A Population of Massive Ultra Compact Dwarf Galaxies in Intermediate Redshift *CLASH* Clusters

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Ultra Compact Dwarf Galaxies (UCDs)

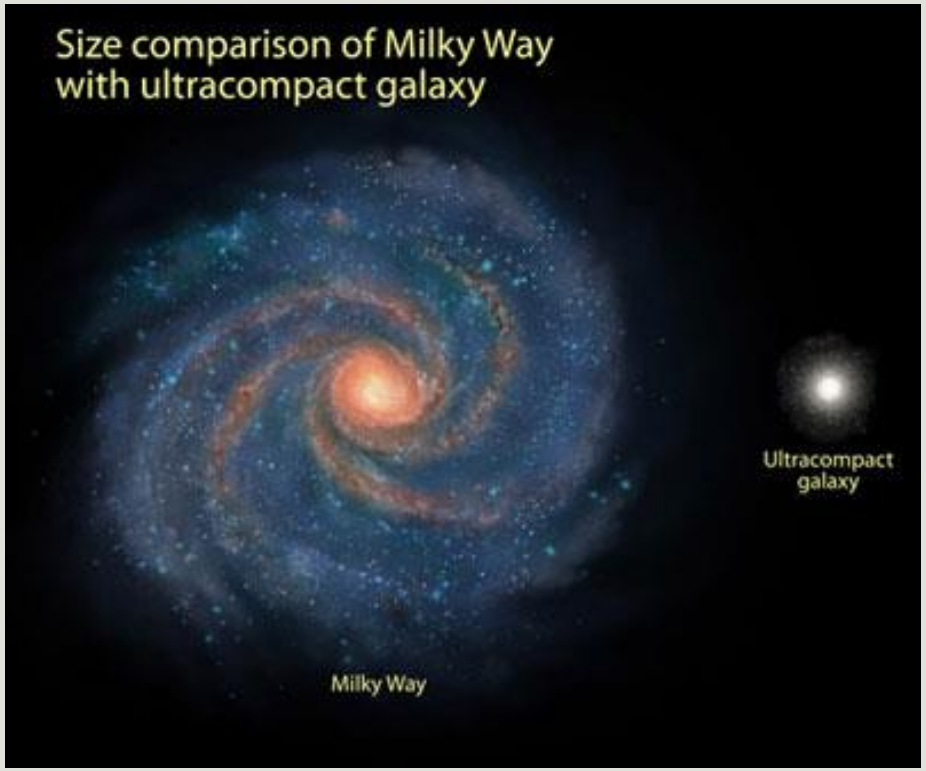
Larger, brighter, and more massive than the biggest Milky Way globular clusters, but more compact than dwarf galaxies of comparable luminosity

At least some have a central black hole

Do not appear to have high dark matter fractions

2 formation theories:

- Stripped nuclei of initially larger galaxies
- Old compact objects that are satellites of a massive dark matter halo



http://www.eso.org/~smieske/ucds.htm

The CLASH Survey

Cluster Lensing and Supernova survey with Hubble

2010 – 2013 census of 25 massive galaxy clusters

Was mostly aimed at studying gravitational lensing but used the Advanced Camera for Surveys and the Wide Field Camera 3 so wide wavelength range with a deep and large field of view

SExtractor

Builds a catalogue of objects from images

“Back in the early nineties, the purpose of SExtractor was to find a compromise between refinement in both detection and measurements, and computational speed. By today’s standards, SExtractor would be more accurately described as a “quick-and-dirty” tool.”

Flexible catalogue output of desired parameters

CLASS_STAR: 0 -1 where zero is galaxy/not star and 1 is star

Data Reduction

17 clusters in redshift range .19 - .6 with Xray temps above 5 keV

Use software to model light profile of bright central galaxies, then subtract out their light

Used on CLASH 30mas F475W, F625W, and F775W images (basically SDSS g, r, and i)

Use F775W in SExtractor to create catalog of sources

To evaluate colors of objects, use F775W images for detections and make measurements from the other two

Use CLASS_STAR >.9 setting to select point-like objects

This returns disk-like objects with half-light radius under .09”. These objects are called “unresolved objects” even though some are still above the resolution limit.

Argument 1: Spatial Distribution

Compare average density profiles of the extended galaxies and nearly unresolved objects in the rest-frame F775W absolute magnitude range of -21 to -16. Both types increase in densities towards the cluster centers

Correct for the density of foreground stars and unresolved background galaxies. Estimate using .3-.5 Mpc annulus. Overall excess of 45.7 unresolved objects within a radius of .3 Mpc.

