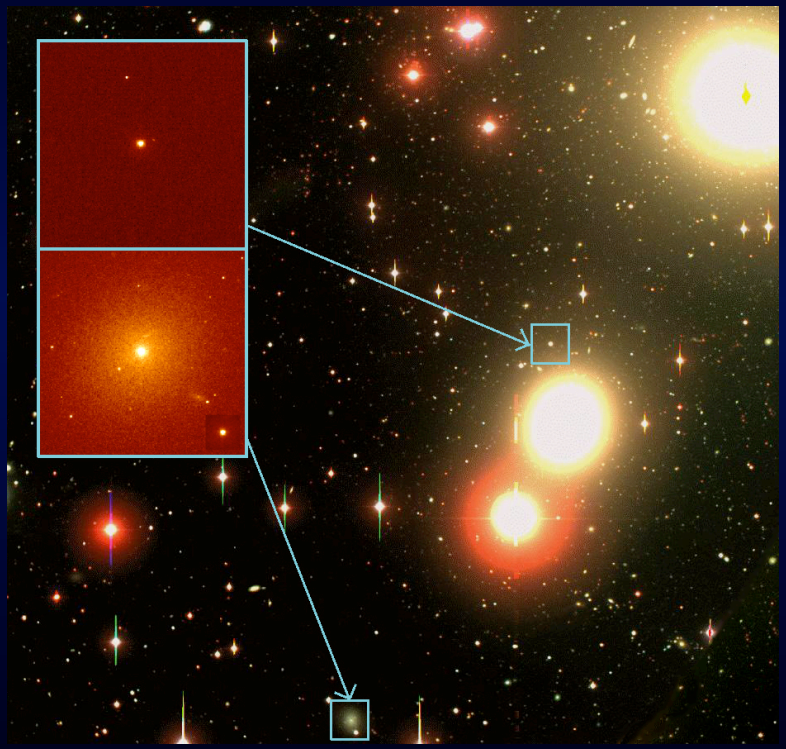
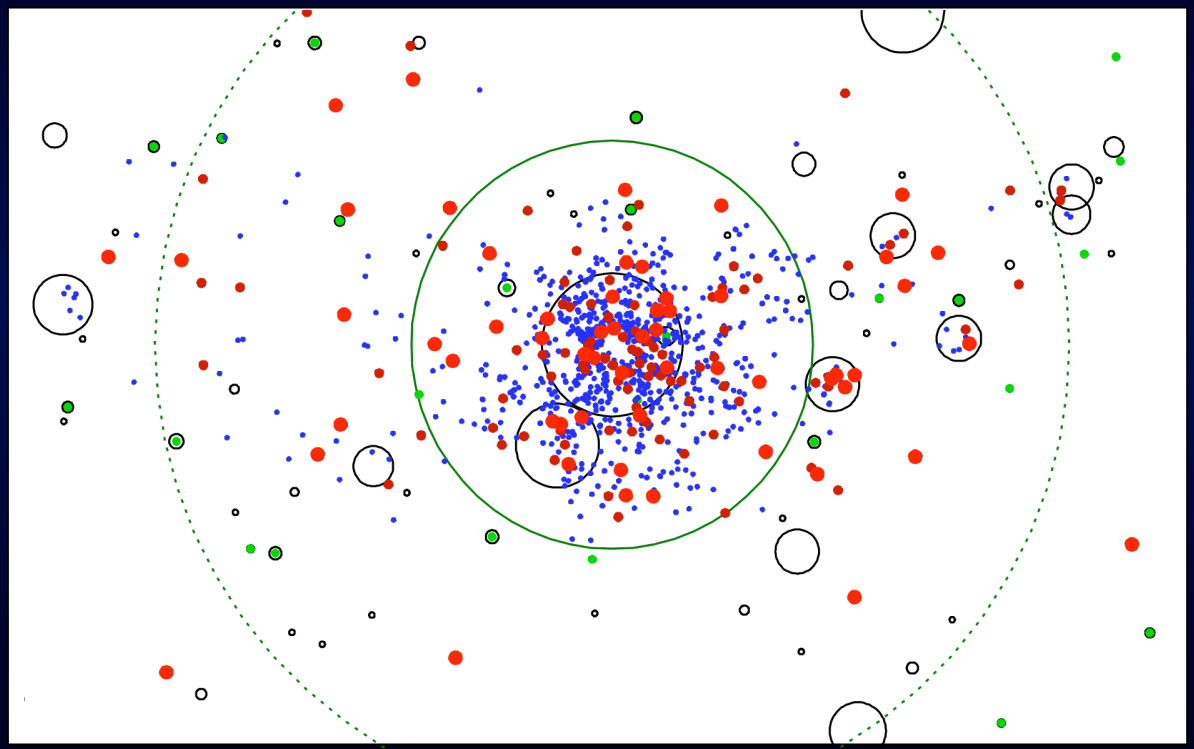
Properties and kinematics of ultra-compact dwarf galaxies in nearby clusters

Michael Hilker (ESO/Garching)





Main collaborators: S. Mieske (ESO), M. Frank (ARI/Heidelberg), I. Misgeld (LMU/Munich), T. Richtler (Concepcion/Chile), T. Puzia (PUC/Chile), L. Infante (PUC/Chile), H. Baumgardt (U. of Queensland), I. Georgiev, Y. Schuberth (AIfA/Bonn)

Characteristics of „Ultra-Compact Dwarf galaxies“ (UCDs)

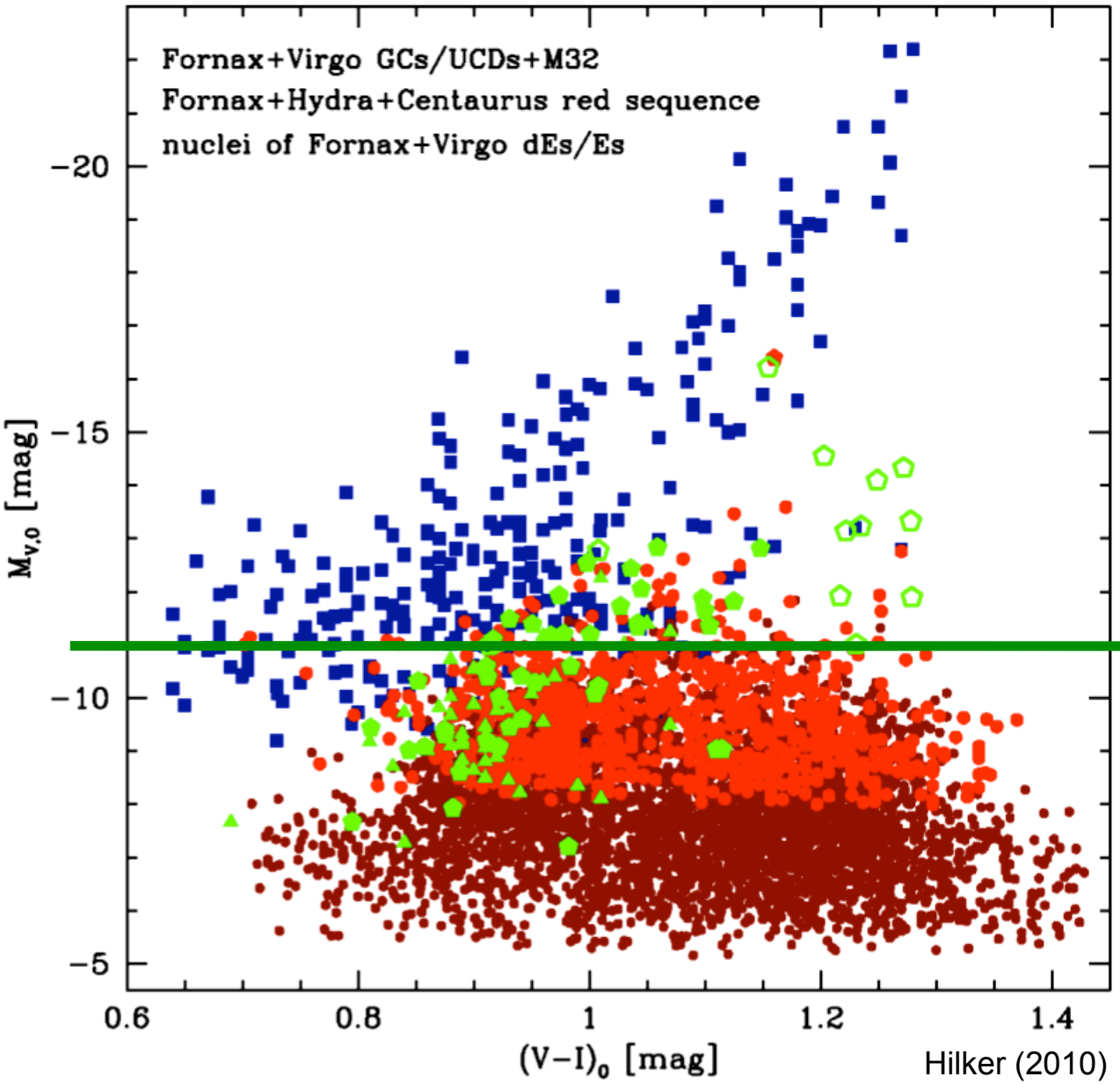
Dr. Michael Hilker (ESO, Garching)

Ultra-compact dwarf galaxies*

Luminosities:	**$-13.5<M_V<-11.0$**	(although ω Centauri, M_V=-10.4, might be a small UCD)
Half-light radii:	**$5<R_{h,p}<30$ pc**	(luminosity-size relation; a few have LSB envelopes with $80<R_{eff}<120$ pc)
Velocity dispersion:	**$25<\sigma_0<45$ km/s**	(extrapolated from the observed velocity dispersion)
Mass range:	**$\geq 2 \times 10^6$-10^8 $M_\odot$**	(dynamical mass)
M/L_{dyn}:	**2-10**	(different from the expected M/L of canonical stellar populations)
Occurence:	**In cores of galaxy clusters or close to major isolated/field galaxies**	

*First discoveries: Hilker et al. (1999), Drinkwater et al. (2000); name 'UCD': Phillipps et al. (2001)

Colour-magnitude diagram of ‚hot' stellar systems in galaxy clusters

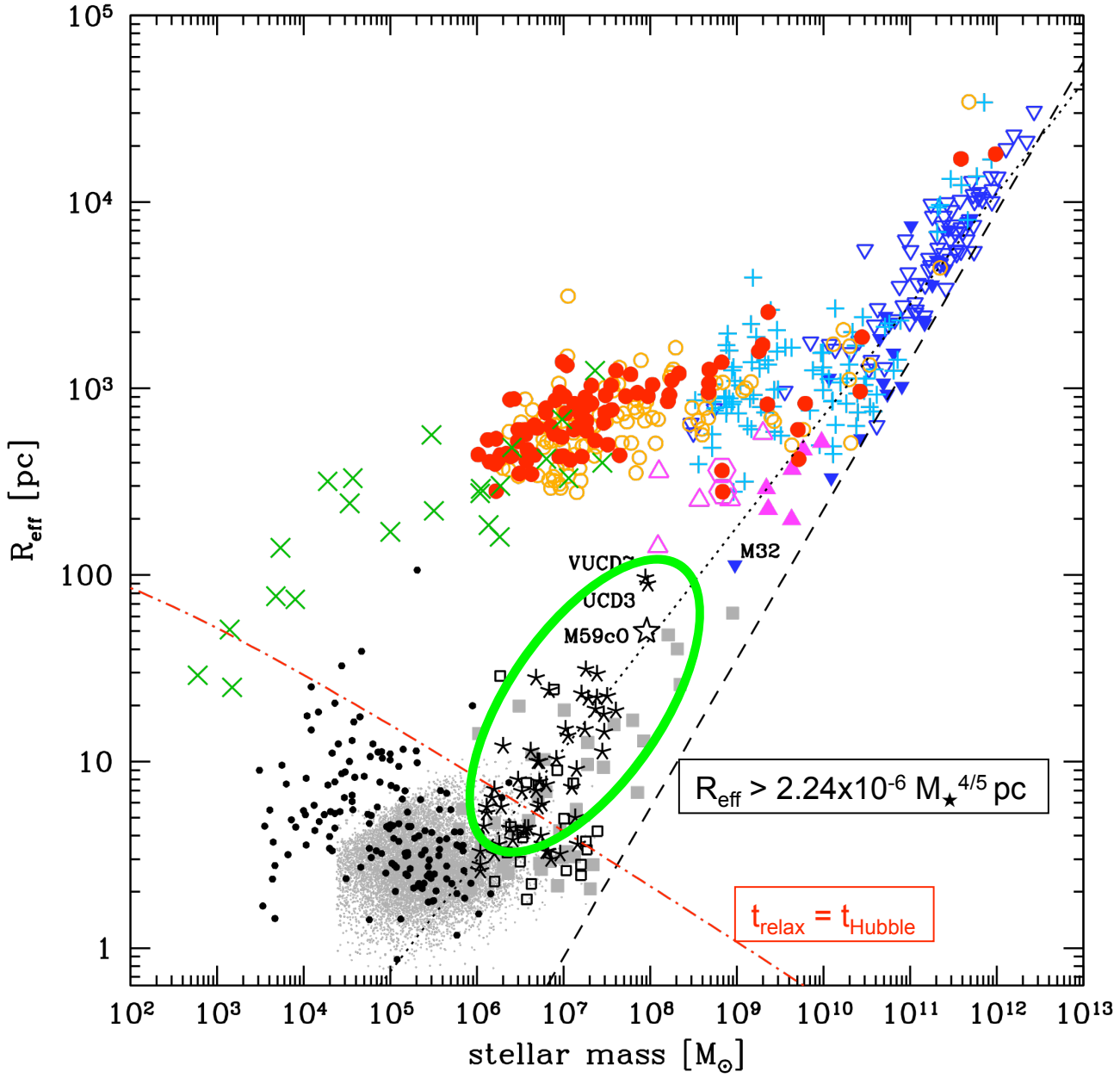


Hilker (2010)

