

The origin of ultra-compact dwarf galaxies in the Virgo cluster

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Abstract. We present the internal velocity dispersions and spectral line indices for six Virgo ultra-compact dwarf (UCD) galaxies obtained from spectroscopy with the Keck II 10-m telescope. We use these results: 1) to compare the Virgo UCDs with the Fornax UCD population; 2) to compare UCDs with globular clusters (GCs) to determine if UCDs and the most luminous GCs are the same or distinct systems; 3) to further test the nucleated dwarf elliptical (dE,N) stripping hypothesis for UCD formation.

Keywords. galaxies: dwarf, galaxies: kinematics and dynamics, galaxies: abundances, galaxies: clusters: individual (Virgo Cluster)

1. Introduction

UCDs are a new type of galaxy recently discovered in the center of the Fornax, Virgo, and other clusters of galaxies (Hilker *et al.* 1999; Drinkwater *et al.* 2003,2004; Jones *et al.* 2005). Possible origins of UCDs include the following hypotheses: 1) they are luminous intra-cluster globular clusters; 2) they are extremely luminous star clusters formed from the amalgamation of stellar super-clusters that were created in galaxy interactions; 3) they are the remnant nuclei of stripped dwarf galaxies which have lost their outer parts in the course of tidal interaction with the galaxy cluster potential; 4) they are highly compact galaxies formed in the early Universe.

Here we present new results of the spectroscopic analysis from the Keck II telescope for six Virgo UCDs (Table 1) to explore and test hypotheses of their formation.

2. Internal Dynamics

Figure 1 compares UCDs to other types of stellar systems, on the luminosity - velocity dispersion plane. The internal velocity dispersions for the UCDs (and GCs) were measured from CaT region (8400–8750Å) using the direct-fitting method (van der Marel 1994). We include the most massive and luminous known GCs: G1, ω Cen, and NGC5128 GCs as well as GCs in the Milky Way and M31, dE,Ns and their nuclei, and giant ellipticals. We find: 1) The Virgo UCDs have the same dynamical properties as the Fornax ones (Drinkwater *et al.* 2003). 2) There is no gap between luminous GCs and UCDs in this plot. We obtained velocity dispersions for the two brightest M87 GCs from Hanes *et al.* (2001) list: they lie in the same part of $M_V - \sigma$ plane as UCDs. 3) The UCDs follow approximately the same relation between luminosity and velocity dispersion as GCs, except for the two brightest ones. More data on the velocity dispersions for bright GCs or fainter UCDs are required to confirm this. 4) There is an overlap in luminosities and

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Table 1. Targets. M_V – the V band absolute magnitude. Strom547 and Strom417 are the two brightest globular clusters in M87 (the central galaxy in Virgo) according to Hanes *et al.* (2001) list. Strom547 has luminosity comparable to that of UCDs and was therefore included into UCD list.

Name	Object type	R.A.(J2000)	Dec.(J2000)	M_V
UCD1/Strom547	UCD/GC	12h30m57.40s	+12°25′44.8″	-12.3
UCD2	UCD	12h30m07.61s	+12°36′31.1″	-12.2
UCD3	UCD	12h31m04.51s	+11°56′36.8″	-12.1
UCD4	UCD	12h31m28.41s	+12°25′03.3″	-12.0
UCD5	UCD	12h31m52.93s	+12°15′59.5″	-13.9
UCD6	UCD	12h31m11.90s	+12°41′01.2″	-12.1
Strom417	GC	12h31m01.29s	+12°19′25.6″	-11.6

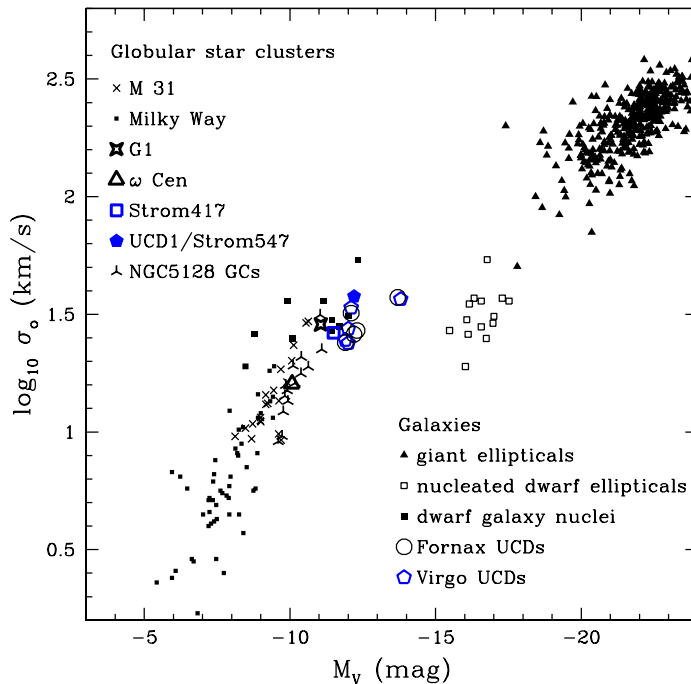


Figure 1. Comparison of the internal dynamics of UCDs (our data) with globular clusters and nucleated dwarf ellipticals (literature data).

velocity dispersions of the nuclei of dE,Ns and the properties of bright GCs and UCDs . It supports the dE,N tidal stripping hypothesis for UCD and GC formation.