If no excess over background, would expect only .61+- .05 objects within 25 kpc of all the BCGs, 2.45 +- .2 within 50 kpc.

Observed values are 9 and 13

Probability of observing 9 or more within 25 kpc is 2 x10^-8 (Poisson) (5 sigma Gaussian)

13 or more within 50 kpc is 2x10^-6 (Poisson) (4.5 sigma Gaussian)

Argument 2: Color Distribution

Compared the observed colors of the extended objects, unresolved objects, and unresolved objects within 50 kpc of the cluster centers

The objects within 50 kpc of the cluster centers have similar color distribution as the extended galaxies (predominantly at the cluster redshift)

Vast majority of unresolved objects within 50 kpc are likely at the redshift of the cluster

Unresolved objects across the field have a wider range of observed colors, consistent with argument that many are foreground stars or background sources

Argument 2: continued

Computed k- corrections for each cluster field, assuming all objects are located at the cluster redshifts to obtain rest frame colors and magnitudes

The color magnitude distribution of the extended galaxies is a clear red sequence, unresolved objects close to center are consistent with bright end of red sequence, and the broader group has a wider color distribution with a peak at red

Consistent with unresolved sources in center being at redshift of cluster and the broader group containing foreground and background sources.

80% or more of unresolved objects within 50 kpc are expected to be cluster galaxies.

They further restrict their selection through a rest frame color cut of $.5 < F475W - F625W < 1.5$

Fig 1

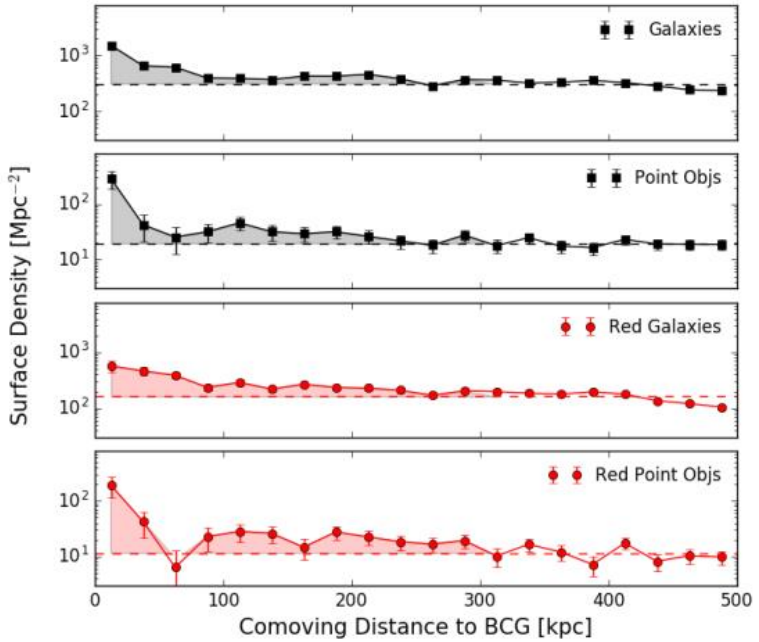


FIG. 1.— Average surface density profiles of extended galaxies (*CLASS_STAR* < 0.1; top panel, black), unresolved objects (*CLASS_STAR* > 0.9; second panel, black), color-selected extended galaxies (*CLASS_STAR* < 0.1; 3rd panel, red) and color-selected unresolved objects (*CLASS_STAR* > 0.9; bottom panel, red). Only Poisson uncertainties are accounted for in this figure. Note that the background densities (shown as dashed lines) are not subtracted.

Mass and Size Estimates of the UCDs

All of these objects are below three pixels: in the size range of globular clusters, dwarf galaxies, and compact galaxies

F775w band magnitudes of 22 to 25 mag in redshift range of .2- .6

Using the stellar population synthesis model with a stellar initial mass function, adopt a formation redshift of 3.0 and an decaying formation history of tau = .1 Gyrs and Z=.008

Stellar masses are higher than 10^8 Msun -> very high stellar density -> consistent with being ultra compact dwarf galaxies