UCDs are continuations of the blue and red GC sequences

Defining UCDs by a luminosity cut seems quite arbitrary

Stellar mass-size relation of ‚hot' stellar systems

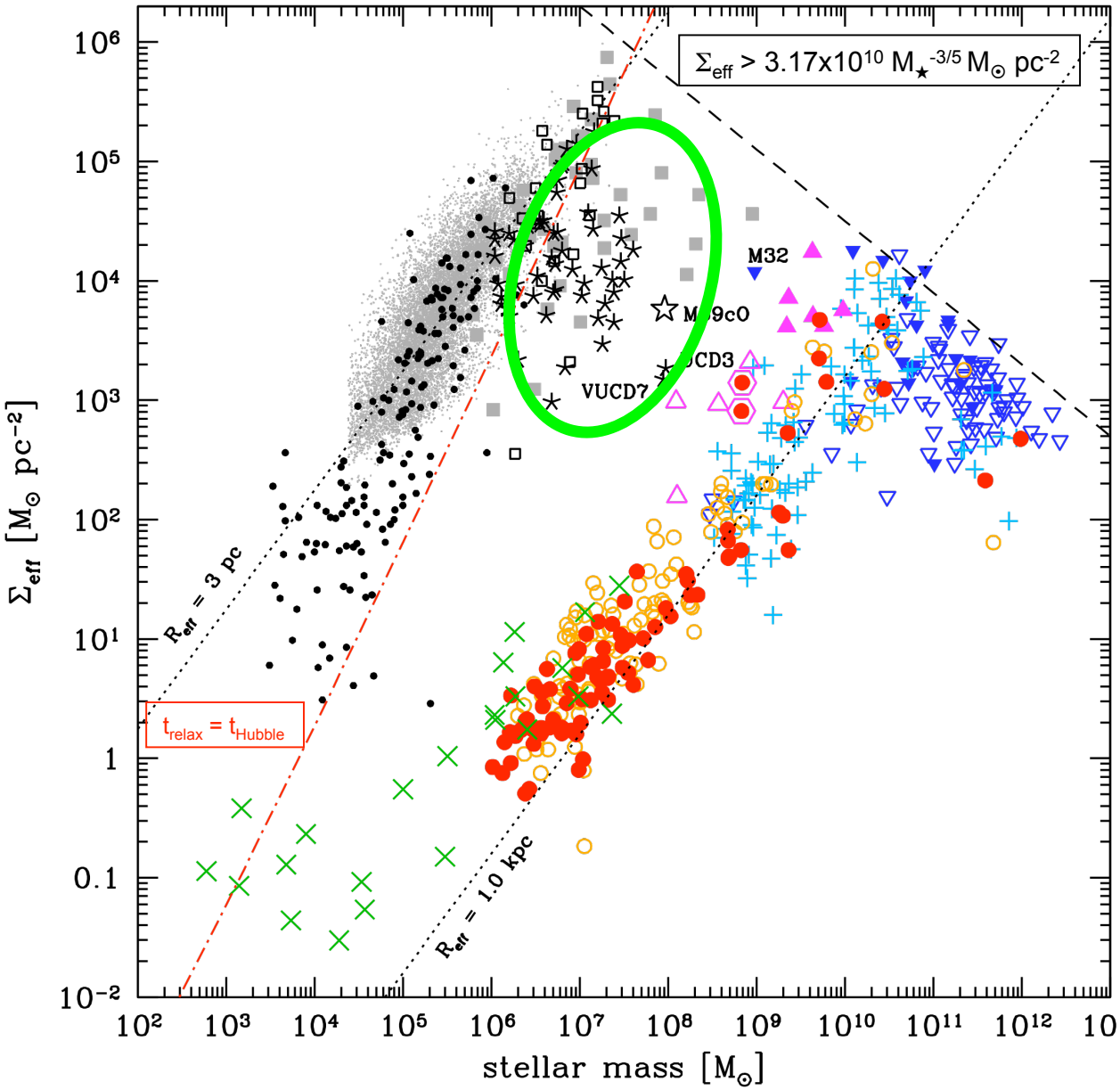


UCDs follow a mass-size relation!

Hasegan et al. (2005)
Mieske et al. (2006)
Dabringhausen et al. (2008)
... and many more ...

Misgeld & Hilker (2011, MNRAS)

Surface density-mass relation of hot stellar systems



In terms of galaxies, UCDs are `ultra-compact'.

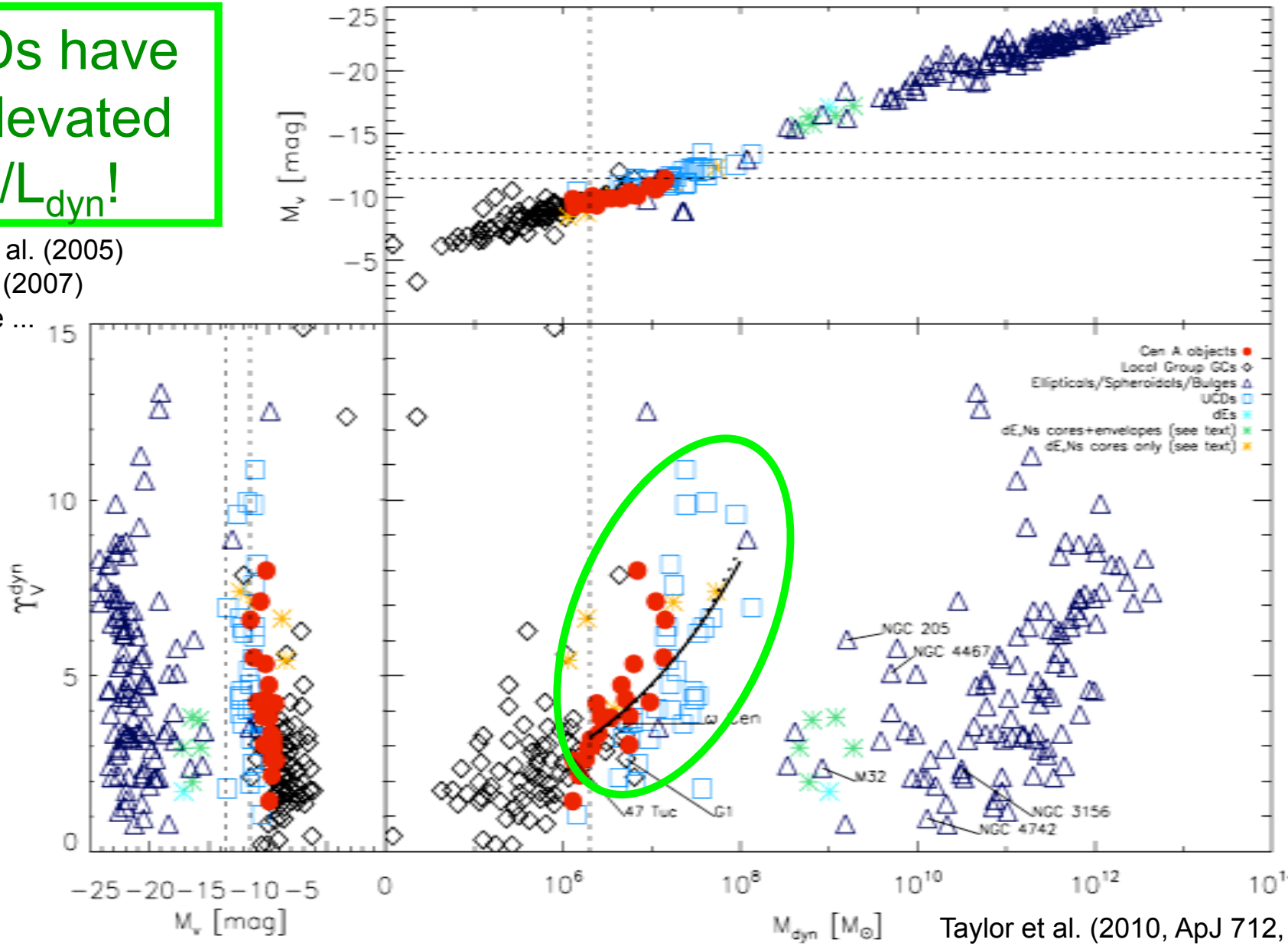
In terms of star clusters, UCDs are rather diffuse.

Misgeld & Hilker (2011, MNRAS)

Dynamical mass-to-light ratio vs. mass/luminosity

UCDs have an elevated M/L_{dyn}!

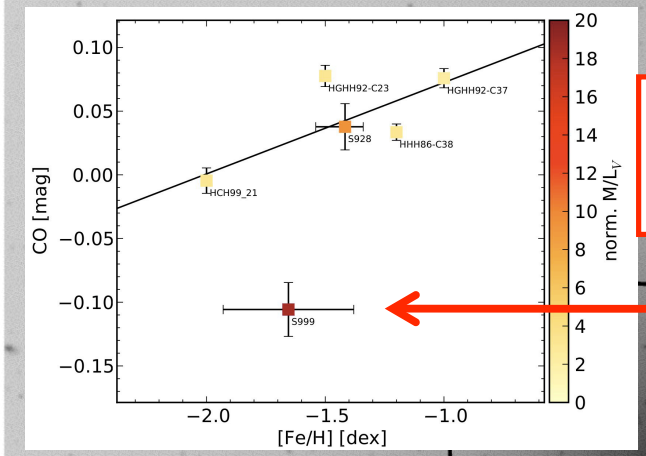
Hasegan et al. (2005)
Hilker et al. (2007)
... and more ...



Taylor et al. (2010, ApJ 712, 1191)

The ACS Virgo cluster survey

-11.8<M_V<-10.8



A bottom-heavy IMF!?
see poster by Frank et al.

N
1'
E

S999 9.4 20.1
S928 6.1 23.2
H8005 3.0 28.7
M87
S348
S1538
S490 4.1 3.6
S314 2.9 3.2
S417 5.8 14.4
S1370

Dwarf-Globular Transition Objects (DGTOs)

V-band image (KPNO 4m)
ACS footprint

mass-to-light ratio M/L_V

half-mass radius r_h

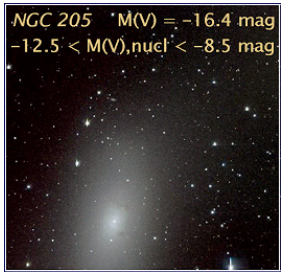
ID	M_V (mag)	L_V ($10^6 L_{V,\odot}$)	M_k ($10^7 M_\odot$)	M_k/L_V ($M_\odot/L_{V,\odot}$)
S314...	-10.91 ± 0.16	1.98 ± 0.30	0.58 ± 0.10	2.94 ± 0.68
S417...	-11.78 ± 0.16	4.39 ± 0.66	2.56 ± 0.46	5.83 ± 1.36
S490...	-11.00 ± 0.16	2.14 ± 0.32	0.87 ± 0.21	4.06 ± 0.15
S928...	-11.58 ± 0.16	3.52 ± 0.53	2.13 ± 0.29	6.06 ± 1.23
S999...	-11.08 ± 0.16	2.31 ± 0.34	2.16 ± 0.29	9.36 ± 1.87
H8005...	-10.83 ± 0.16	1.84 ± 0.28	0.55 ± 0.23	2.98 ± 1.35

Hasegan et al. 2005 (ApJ 627, 203)

The top 4 formation scenarios for UCDs

"Remnant nuclei of disrupted galaxies" - NCs

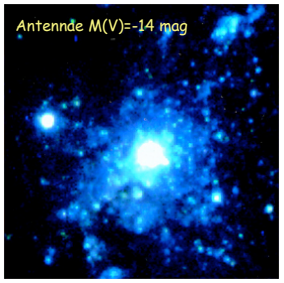
(Bekki et al. 2001, 2003, Bassino et al. 1994, Zinnecker et al. 1988)



vs.

"Merged supercluster complexes" - MSCs

(Fellhauer & Kroupa 2002, 2005, Kroupa 1998)

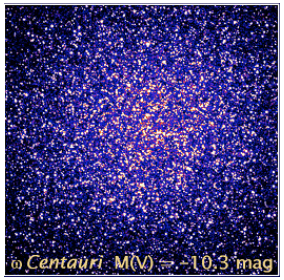


↕ =

vs.

"Most massive globular clusters" - GGCs

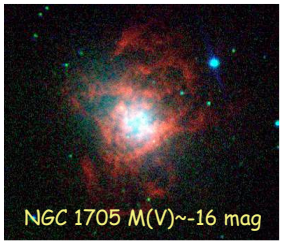
(Mieske et al. 2002, 2004, Norris & Kannappan 2011)



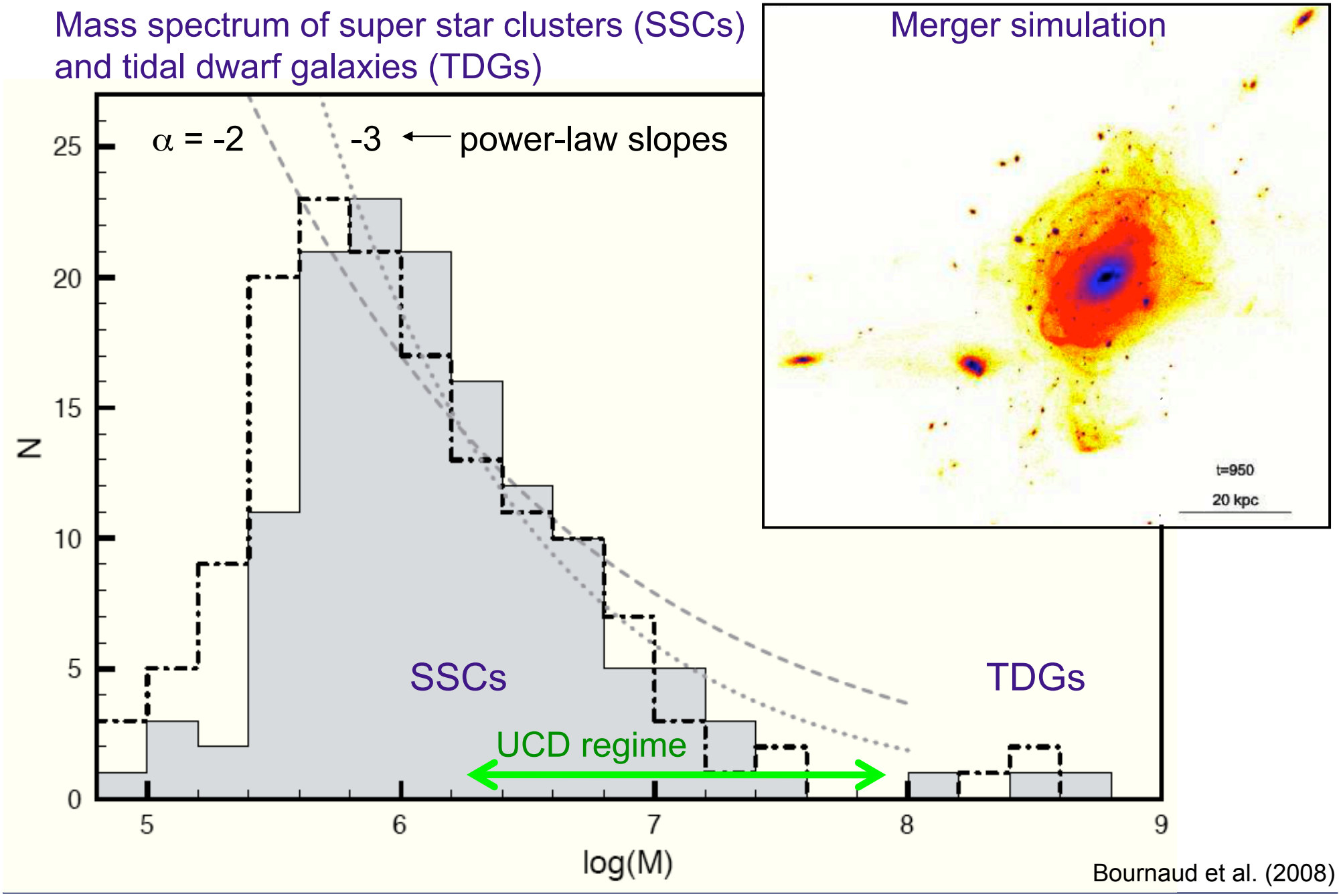
vs.

