuming an exponential profile. The average SB of the Subaru UDGs is distributed from about $25\,\mathrm{mag\,arcsec^{-2}}$ (i.e., a cut-off due to the selection) to $28\,\mathrm{mag\,arcsec^{-2}}$ (due to the detection limit; this lower boundary is lower than the pix-to-pix detection limit, because the UDGs are extended).

The absolute magnitudes correspond to stellar masses of $1 \times 10^7 \mathrm{M_\odot}$-$5 \times 10^8 \mathrm{M_\odot}$ if we adopt a mass-to-light ratio of $M/L_R \sim 3$. Note the M/L_R varies by a factor of ~ 2 for ages of 4-12 Gyr and metallicities between 0.2-1.0 solar based on calculations using Starburst99 (Leitherer et al. 1999), a single starburst, and a Kroupa initial mass function.

6. A PASSIVELY-EVOLVING POPULATION

The UDGs are distributed widely over the entire area of the cluster with a concentration toward its center (Figure 1b). This spatial correlation also supports the assumption that the great majority are cluster members. Figure 1 nearly covers the virial radius of the cluster (~ 2.8 Mpc; $\sim 1.7\,\mathrm{deg}$; Kubo et al. 2007), and reveals their relatively symmetric distribution around the center with a potential elongation toward the south west (roughly toward NGC 4839). This symmetric, widespread distribution may indicate their long history within the cluster.

The UDGs closely follow the red-sequence of a passively-evolving galaxy population on the color-magnitude diagram. 232 UDGs are in the catalog of Yamanoi et al. (2012) with both B and R photometry. Figure 5 shows their distribution (green). The comparison data (red and blue) show other cluster member galaxies, as well as background galaxies, and are also from Yamanoi et al. (2012). The red-sequence is evident, and the solid line is a fit by Yamanoi et al. (2012). Clearly, the UDGs lie along this red-sequence, and their B-R colors are around 0.8-1.0 mag. This is similar to the trends found among dwarfs and low SB galaxies in clusters (Adami et al. 2009; Ulmer et al. 2011; Lieder et al. 2012).

No significant Hα excess was found in UDGs. 217 UDGs are within the Subaru Hα coverage (yellow in Figure 1a), which was designed to detect faint Hα emission around Coma member galaxies (Yagi et al. 2010).