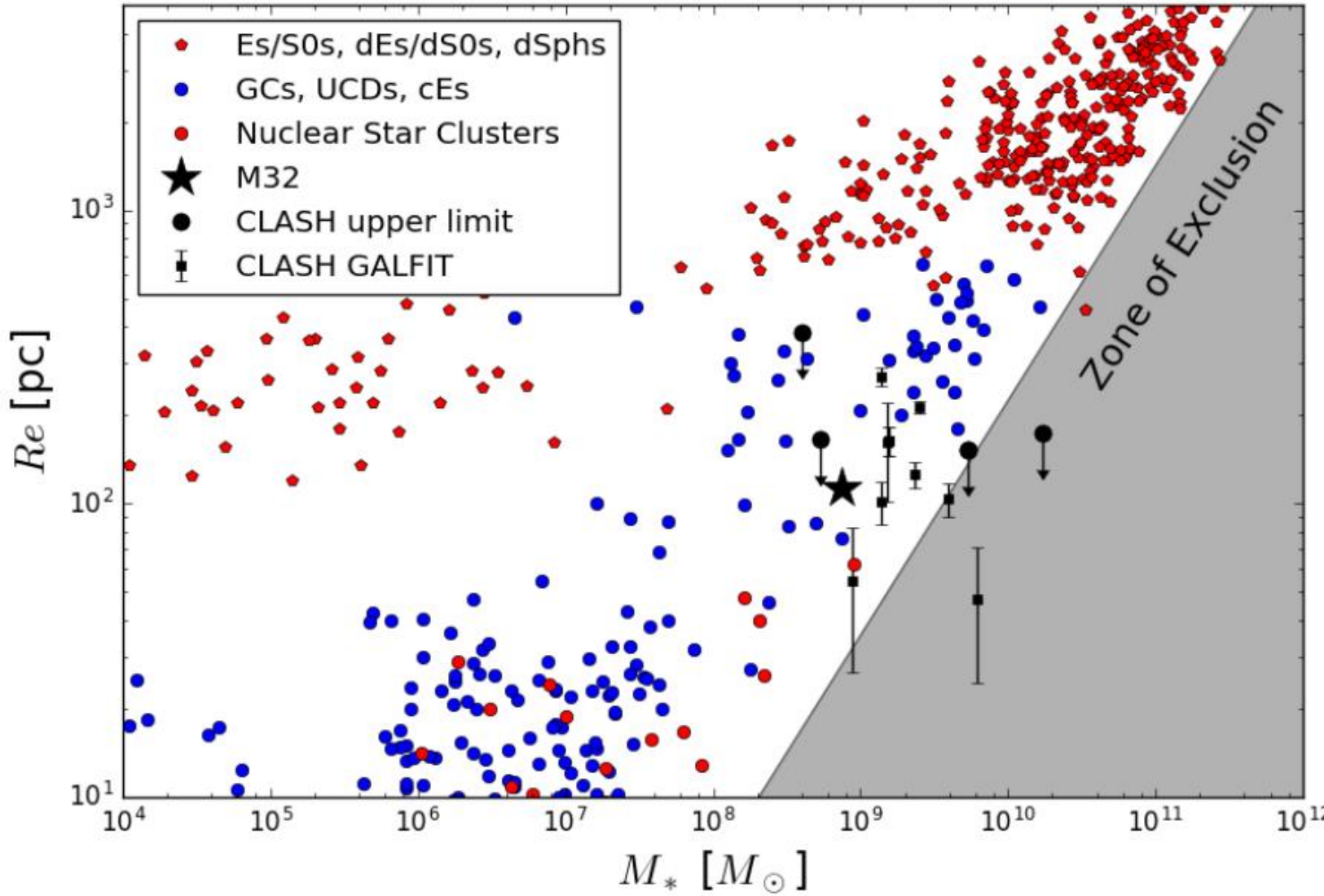


FIG. 4.— The mass and size distribution of the UCD candidates reported in this paper. For the UCD half light radii, we plot either the Galfit values or the *Class_star* upper limits, whichever is lower. In this figure, we also over-plot the compiled list of nuclei, GCs, UCDs, CEs and dwarf galaxies in Norris et al. (2014). The UCD satellite of the Andromenda galaxy, M32, is marked with a filled star. The UCD population reported in this paper appear analogous to M32.