"Genuine compact dwarf galaxies" - cEs

(Phillipps et al. 2001, Drinkwater et al. 2004)



Mass spectrum of super star clusters (SSCs) and tidal dwarf galaxies (TDGs)



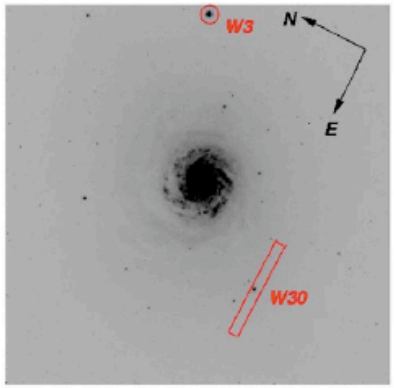
Bournaud et al. (2008)

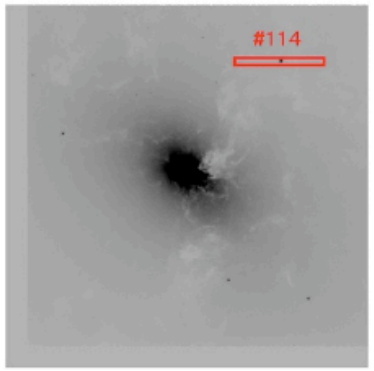
The Most Massive YMCs

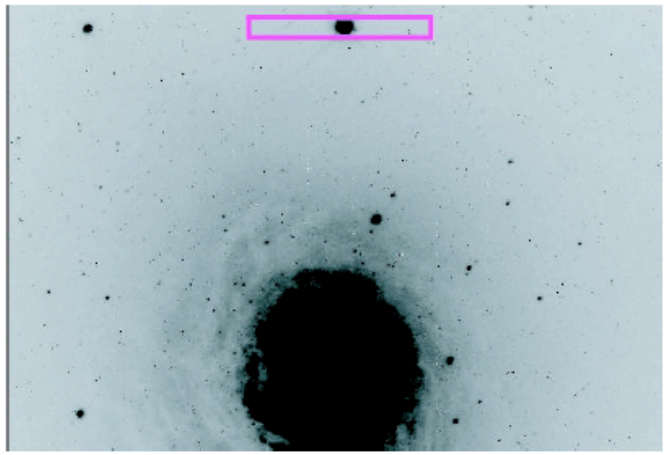
Clusters with M~10^7 $M_\odot$ in starbursts → ICMF more top-heavy than in spiral discs

Arp 220 - most massive clusters ~10^7 $M_\odot$, R_{eff} ~ 10 pc (Wilson et al. 2006).

NGC 7252 - W30: M_{Vir} = (1.6±0.3)x10^7 $M_\odot$, R_{eff} ~ 9 pc
NGC 1316 - G114: M_{Vir} = (1.6±0.1)x10^7 $M_\odot$, R_{eff} ~ 4 pc
(Bastian et al. 2006)



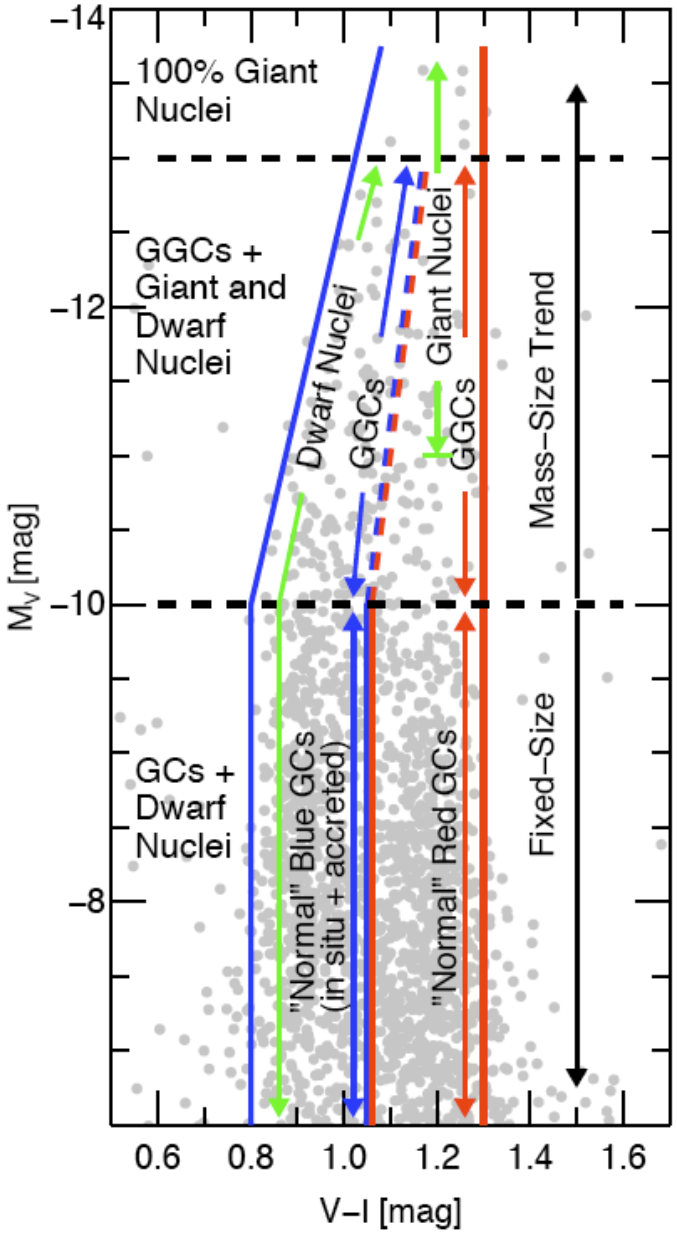


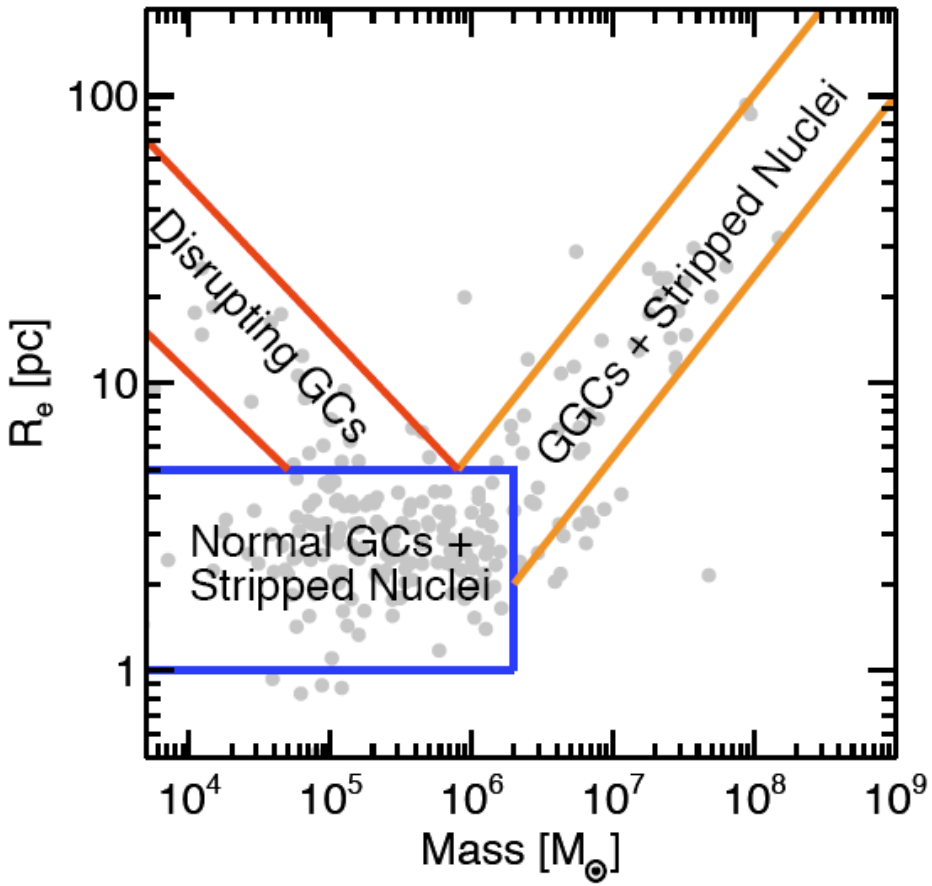


NGC 7252 - W3: M_{Vir} = (8±2)x10^7 $M_\odot$,
R_{eff} ~ 18 pc (Maraston et al. 2004)

Slide taken from P. Goudfrooij's presentation at the ESO Workshop on `Dynamics of Low-Mass Stellar Systems: From Star Clusters to Dwarf Galaxies', Santiago, Chile, April 4-8, 2011

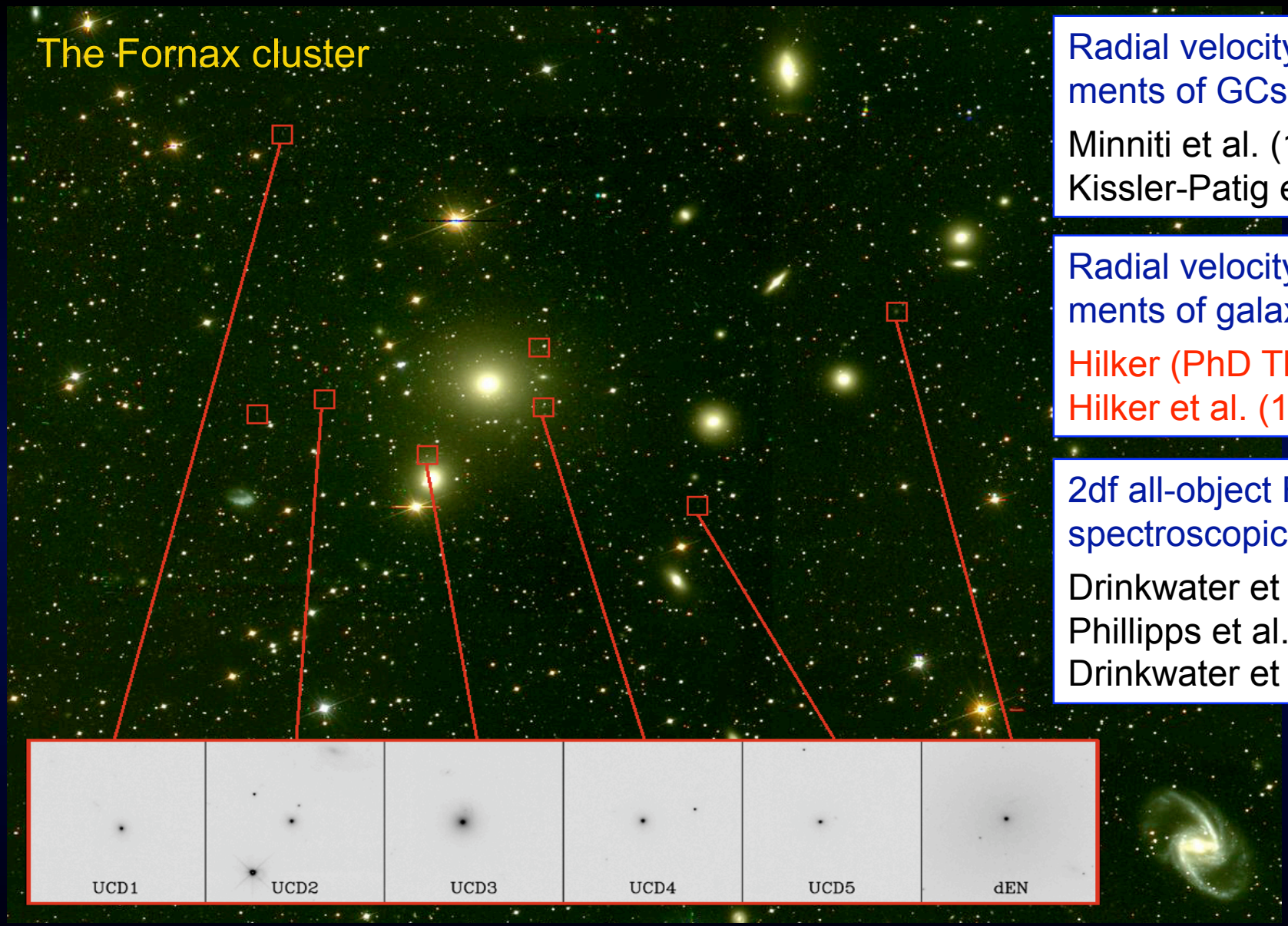
The origin of GCs and UCDs in the colour-magnitude plane and the mass-size plane





Norris & Kannappan (2011)

Where it all began: the Fornax cluster



Radial velocity measurements of GCs:

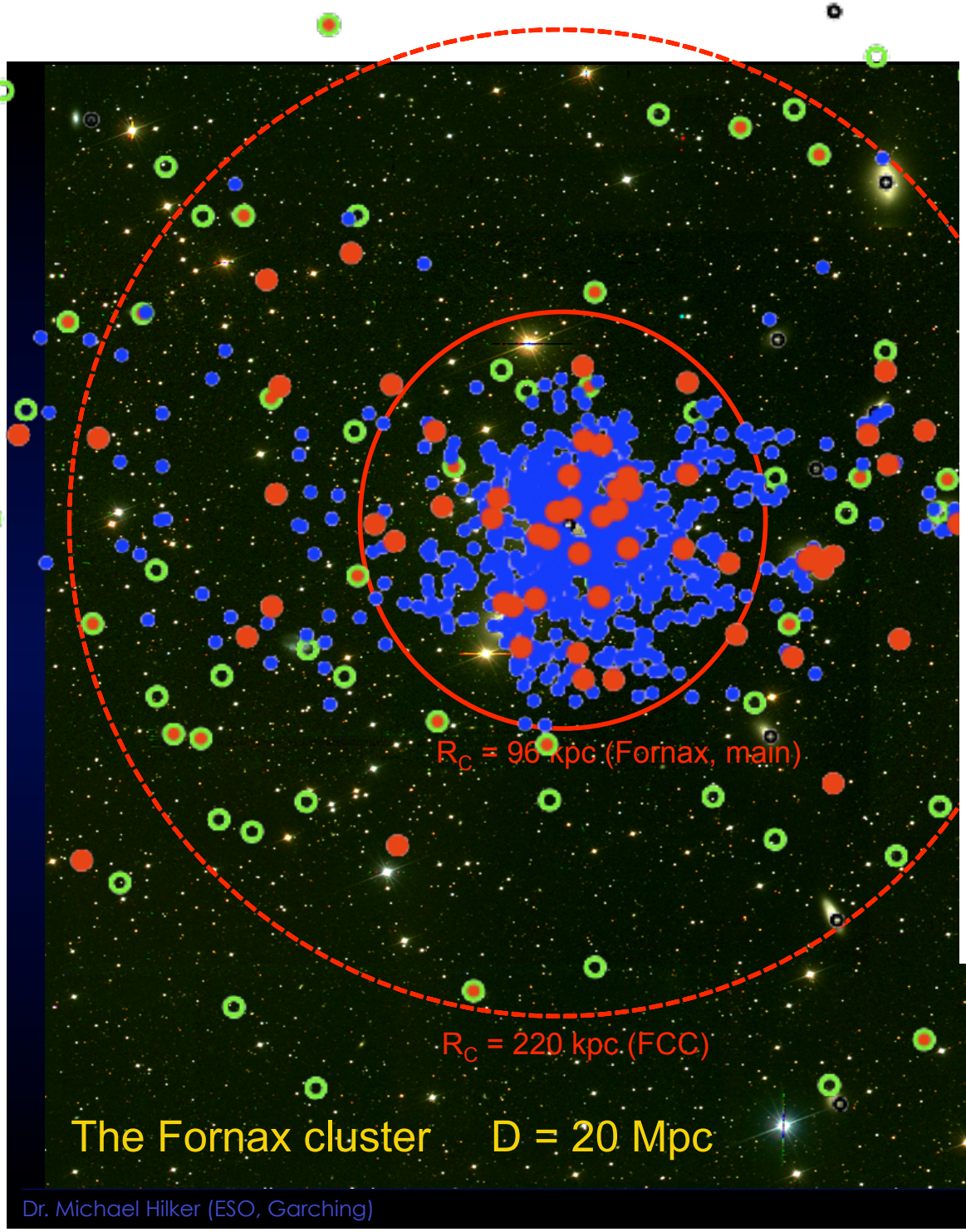
Minniti et al. (1998)
Kissler-Patig et al. (1999)

