Discovery of About 1000 Ultra Diffuse Galaxies in the Coma Cluster: Opening the Low Surface Brightness Universe with Archival Data

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Forty-seven low surface brightness (LSB) galaxies were recently discovered in the direction of the Coma cluster [1]. If they really reside in the cluster, these galaxies, namely ultra-diffuse galaxies (UDGs), have only ~1/1000 of the Milky Way (MW)'s stellar mass ($\sim 10^{7-8}\,M_\odot$), but being as large as the MW in size with the effective radius of $r_e \gtrsim 1.5$ kpc. Such diffuse and puffy stellar structures are subject to tidal disruption in the cluster's gravitational potential [1,2]. If they are long-lived, these stellar systems must be protected by a large amount of dark matter halo, suggesting them to be potential "dark galaxies". Therefore, UDGs in clusters provide an important clue to studies of galaxy formation and evolution, galactic dark matter, and galaxy clusters.

We analyzed archival data from the Subaru Prime Focus Camera (Suprime-Cam) and discovered 854 UDGs in the Coma cluster, ~ 20 times more than previously reported [3]. Many of them (332) are Milky Way-sized with very large effective radii of r_e >1.5 kpc. About 2/3 of the Coma cluster field (4.1 degree^2) was observed by Suprime-Cam in the past, having deep *R* band images with partial *B*, *i*, and Hα band coverage.

This significant leap in sample size enhanced our knowledge of this important galaxy population. Our discovery suggests about 1,000 UDGs in the Coma cluster after accounting for the whole cluster size compared to the smaller Subaru field. The Subaru UDGs show a distribution concentrated clearly 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 $\mu_e(R) = 25$–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 and longevities, indicates a large dark matter fraction protecting the diffuse stellar component. The indicated baryon fraction < 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.

Beyond the importance of UDGs, this study clearly demonstrated the treasury value of archival data, and unveiled the new discovery space of the low surface brightness universe using the Subaru telescope and its large format cameras.

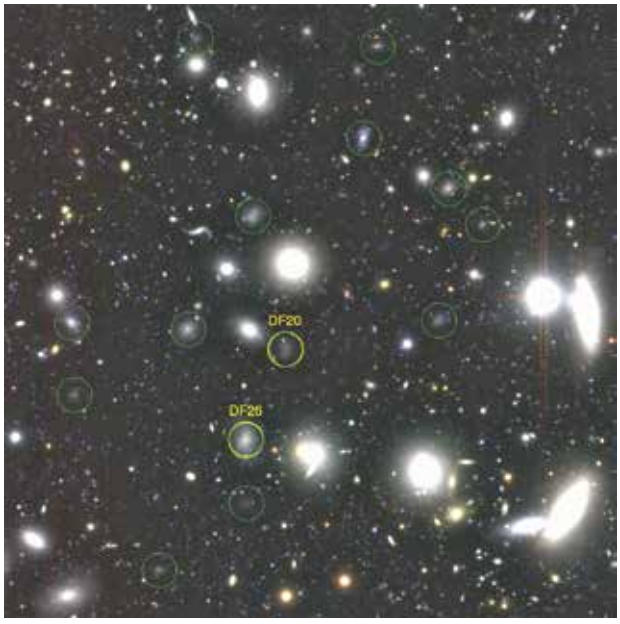

Figure 1: Subaru *BRi* color image of the ~6′ × 6′ region (~ 170 × 170 kpc^2 region at d = 97.7 Mpc) out of the 4.1 degree^2 Subaru coverage. The van Dokkum's Dragonfly UDGs and Subaru UDGs are marked respectively with yellow and green circles with a diameter of 20″ (~ 9.5 kpc).

References

[1] van Dokkum, P. G., Abraham, R., Merritt, A., et al.: 2015, *ApJ*, **798**, L45.
[2] Penny, S. J., Conselice, C. J., de Rijcke, S., Held, E. V.: 2009, *MNRAS*, **393**, 1054.
[3] Koda, J., Yagi, M., Yamanoi, H., Komiyama, Y.: 2015, *ApJ*, **807**, L2.