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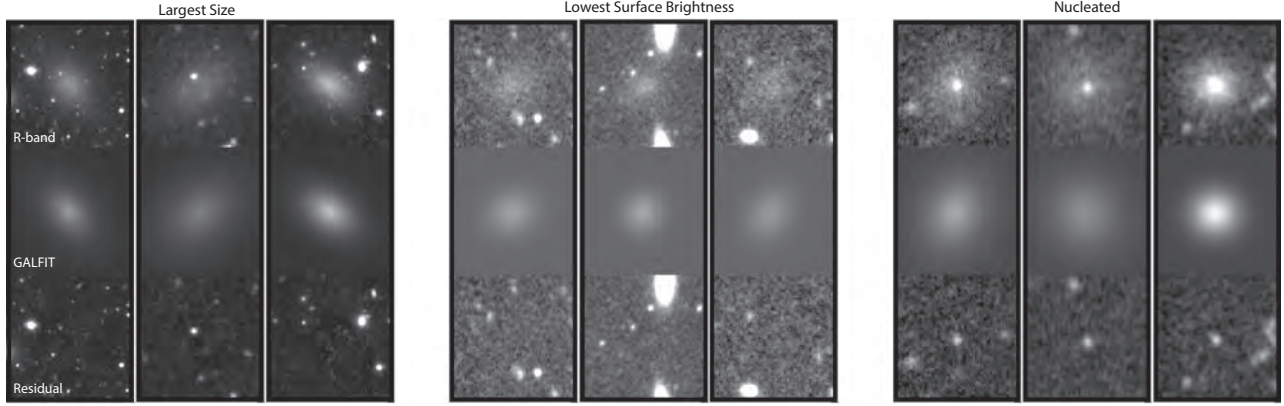
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FIG. 3.— Examples of GALFIT results drawn from the groups of largest-size UDGs, lowest surface-brightness UDGs, and nucleated UDGs.
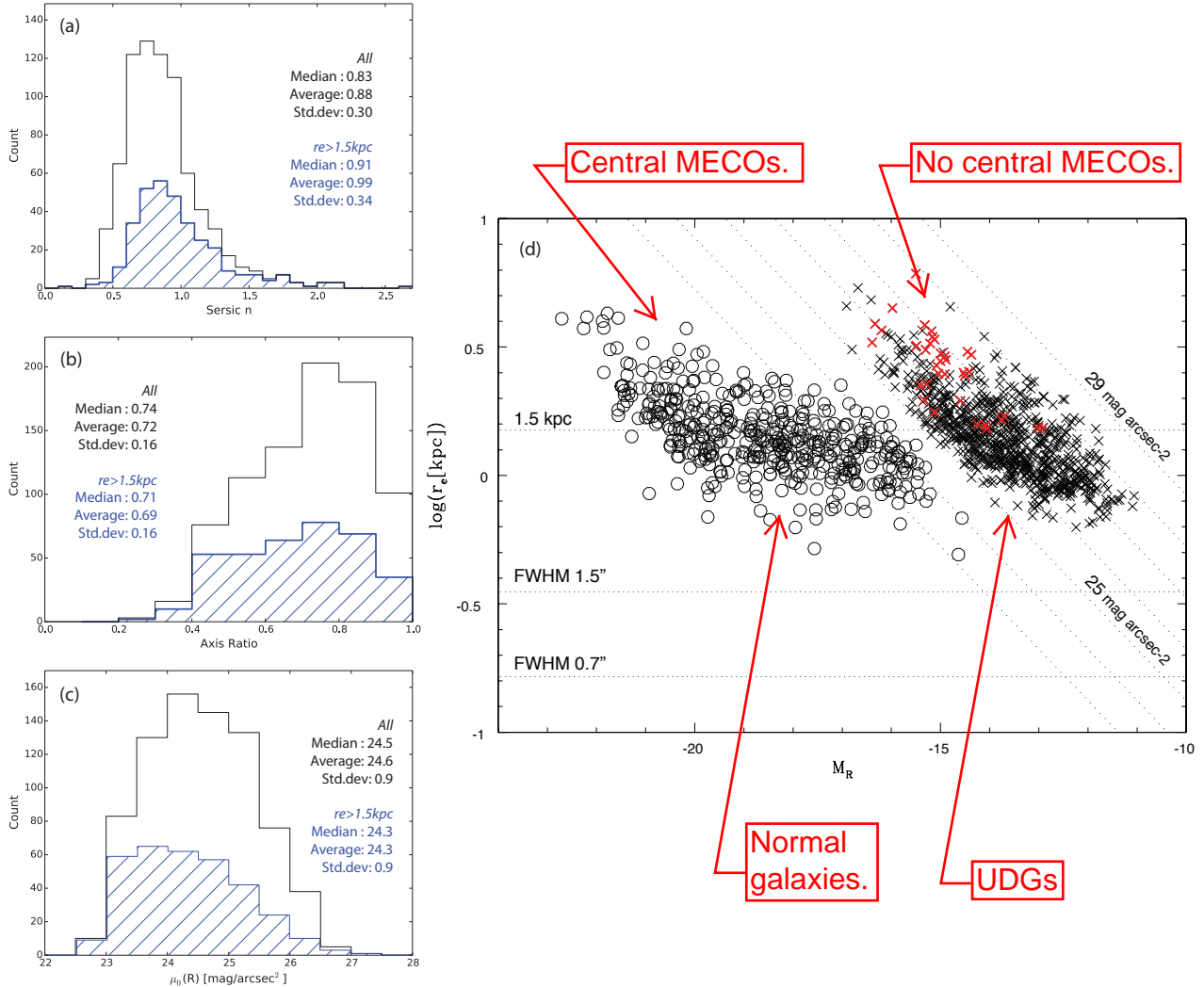

