UCDs as Probes of the Merger Histories of Galaxies

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Abstract

Ultra Compact Dwarfs (UCDs) are a class of stellar system with properties intermediate between those of globular clusters (GCs) and dwarf galaxies. By focussing on the non-cluster environments where young UCDs may be most common we have discovered the first UCD that is clearly the result of the recent (<3 Gyr ago) stripping of a gas-rich dwarf galaxy. However we also find a clear case of a multiple-UCD system created via star cluster formation processes. We demonstrate that it is possible to reliably distinguish the two, thereby providing a probe of both the major and minor merger histories of individual galaxies. We go on to present a formation scenario that unifies the evolution of GCs, UCDs and dwarf nuclei.

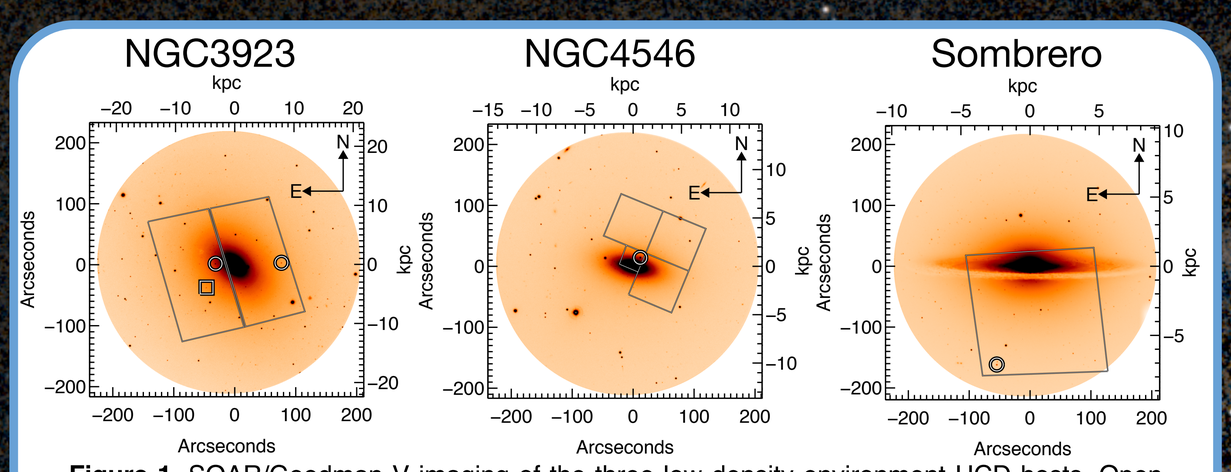

Figure 1. SOAR/Goodman V imaging of the three low density environment UCD hosts. Open circles/box indicate locations of confirmed/unconfirmed UCDs. Lines indicate HST imaging.