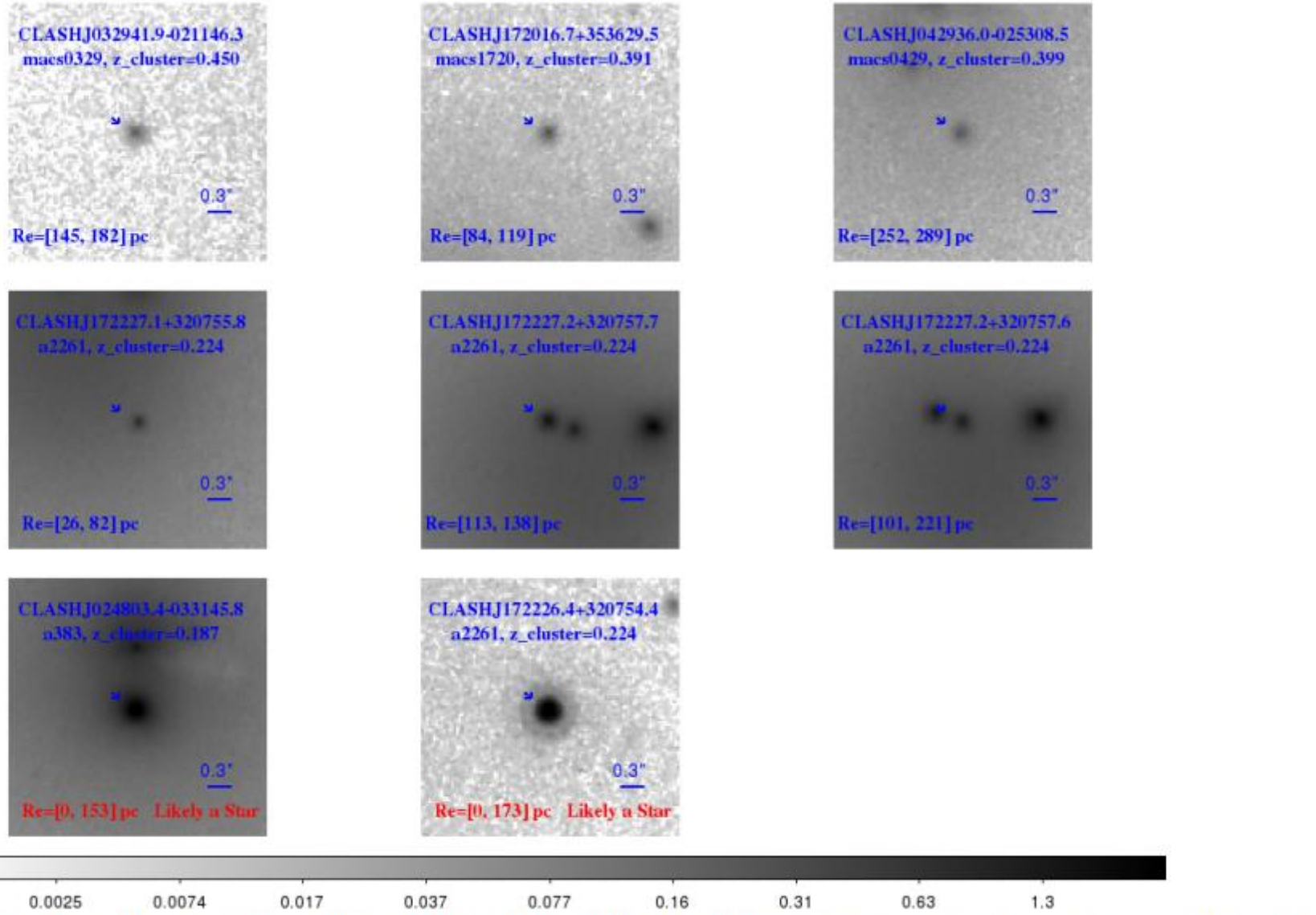


FIG. 3.— Images, designation and host information of 8 UCD candidates in the *CLASH* clusters. In the bottom panels, we also show two candidates that are likely to be foreground star contamination. Comparison with the density of foreground and background unresolved sources suggests that $\sim$ 80% of the sample within 50kpc are expected to be real UCDs.

Conclusion

Spectroscopic follow up could be helpful

Some of the densest UCDs to date

45.7 UCD-like objects within .3 Mpc for all 17 CLASH clusters

Given mass range, sample is consistent with being stripped nuclei of cluster galaxies

Alternatively, they could be early formed compact objects trapped within the cluster

Larger samples would likely reveal the origin

If stripping there should be a higher concentration of UCDs/CEs compared to cluster galaxies (a factor of 2 difference was found in this survey)

Link to Paper

https://arxiv.org/pdf/1610.06174.pdf