3. Ages and Chemical Compositions

We estimate ages, metallicities, and abundances of UCDs using Lick/IDS indices (Worthey *et al.* 1994) and single-aged stellar population models of Thomas *et al.* (2003).

In *Figure 2a* we plot abundance ratios of the Virgo UCDs. To estimate $[\alpha/\text{Fe}]$, we plot Mg b (an indicator of α -elements) versus $\langle \text{Fe} \rangle$ (an average of the indices Fe5270 and Fe5335). $[\alpha/\text{Fe}]$ traces the timescale of star formation activity in galaxies. Most α -elements are produced rapidly by Type II supernovae, while Fe is produced by Type Ia

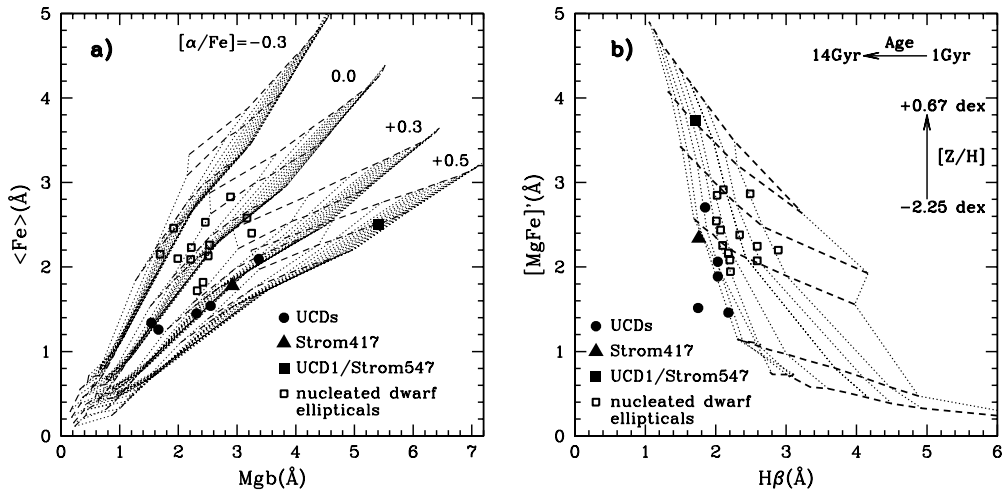


Figure 2. Comparison of our data with model grids from Thomas *et al.* (2003). **a)** $Mgb - \langle Fe \rangle$. Thomas *et al.* models with variable $[\alpha/Fe]$ are shown for ages 1, 2, 3, ..., 15 Gyr (dotted lines, from left to right) and metallicities $-2.25, -1.35, -0.33, 0.0, +0.35, +0.67$ dex (dashed lines, from bottom to top). **b)** $H\beta - [MgFe]'$. Thomas *et al.* models are shown for ages 1, 2, 3, 4, 6, 8, 10, 12, 14 Gyr (dotted lines, from right to left) and metallicities $-2.25, -1.35, -0.33, 0.0, +0.35, +0.67$ dex (dashed lines, from bottom to top).

SNe on longer timescales. We find: 1) Four UCDs and Strom417 (GC) have super-solar abundance ratio, $[\alpha/Fe] \sim +0.3 - +0.5$, and two UCDs appear to have solar abundances, $[\alpha/Fe] \sim 0.0$. The super-solar abundances are typical for old stellar populations (in globular clusters and elliptical galaxies). 2) Virgo dE,Ns (Geha *et al.* 2003) are also shown in the same plot. The majority of dE,Ns are consistent with solar abundance ratios, while the majority of UCDs have super-solar abundances. This can be the evidence that UCDs and dE,Ns have different star formation histories.

Figure 2b shows ages and metallicities of the Virgo UCDs. We plot the age-sensitive $H\beta$ index versus the metallicity sensitive $[MgFe]'$ index (Thomas *et al.* 2003). We find: 1) The UCDs are old and metal-poor, except UCD1 which appears to be intermediate-aged and metal-rich. 2) The ages and metallicities of UCDs (except UCD1) are similar to Strom417 (GC) and to those found for M87 globular clusters by Cohen *et al.* (1998). 3) The UCDs have older integrated stellar populations than present-day dE,Ns. It is consistent with the stripping formation scenario, when the ISM is removed from the UCD progenitor and star formation activity ceases.

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