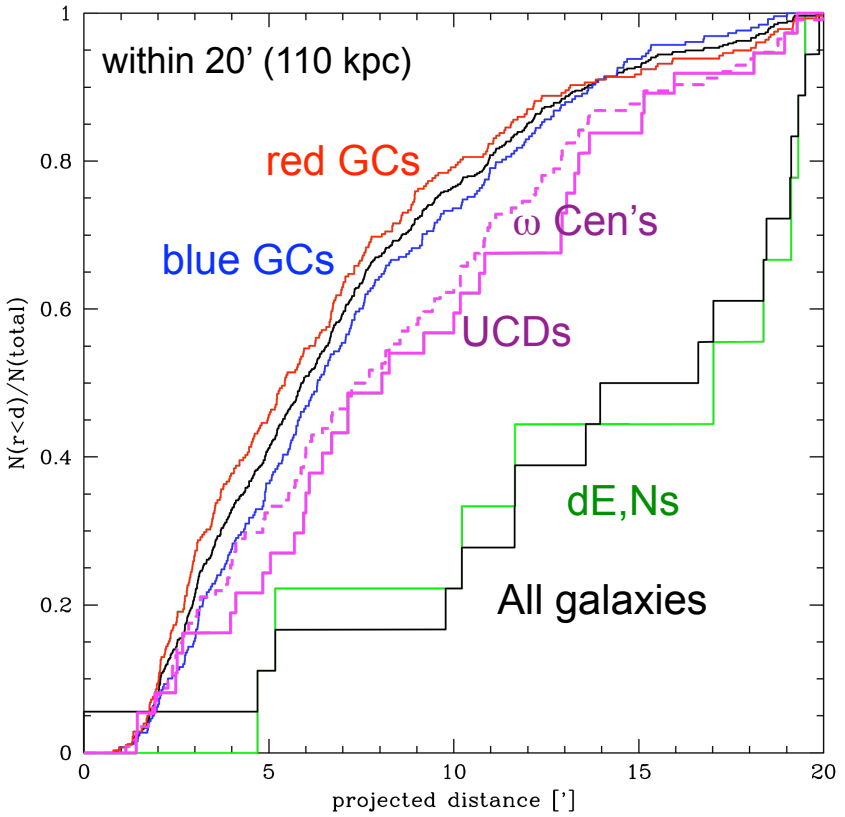
Radial velocity measurements of galaxies:

Hilker (PhD Thesis 1998)
Hilker et al. (1999)

2df all-object Fornax spectroscopic survey:

Drinkwater et al. (2000)
Phillipps et al. (2001)
Drinkwater et al. (2003)





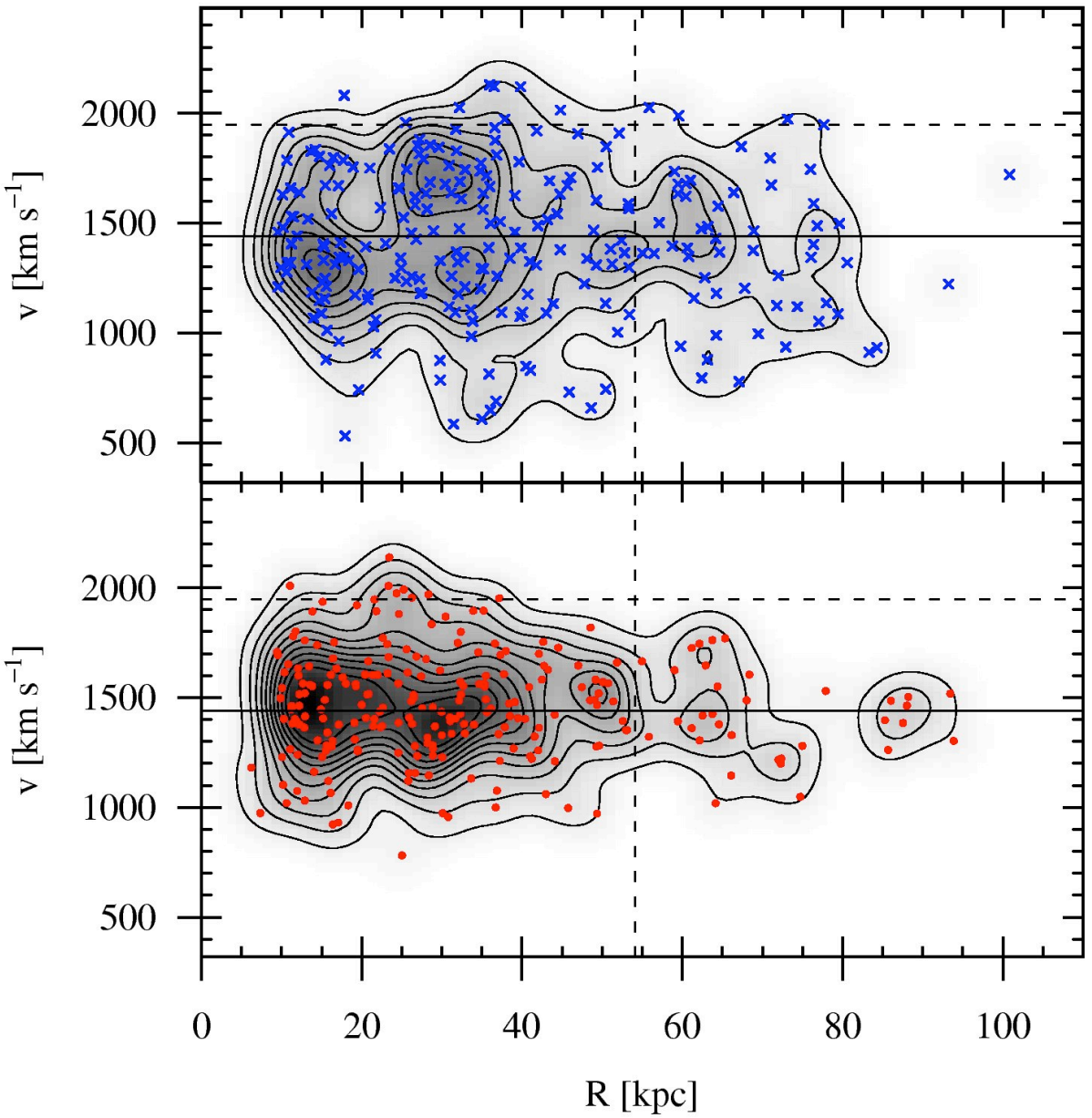
red GCs < blue GCs < ωCen's < UCDs < dE,Ns < dEs < all galaxies

Hilker (2010)

NGC 1399 – GC velocities

Blue GCs
(metal-poor)

Red GCs
(metal-rich)

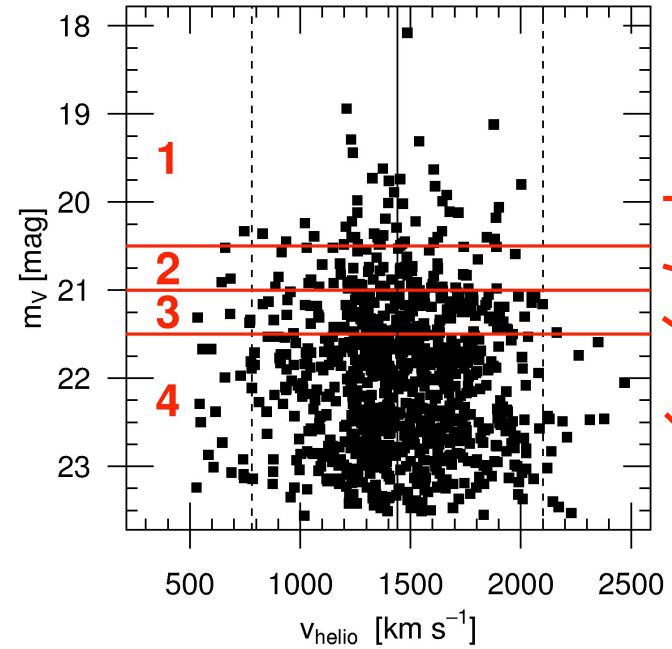


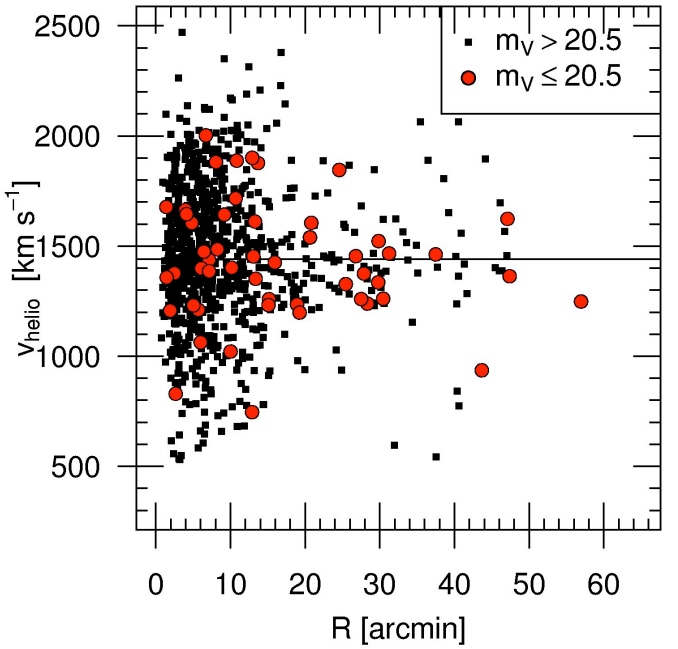
very **jagged**
σ_{los}(R)

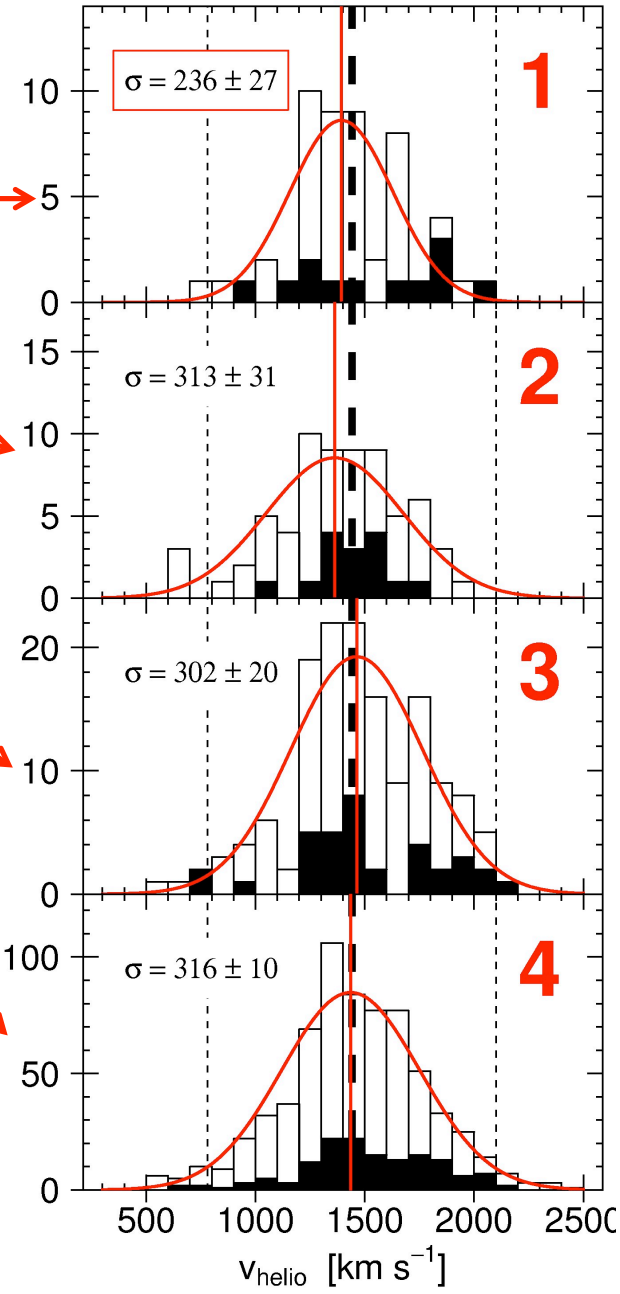
smooth
σ_{los}(R)

Schuberth et al.
(2010, A&A 513, 52)