FIG. 4.— Structural properties of UDGs. (a) Histograms of Sersic index n, (b) axis ratio b/a, and (c) central SB $\mu_0(R)$ with their medians, averages, and standard deviations. Black lines are for all 854 UDGs, while blue are for 332 MW-sized UDGs alone. (d) Effective radius vs. R magnitude. The parameters of the UDGs (crosses; red for the Dragonfly UDGs) are derived with GALFIT. Normal galaxies (circles) –spestroscopically-confirmed Coma members (Mobasher et al. 2001) – are also plotted for comparison (from Komiyama et al. 2002, with the conversion R(AB)-R(Vega)=0.21). Dotted, diagonal lines show constant SBs (μ_es) from 23 to 29 mag arcsec^{-2} with a 1 mag arcsec^{-2} interval for the case of an exponential profile (note $\mu_0 = \mu_e - 1.82$ for $n = 1$). The gap between the normal galaxies and UDGs is due to selection effects. Horizontal lines show r_e of PSF with a FWHM of 1.5 arcsec (Komiyama et al. 2002) and a FWHM of 0.7 arcsec (this study).

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The radius of the MW halo is 40x10^20 m. The UDGs appear to be clumped.

Therefore, the UDGs are not forming stars at the current epoch, as expected for passively-evolving galaxies.

7. DISCUSSIONS

We report the discovery of ~ 1000 UDGs in the Coma cluster, about 40% of which are MW-sized. The new UDG sample is by no means complete, but already contains 10-20 times more than previously known (van Dokkum et al. 2015a). None of the UDGs show a signature of tidal distortions; this is our selection criteria, but indicates that this sample of UDGs are not likely recently-disrupted tidal debris.

The UDG population, compared to brighter galaxies, is elevated in the Coma cluster, although a small number of large, low-SB galaxies are known in the field (Dalcanton et al. 1997; Impey et al. 2001; Burkholder et al. 2001). f the UDG-to-brighter galaxy number ratio in Coma were common in the field, the expected UDG population would be implausibly large, $\gtrsim 10^5$ within 100 Mpc of the MW. To obtain this rough estimate, we used, as a reference, galaxies in the SDSS (Ahn et al. 2012) within $16 < r < 17$ mag ($-19 < M_r < -18$ in absolute magnitude) at the cluster's redshift of 0.013-0.033 (Mobasher et al. 2001). The number of reference galaxies in the field was estimated from the luminosity function of Blanton et al. (2001). The estimated number in the field, $\gtrsim 10^5$, is crude, but seems too large compared to the small number discovered so far. The cluster environment must play a role in their formation and evolution.

van Dokkum et al. (2015a) speculated that the MW-sized UDGs might be a dark-matter (DM) dominated population in order for them to survive in the strong tidal field around the cluster core. In fact, the Dragonfly UDGs spatially avoided the central $r \sim 300$ pc region as if the ones there had been tidally disrupted; this apparent disruption was used to constrain the DM fraction (as large as $\gtrsim 98\%$; van Dokkum et al. 2015a). Surprisingly, we found UDGs even closer to the core (Figure 1b), and the closest one is MW-sized only about $3'$ (~ 85 kpc)

No. Nonbaryonic dark matter has diffused away,

away on the sky. Eleven UDGs were found within a radius of $5'$ (~ 141 kpc). These detections were, of course, not complete due to the high background emission there, and their apparent proximity may result from a chance coincidence along a line of sight. If any of them are within ~ 100-150 kpc from the core, an even larger DM mass than the estimate by van Dokkum et al. (2015a) is necessary, and the baryon fraction within a tidal radius should be $\lesssim 1\%$. This is below the cosmic average, and therefore, the baryons must have been removed from the possibly very deep DM potential. ← NO.

The possible removal of the gas, and quenching of star formation (SF), are consistent with their red color and clustering in Coma (indicating their longevity within the cluster). The red-sequence can be produced by a metallicity-sequence if galaxies have been evolving passively since SF was quenched (Kodama & Arimoto 1997). Physical processes often suggested for the quench include (see Boselli & Gavazzi 2014, for review): (a) blow out of gas due to galactic winds from supernovae or AGN activities (Dekel & Silk 1986; Arimoto & Yoshii 1987), (b) ram-pressure stripping (Gunn & Gott 1972), (c) tidal-interaction and harassment (Moore et al. 1996), and (d) starvation due to the cessation of gas infall (Larson et al. 1980). The elevated population in the cluster indicates that environmentally-driven mechanisms, such as (a), (b), and (c) are the most likely solutions [(a) may occur if SF is induced by (b) or (c).].