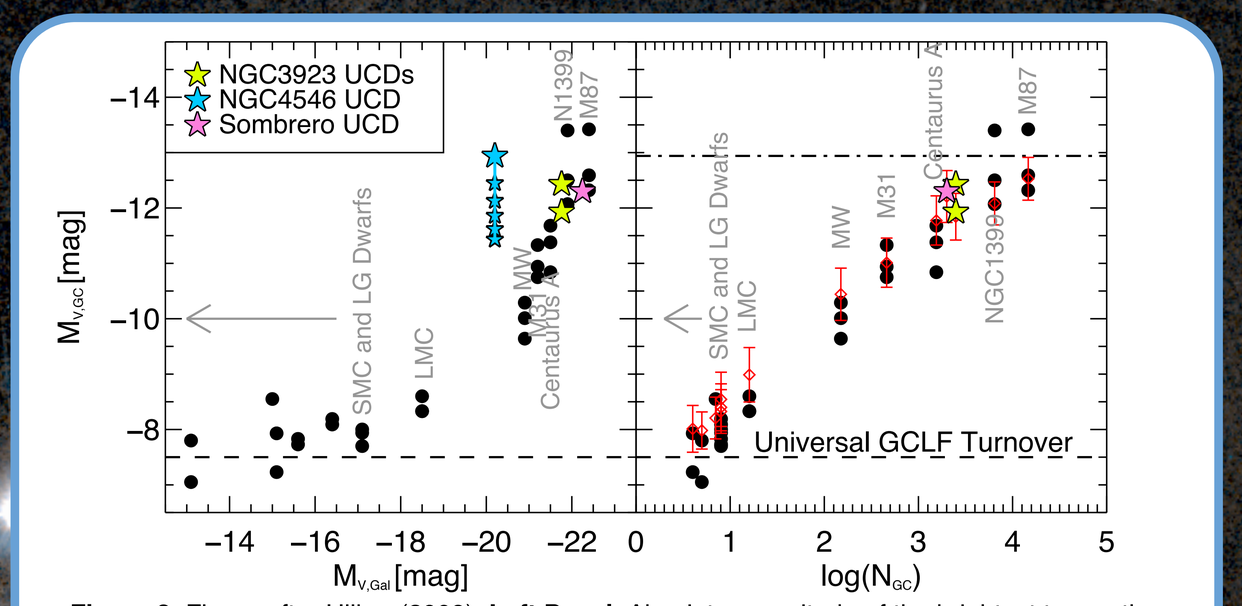

Figure 3. Figure after Hilker (2009). **Left Panel:** Absolute magnitude of the brightest two or three GCs/UCDs of a galaxy as a function of host galaxy total luminosity. **Right Panel:** Absolute magnitude of the brightest two or three GCs/UCDs of a galaxy as a function of the total number of GCs present in the GC system of the host galaxy. Red diamonds with error bars are the result of a model in which UCDs are merely the high luminosity end of the GCLF of a galaxy.

Results

Intrigued by the possible ubiquity of UCDs, we searched for evidence of a significant population of UCDs associated with low density environment galaxies. We visually examined archival HST WFPC2/ACS imaging of 76 galaxies visible from the southern hemisphere during spring, discovering 11 UCD candidates associated with 9 individual galaxies. In this work we focus on three systems with spectroscopically confirmed UCDs (see Fig. 1): NGC3923 (2 newly confirmed + 1 probable), NGC4546 (1 newly confirmed), and the Sombrero (1 UCD previously discovered by Hau et al. 2009). Using new SOAR spectroscopy, archival SAURON spectroscopy, and HST imaging we find evidence for two distinct UCD formation channels. One is associated with GC formation, forming giant GCs (GGCs) that follow a mass-size relation unlike "normal" GCs. The second is due to the stripping of dwarf galaxy nuclei by larger galaxies, yielding a similar mass-size relation.

Evidence that the UCDs of NGC3923 are GGCs:

- There are multiple UCDs (at least 2) associated with NGC3923.
- The UCDs smoothly extend the colour-magnitude relation of the blue GCs (Fig. 4)
- All three possible UCDs have long dynamical friction decay timescales (> 7 Gyr).
- All three candidate UCDs are consistent with the bright extension of the GC luminosity function (GCLF, see Fig. 3).

Evidence that the Sombrero UCD is a GGC:

- Its stellar population (Age ~12.6 Gyr, [Fe/H] = -0.08, [σ/Fe] = 0.06 is entirely consistent with those of the GC system of the Sombrero (Larsen et al. 2002).
- It has a long dynamical friction decay timescale (>Hubble time).
- Statistically it can be explained as an extension of the GCLF (see Fig. 3).

Evidence that the NGC4546 UCD is a stripped nucleus:

- It is young (~3 Gyr old). NGC4546 has a uniformly old (~12 Gyr) stellar population.
- It does not seem to be associated with an equivalently young GC population.
- It has a short dynamical friction decay timescale (~0.5 Gyr).
- It is not explainable as the bright extension of the GCLF of NGC4546 (see Fig. 3.)
- The UCD and gas of NGC4546 counterrotate relative to the disk (see Fig. 2.)