Velocity dispersion of UCDs in Fornax

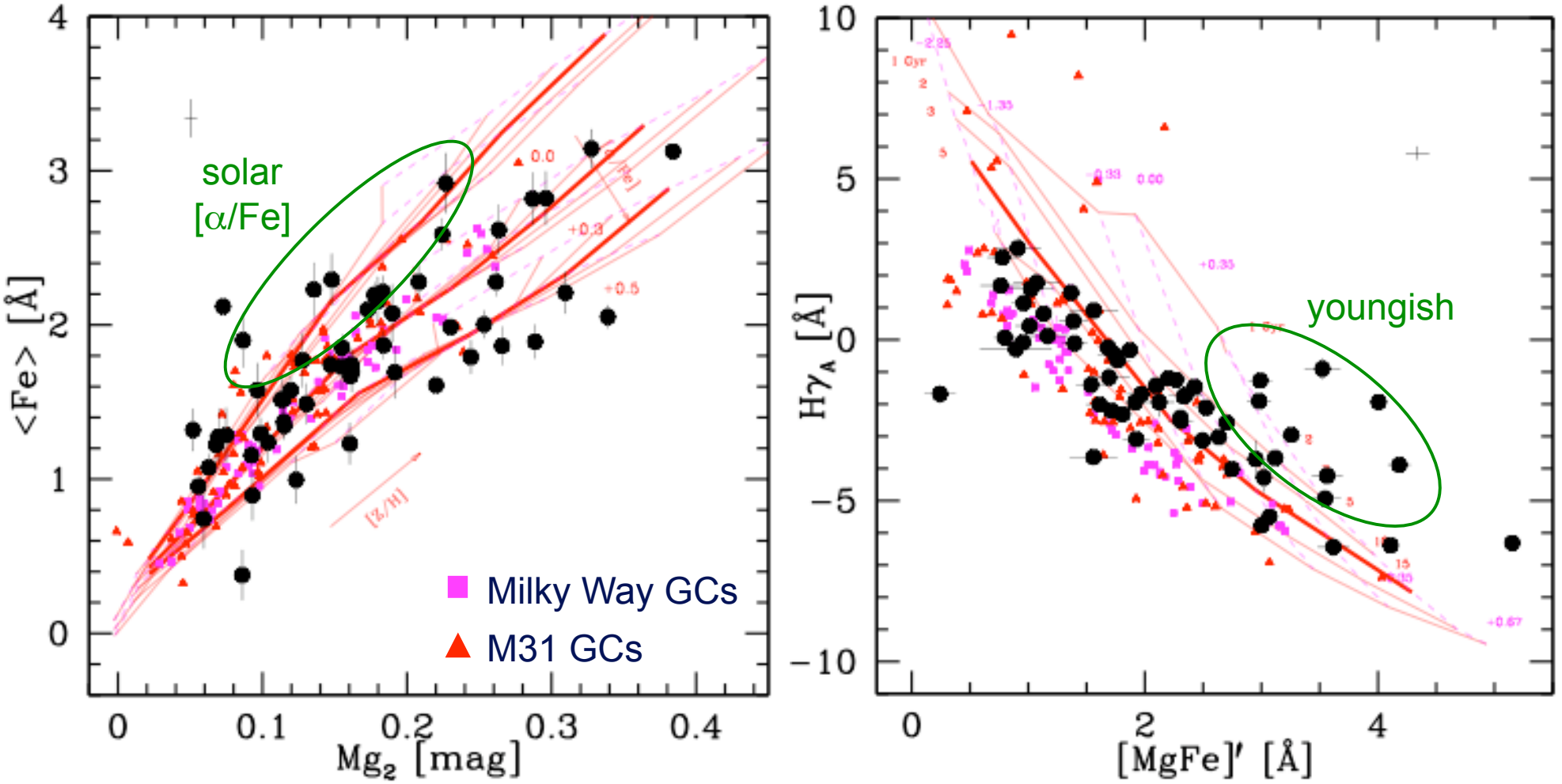






UCDs in Fornax are kinematically `colder‘ than GCs

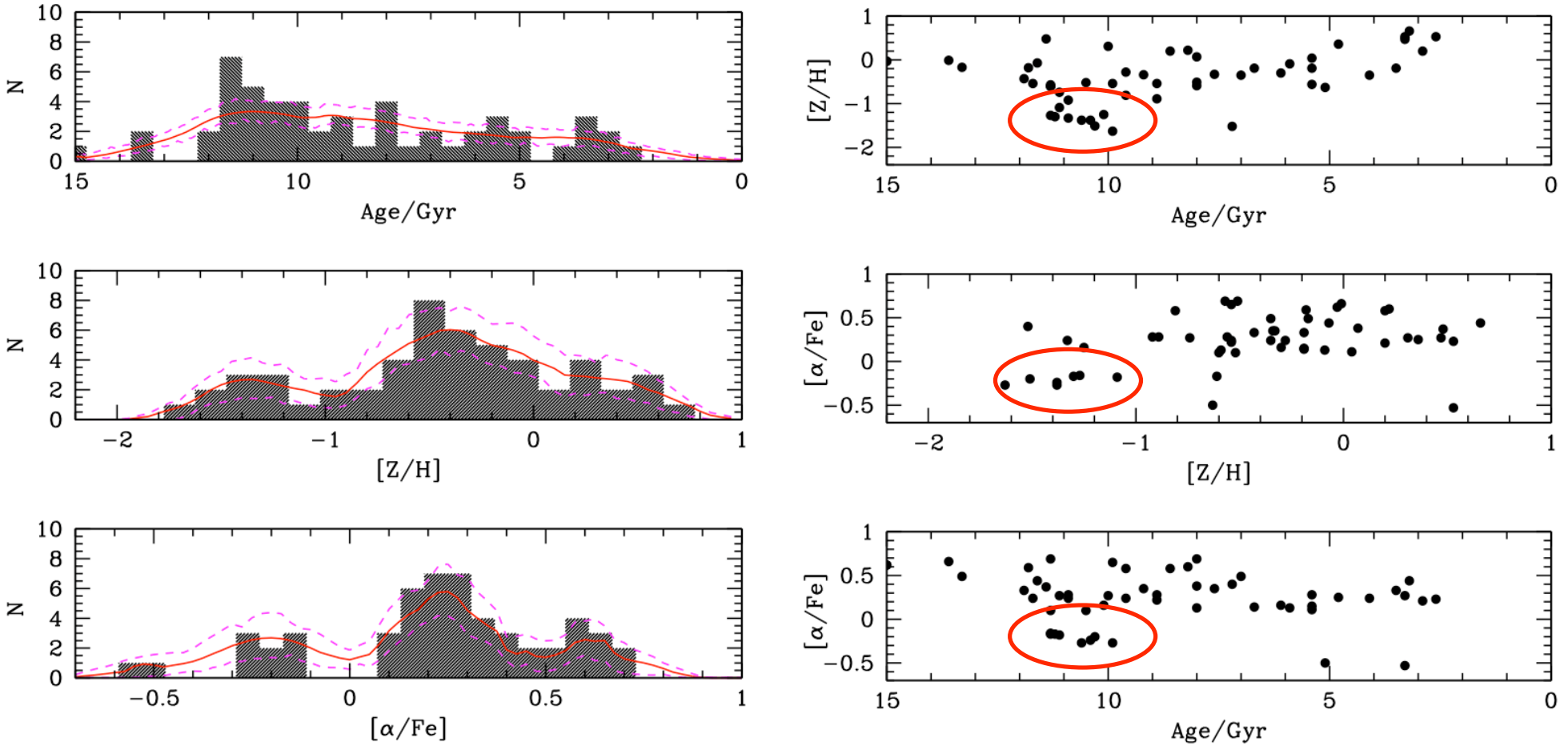
Abundances and ages of GCs/UCDs in the Fornax cluster



High S/N VLT/FORS spectra of ~60 bright GCs/UCDs in Fornax (M_V<-9.5)

Puzia, Hilker et al. (2011, in prep.)

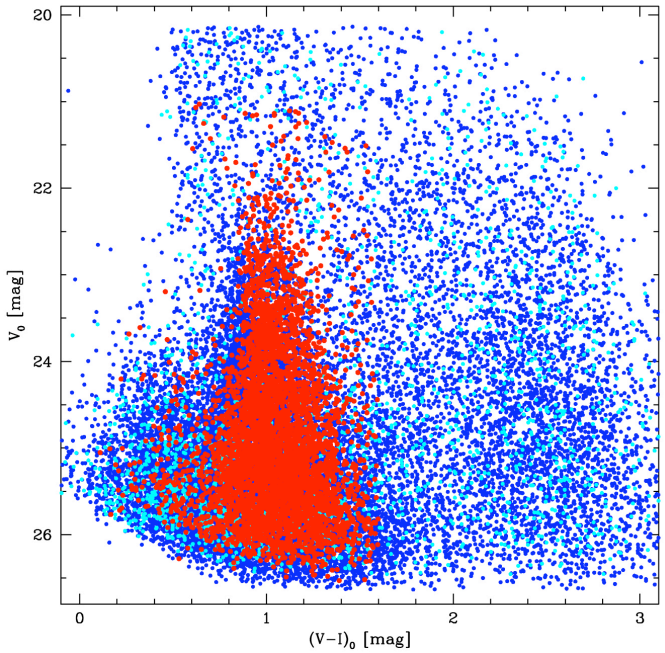
Abundances and ages of GCs/UCDs in the Fornax cluster

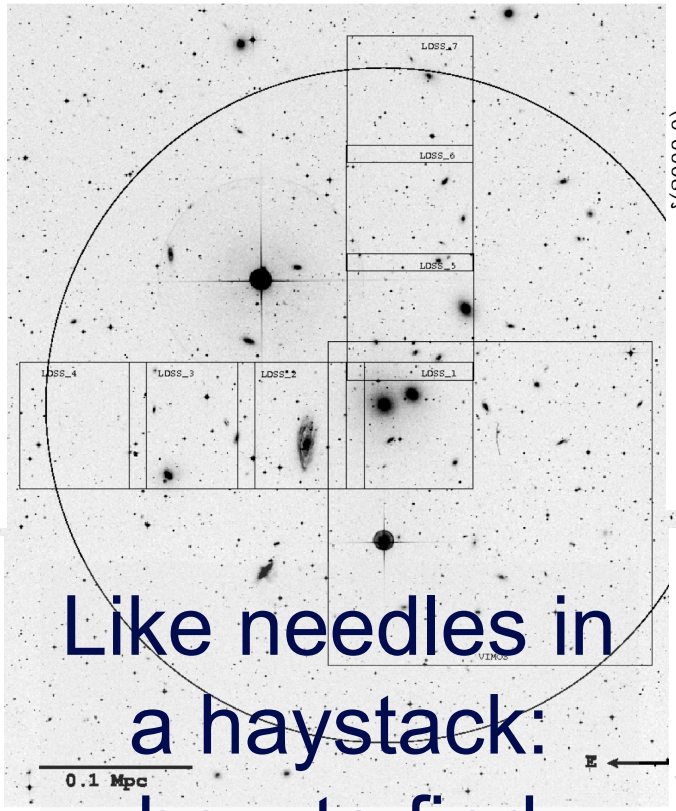


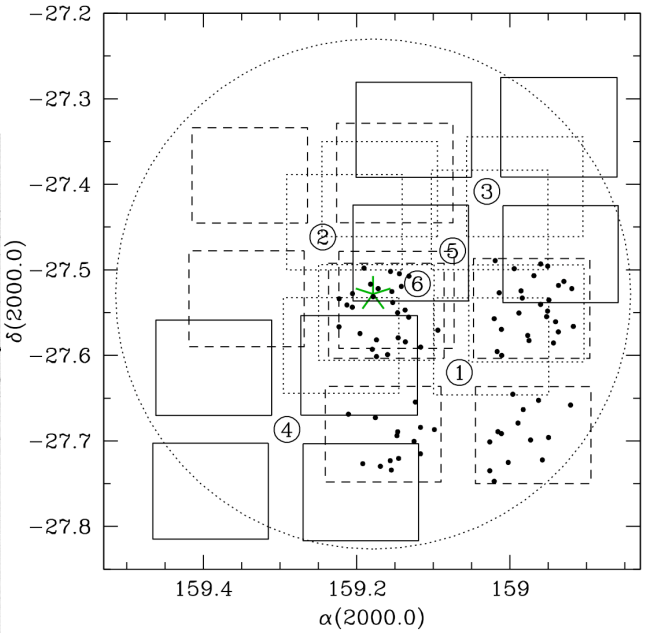
Puzia, Hilker et al. (2011, in prep.)

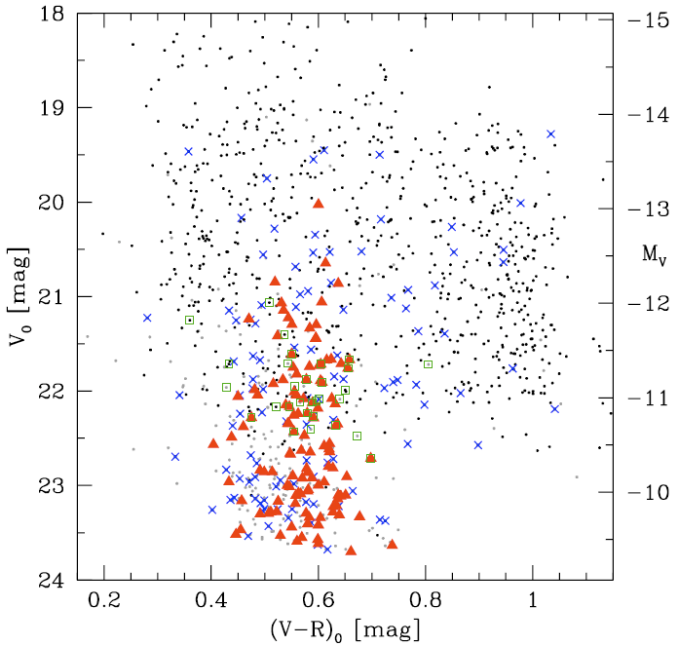
UCDs in Centaurus, Hydra I, Virgo and Coma

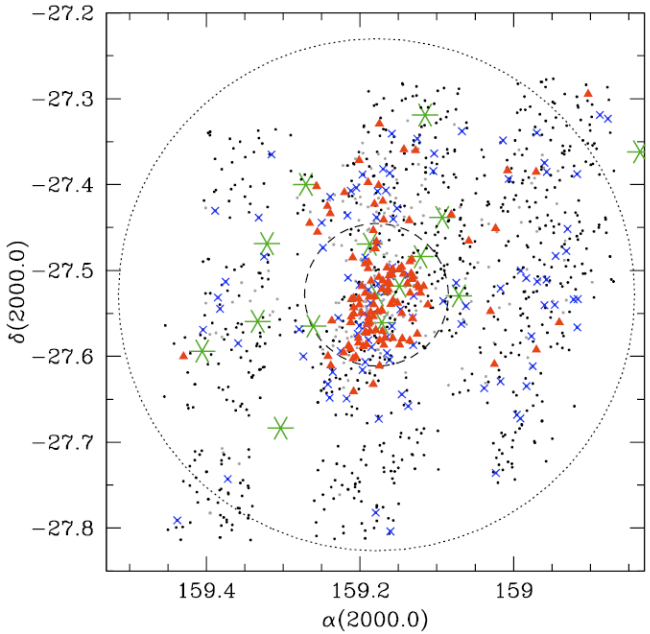
Dr. Michael Hilker (ESO/Garching)











Like needles in a haystack: how to find UCDs?

Mieske et al. (2007, 2009)
Misgeld et al. (2008, 2010)