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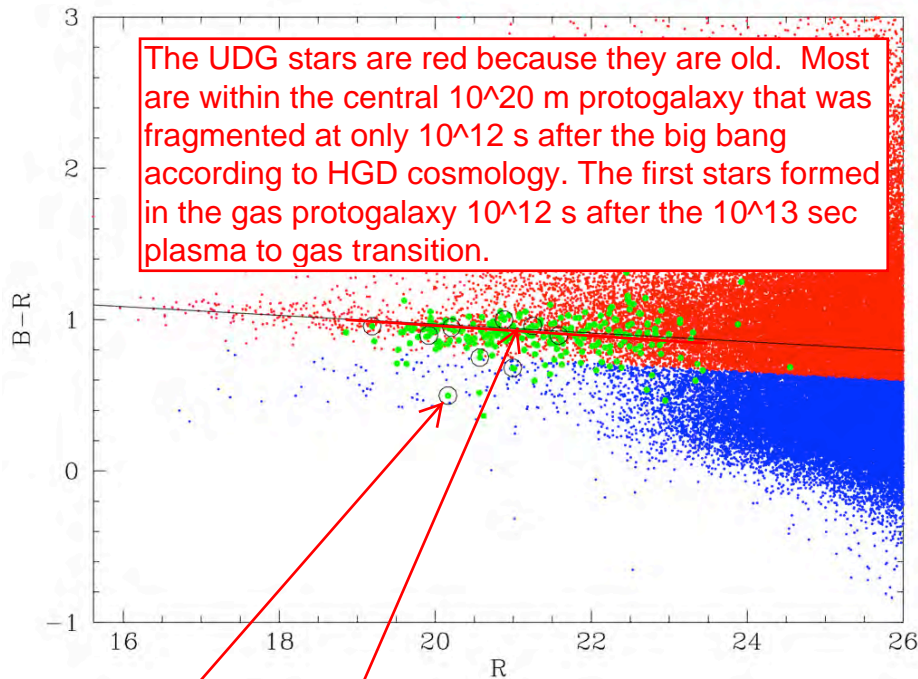Peng, C. Y., Ho, L. C., Impey, C. D., & Rix, H.-W. 2002, AJ, 124, 266

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The UDG stars are red because they are old. Most are within the central 10^20 m protogalaxy that was fragmented at only 10^12 s after the big bang according to HGD cosmology. The first stars formed in the gas protogalaxy 10^12 s after the 10^13 sec plasma to gas transition.

FIG. 5.— Color-magnitude diagram using B and R band photometry. The green points are 232 UDGs observed both in B and R with Subaru (the Dragonfly UDGs are circled), and the red and blue are red and blue galaxies taken from the Coma1 field of Yamanoi et al. (2012) which includes cluster members as well as background galaxies. Due to saturation, most giant galaxies are not included, but the red-sequence is evident. The UDGs clearly follow the red-sequence population of the Coma cluster.

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van Dokkum et al. 2015a has been commented in Journal of Cosmology (2015), Vol. 25, No. 7, and these comments apply to the present Koda et al. (2015) paper. All attempts in both papers to explain their very interesting UDG measurements in terms of LCDMHC cosmology or in terms of nonbaryonic dark matter of any kind should be ignored. NBDM material comprises most of the mass of the universe, but is so weakly collisional that it must diffuse to form such large halo sizes that its contribution to individual galaxy mass is quite small, and can have no affect on the population of UDG galaxies discovered. HGD collisional fluid mechanics is recommended as the best cosmology to apply to both the COMA cluster, which is a supercluster with its thousands of galaxies, as well as the individual low surface brightness UDGs. A particularly interesting result is the evidence presented that near the COMA cluster center, eleven UDGs are clumped together at scales smaller than the size of the Milky Way galaxy's outer halo. The implication is that collisional fluid mechanics may apply to the population of protogalaxies in a supercluster, acting as fluid particles. It seems likely that the UDG galaxies form a unique population, peculiar to superclusters like COMA. As shown in fig. 2, most of the stars of the UDGs are confined to the central protogalaxy of size 10^20 meters (red circle). PGC clumps of dark matter planets will begin to diffuse out of the central core after the temperature falls below the hydrogen triple point 13.8 K to form the outer galaxy halo, but with a lower than average amount of PGC clumping and little tendency to form active galactic nuclei. The population will retain a state of arrested development.