Figure 2. Kinematics of NGC4546 and its UCD. The UCD and the gas of NGC4546 counterrotate relative to the stars of NGC4546, indicative of an accretion event.

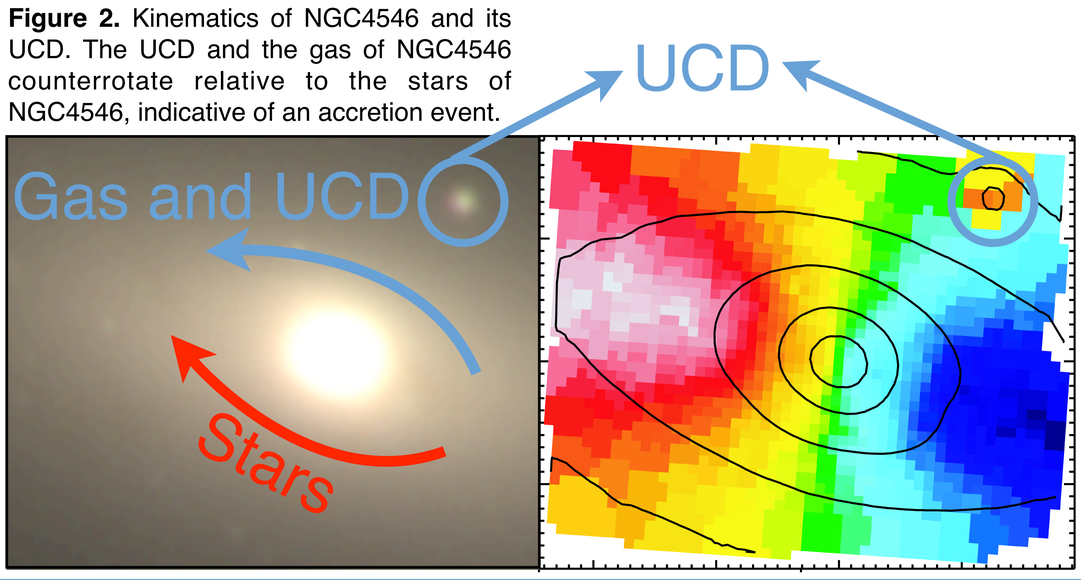

Figure 4 demonstrates a possible description of the formation of GCs, UCDs, and dwarf nuclei. Both GGC-UCDs and stripped-nucleus UCDs as well as intact dwarf galaxy nuclei smoothly extend the "blue tilt" of blue GC populations, perhaps a sign of a common self enrichment process. The locus of intact dwarf nuclei (blue squares) seems to indicate that what are traditionally classed as "normal" blue GCs likely include a few fainter accreted dwarf nuclei (lower mass counterparts to stripped-nucleus UCDs) as well as normal GCs formed in situ and GCs formerly bound to dwarf galaxies. The red branch of the CM diagram is a combination of normal GCs formed in situ, the GGCs which formed alongside them, and massive metal-enriched UCDs most likely stripped from large dwarfs or giant galaxies. Above a certain luminosity (around M_I = -14) it becomes highly implausible to explain a UCD as an extension of the GCLF. Therefore, above this limit we infer that essentially all UCDs are stripped nuclei, and may form a continuum with larger stripped objects and/or elliptical galaxies, as also evidenced by their similar mass-radius relations (Hasegan et al. 2005).