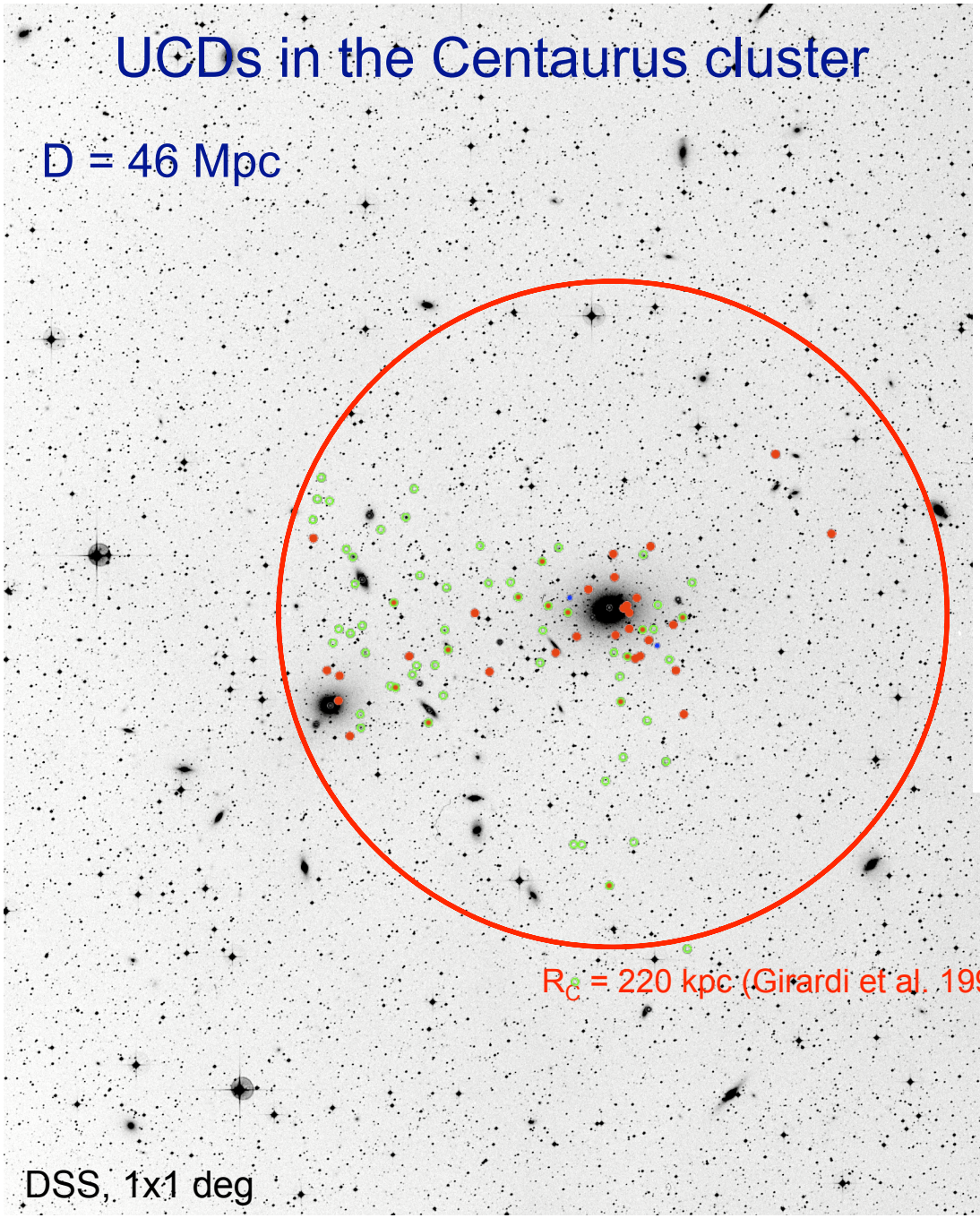
NGC 4696

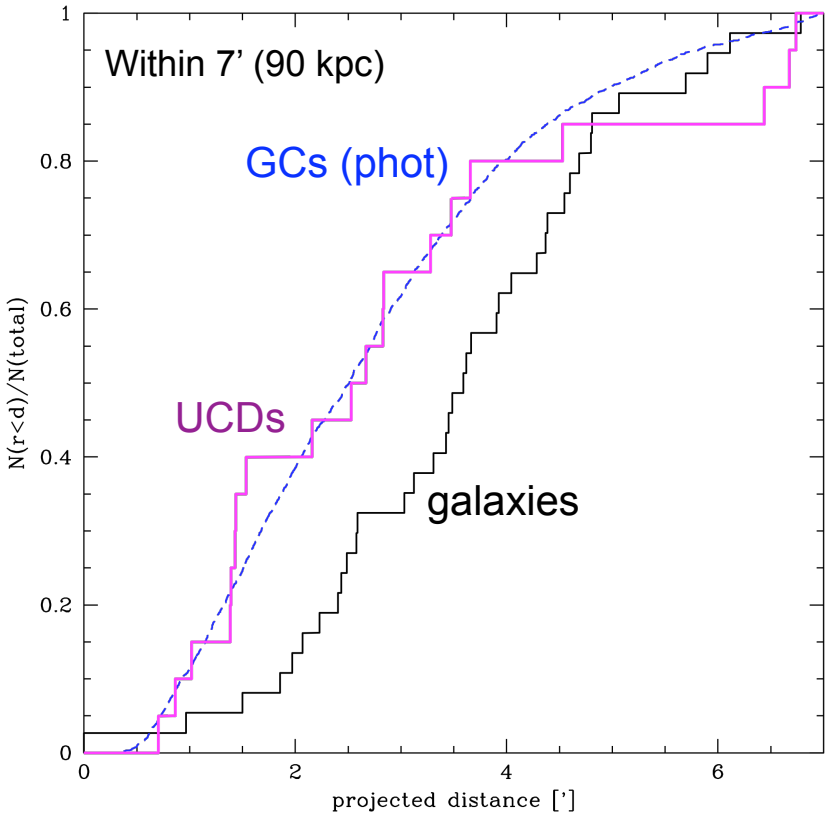
the central galaxy of the Centaurus cluster

Dr. Michael Hilker (ESO/Garching)

UCDs in the Centaurus cluster

D = 46 Mpc

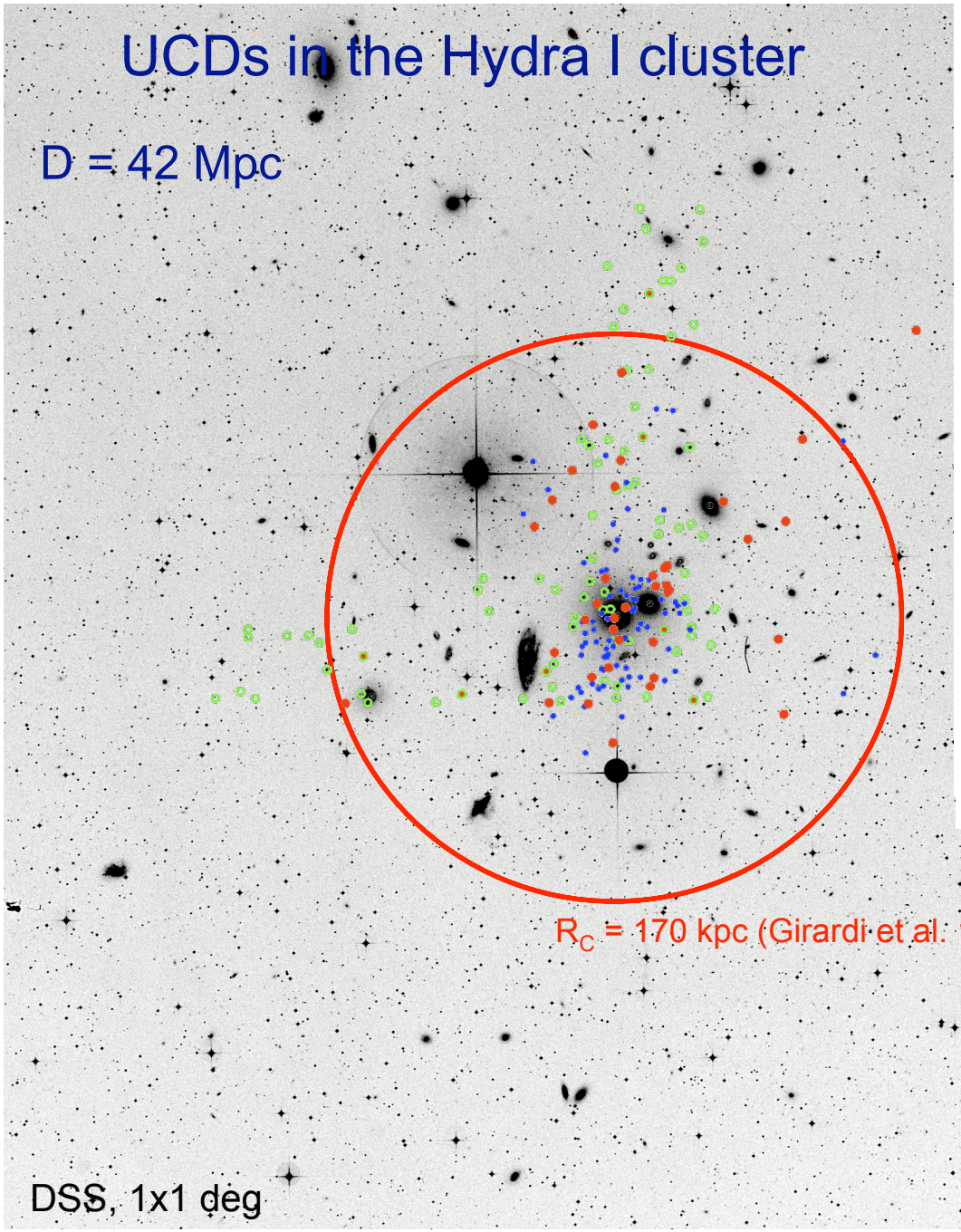


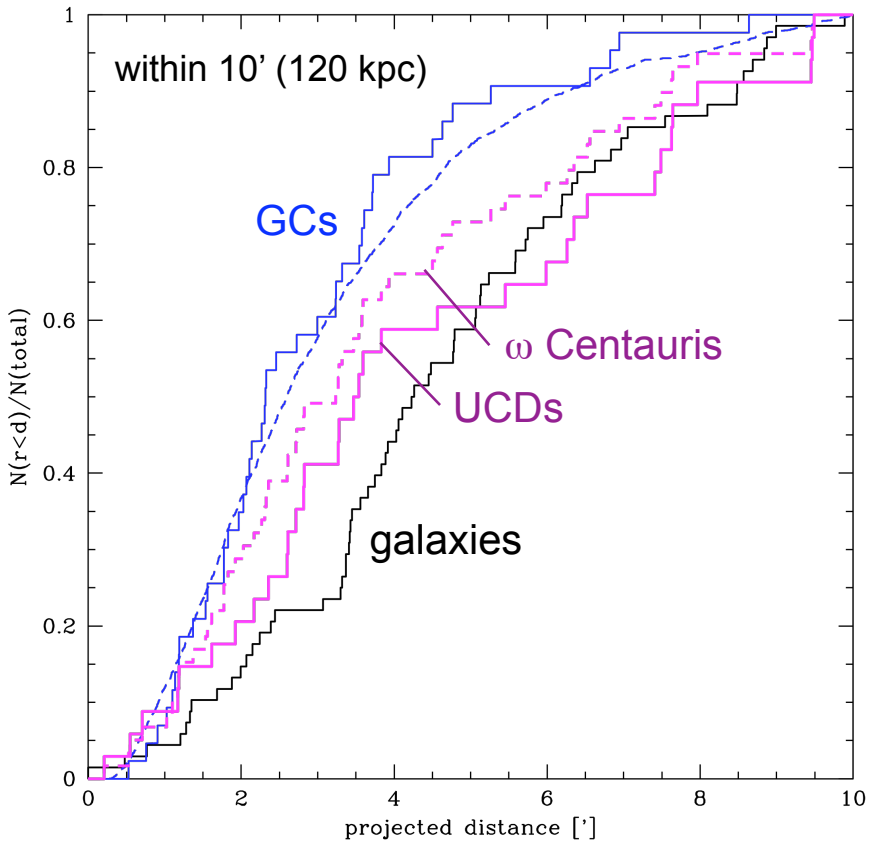


GCs=UCDs<dEs
but incompleteness!

UCDs in the Hydra I cluster

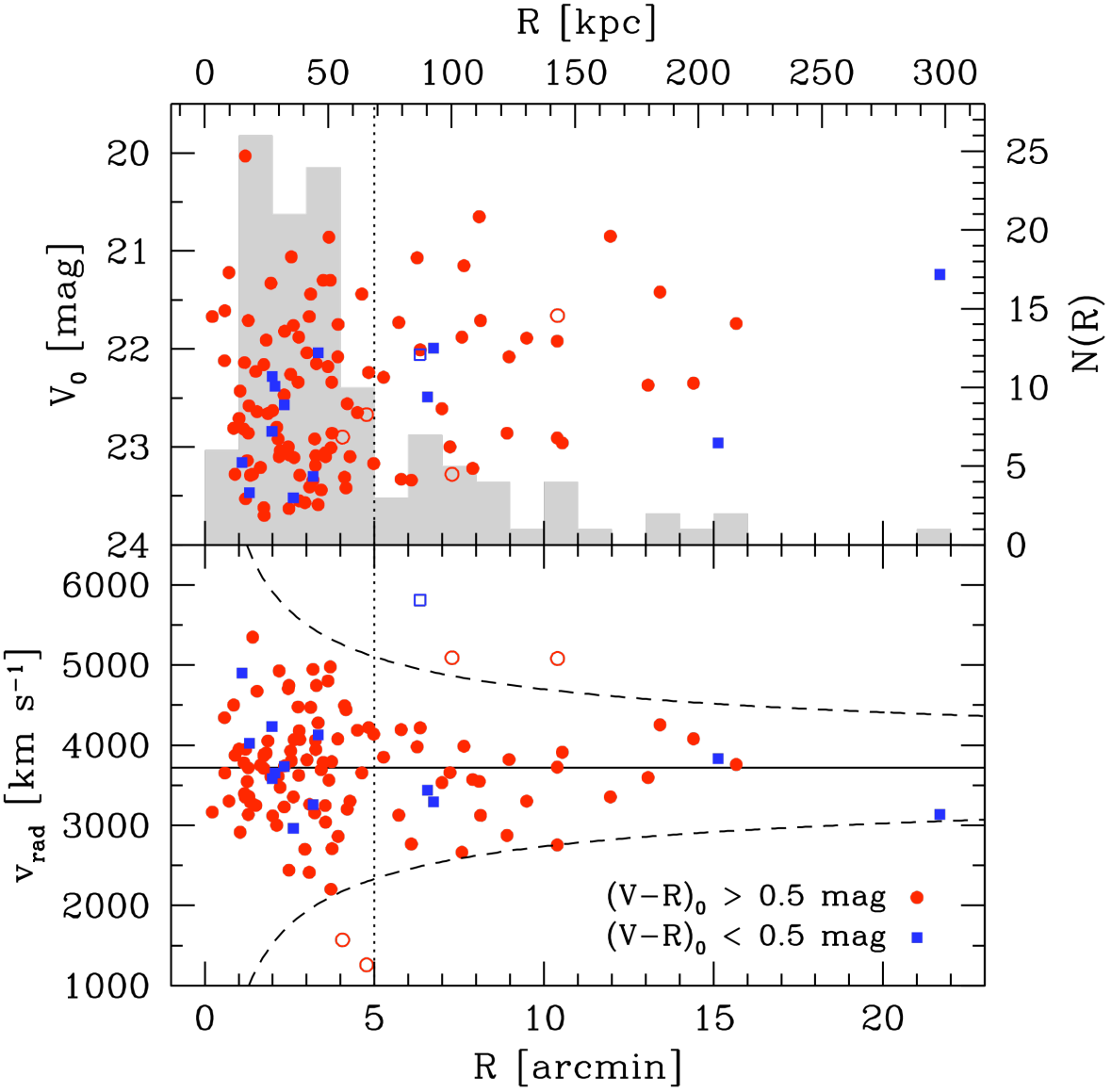
D = 42 Mpc

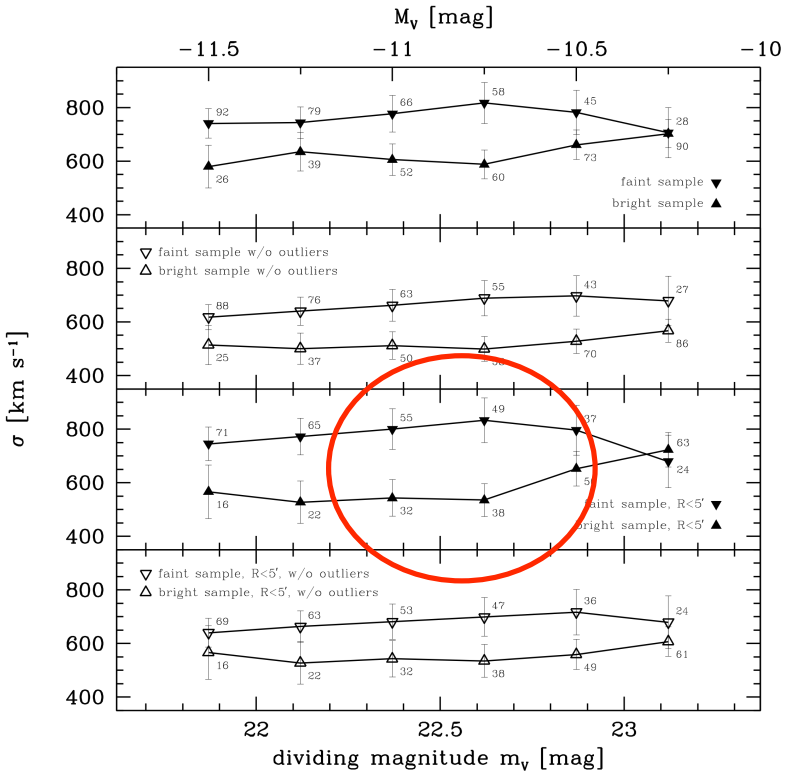




GCs<ω Cens<UCDs<dEs

Kinematics of UCDs/GCs in the Hydra I cluster

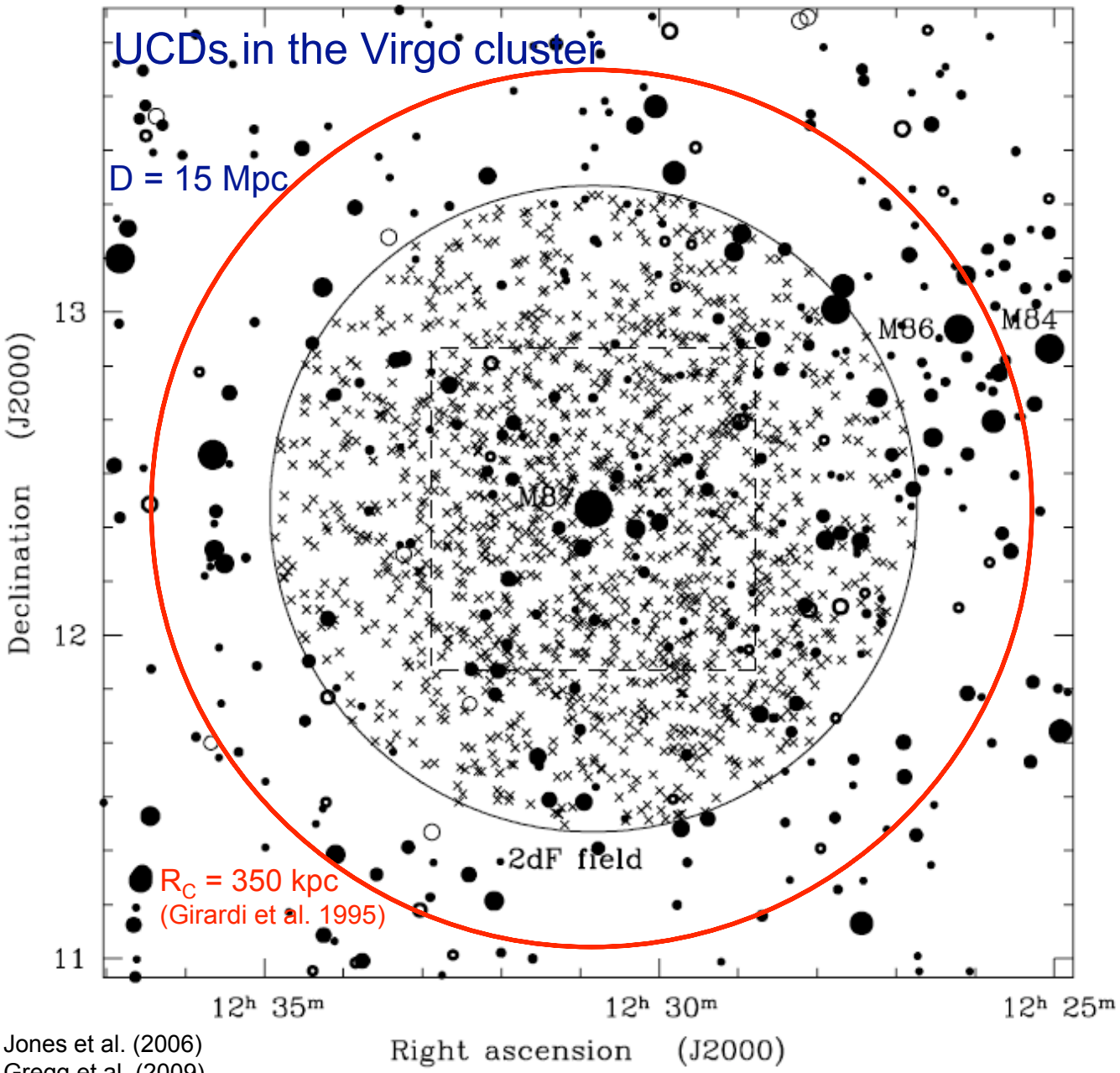




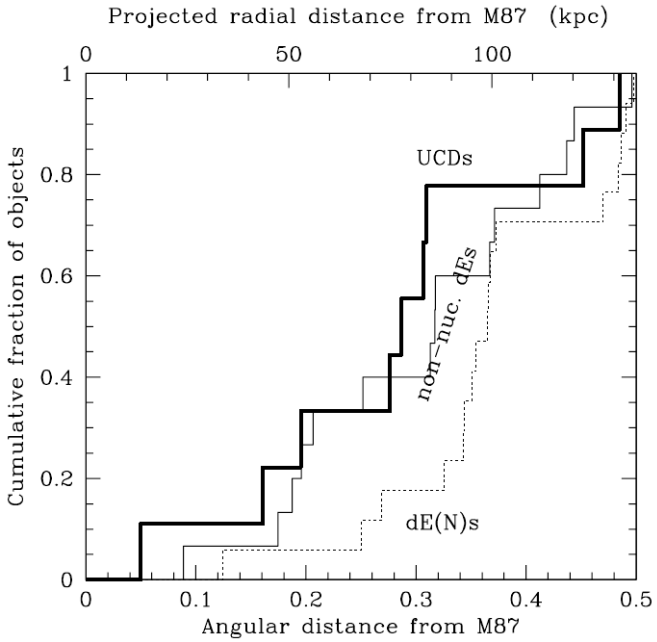
UCDs have a lower velocity dispersion than GCs in the core of the Hydra I cluster

Misgeld et al. (2011, A&A 531, 4)

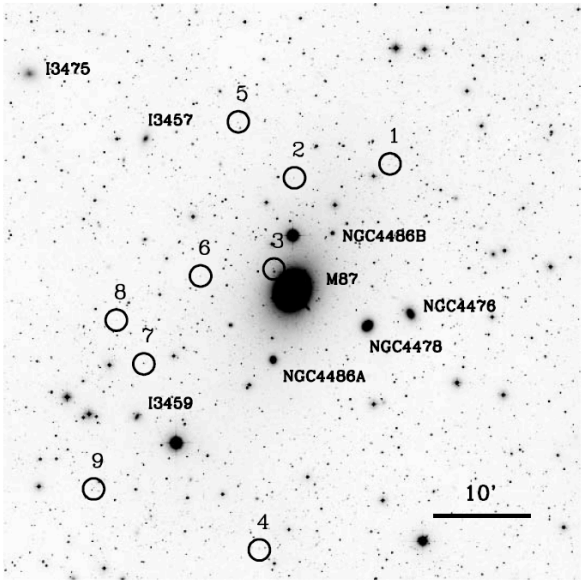
UCDs in the Virgo cluster



Jones et al. (2006)
Gregg et al. (2009)



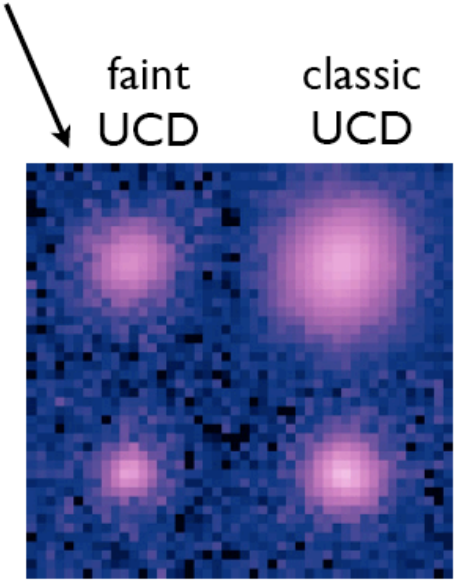
GCs<UCDs<dEs



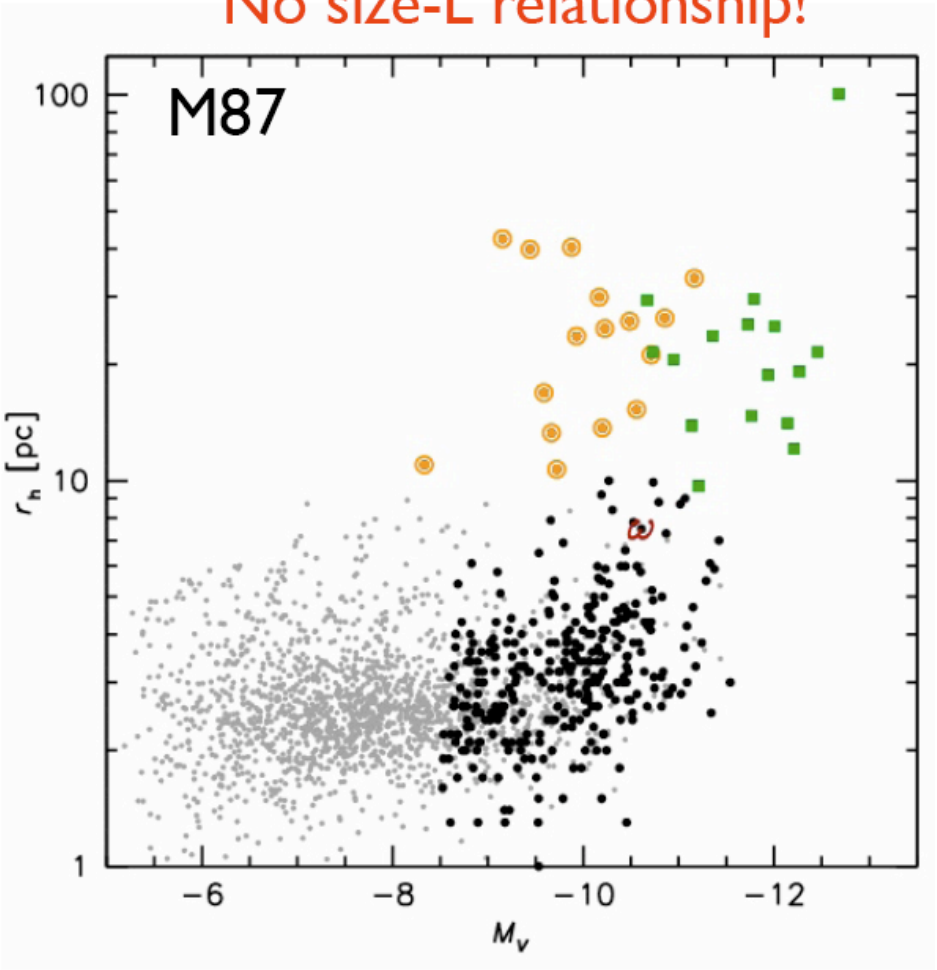
The Relationships between Compact Stellar Systems: A Fresh View of UCDs in M87

Brodie et al 2011

New area of parameter space

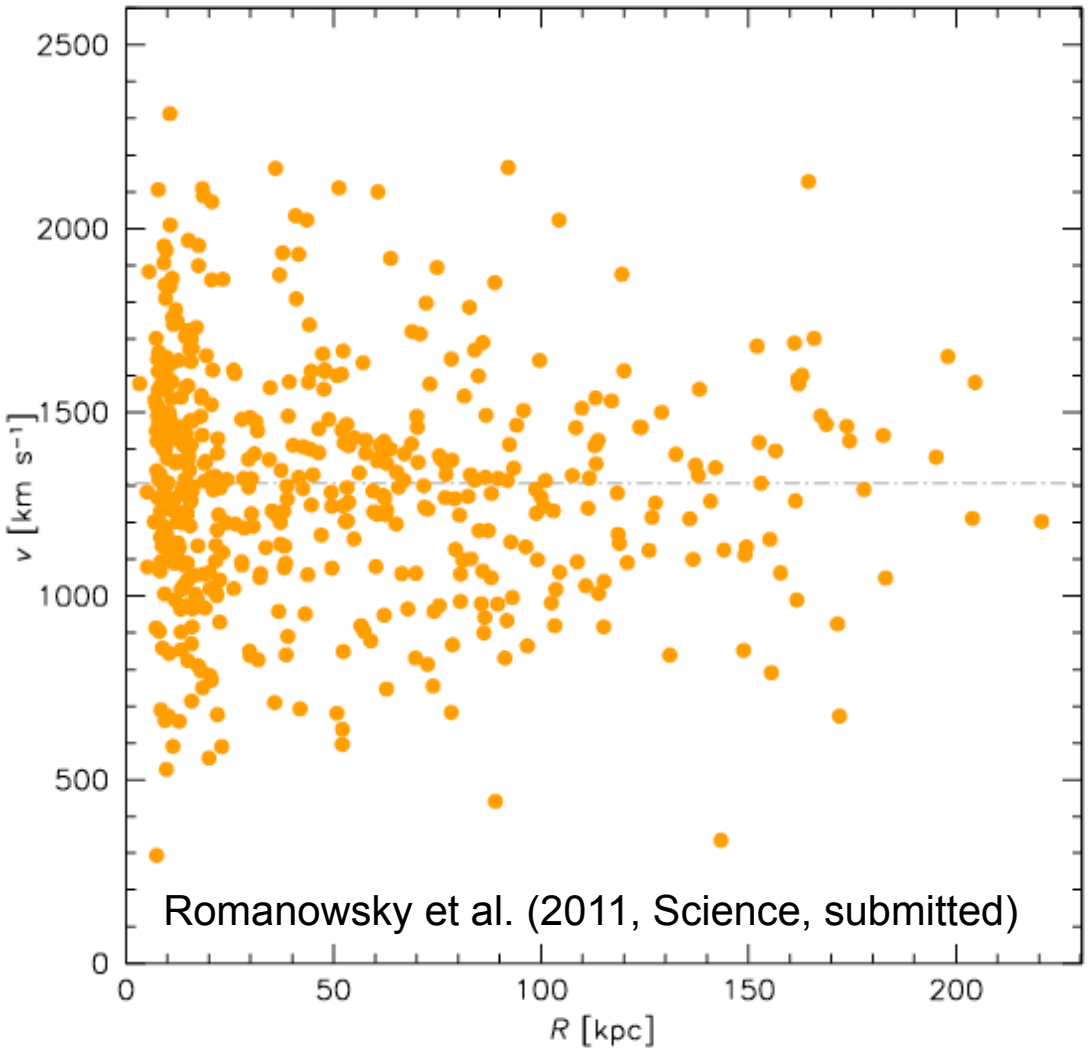


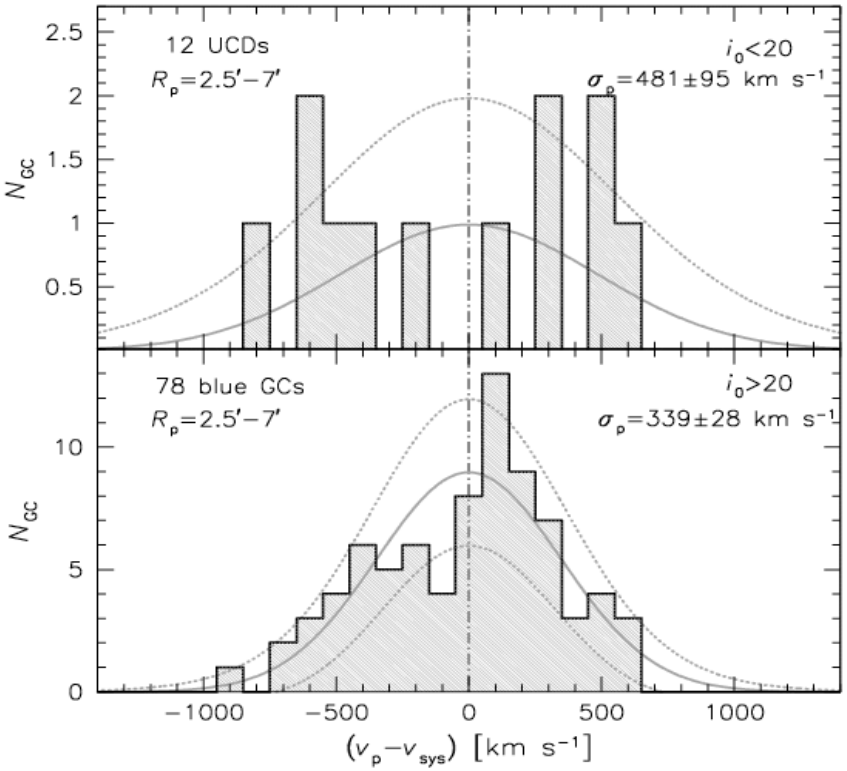
No size-L relationship!