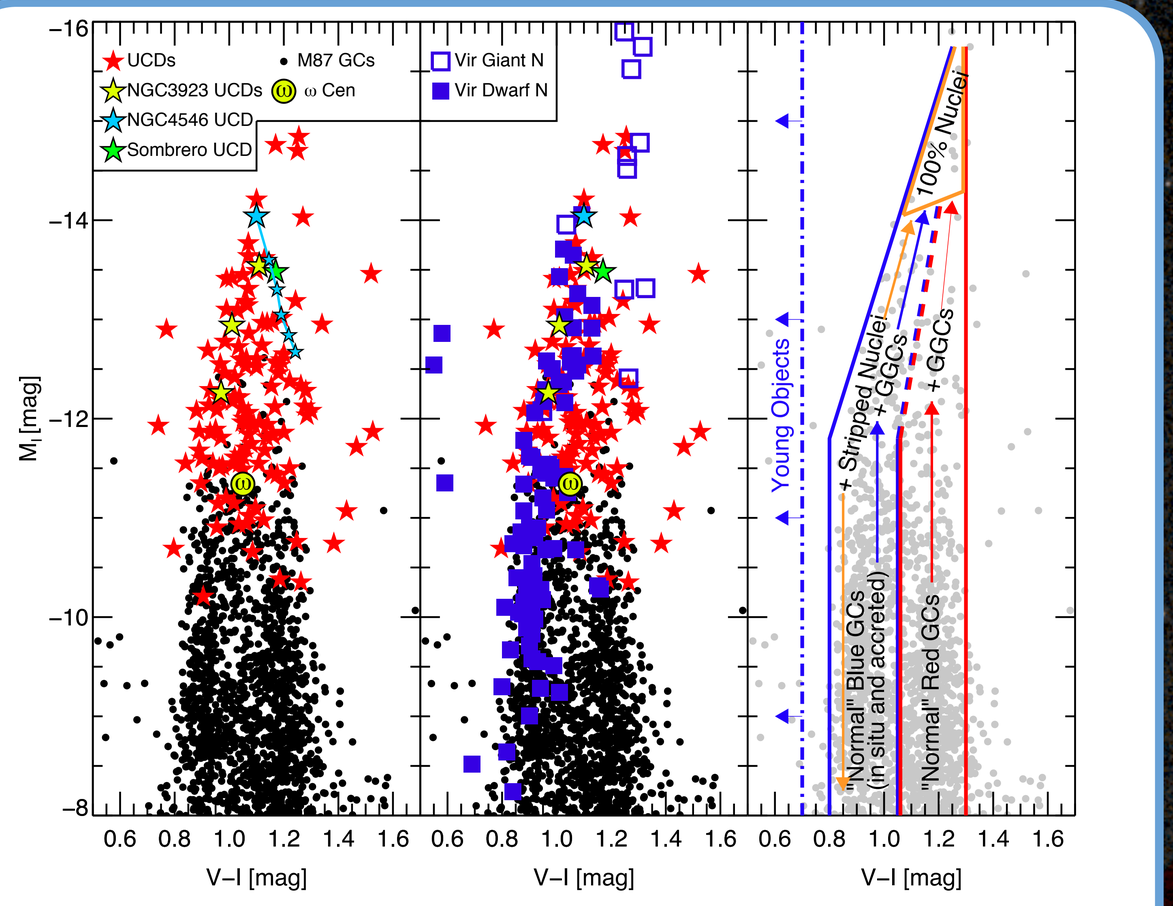

Figure 4. Left and Center Panels: M87 GCs (Peng et al. 09), literature UCDs and Virgo and Fornax dwarf nuclei. **Right Panel:** A possible scheme describing the origin of GCs and UCDs.

Conclusions

- In a search for UCDs in low density environments we have found unambiguous evidence of two UCD formation channels: stripped-nucleus and giant GC (GGC).
- We have found the first clear example of a young UCD formed by the stripping of a dwarf galaxy (complementing the young GGC described by Maraston et al. 04).
- The 3 UCDs of NGC3923 are GGCs, with properties matching the GC system.
- Blue GCs, blue UCDs and dwarf galaxy nuclei display the same CM locus including the blue tilt, allowing for overlapping formation scenarios at all masses.
- Red stripped-nucleus UCDs emerge at high masses, distinct from red GCs.

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SOAR TELESCOPE

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