Slide taken from J. Brodie's presentation at the ESO Workshop on `Dynamics of Low-Mass Stellar Systems: From Star Clusters to Dwarf Galaxies', Santiago, Chile, April 4-8, 2011

M87: luminosity/size - kinematics connections

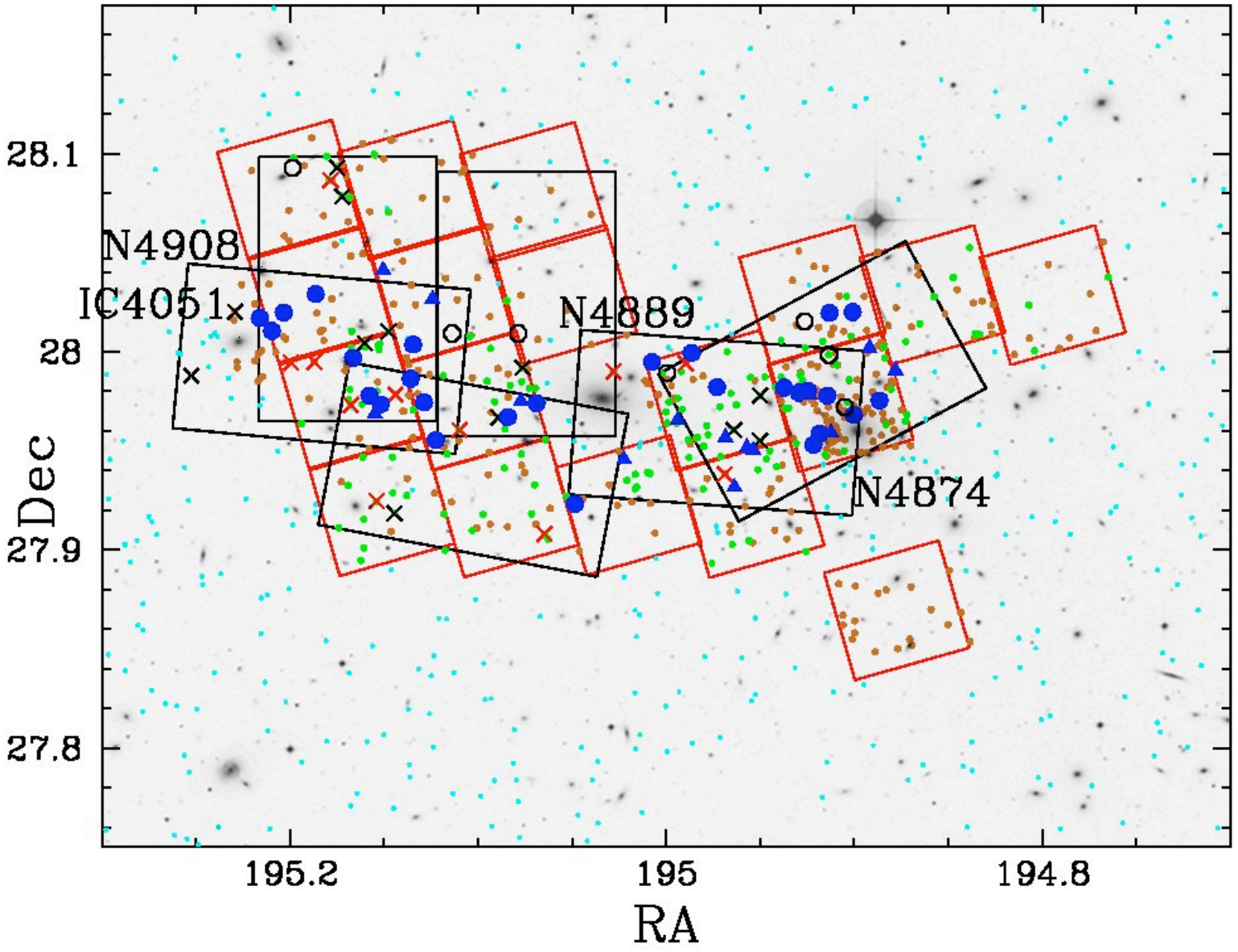




UCDs avoid the systemic velocity (very non-Gaussian velocity distribution)

Taken from A. Romanowsky's presentation at the ESO Workshop on `Dynamics of Low-Mass Stellar Systems: From Star Clusters to Dwarf Galaxies', Santiago, Chile, April 4-8, 2011

UCDs in the Coma cluster



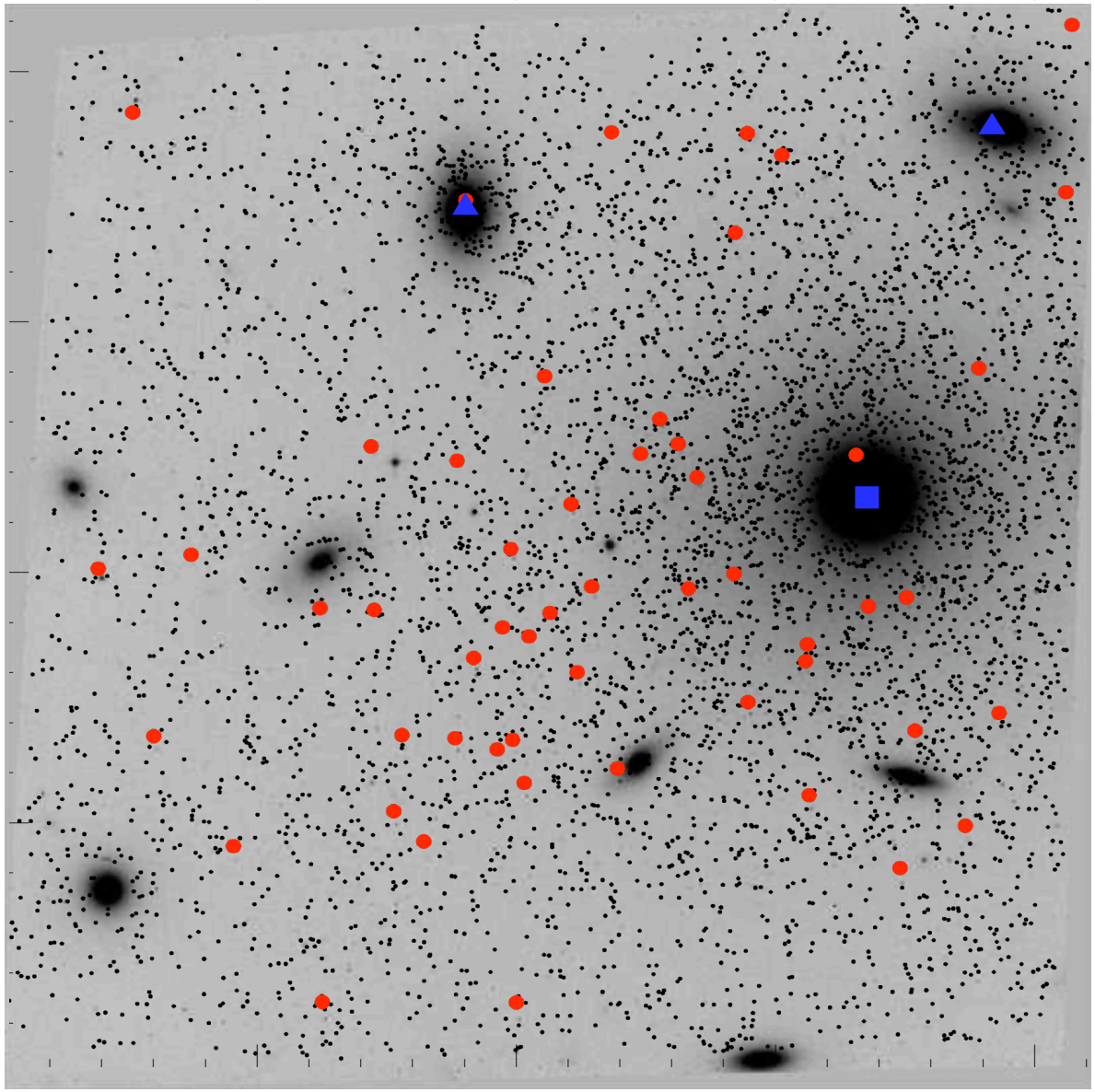
HST/ACS Coma Cluster Treasury Survey (red boxes)

Keck/LRIS spectroscopy (black boxes)

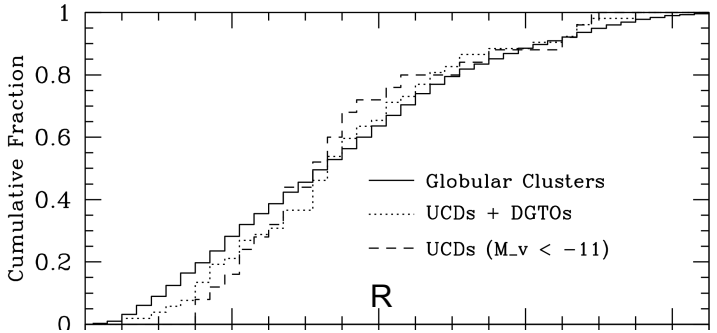
Blue dots: 27 confirmed UCDs with M_R<-12 mag

Chiboucas et al. (2010)

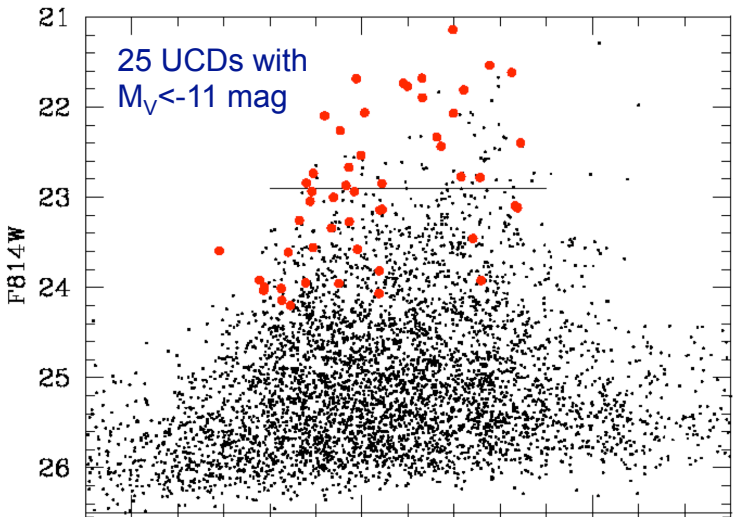
UCDs around the central Coma gE NGC 4874



Radial distribution of GCs and UCDs

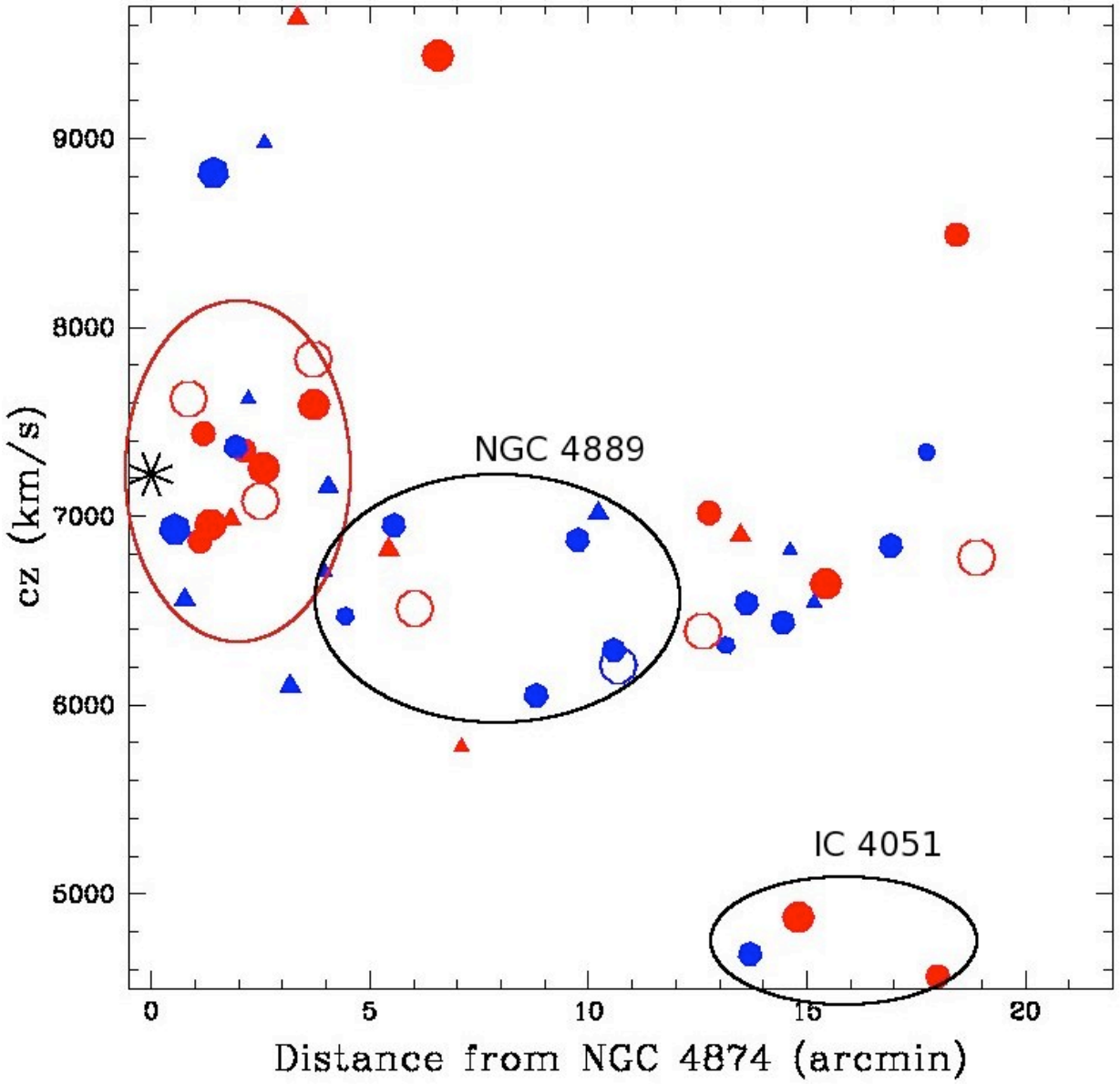


UCDs avoid the very central region (R<15 kpc)



Madrid et al. (2010)

Kinematics of UCDs in Coma



Blue symbols:
(V-I) < 1.05 mag

Red symbols:
(V-I) > 1.05 mag

Open circles:
Compact dEs (cEs)

Most UCDs and cEs are kinematically related to major galaxies or Coma cluster substructure

Chiboucas et al. (2010)

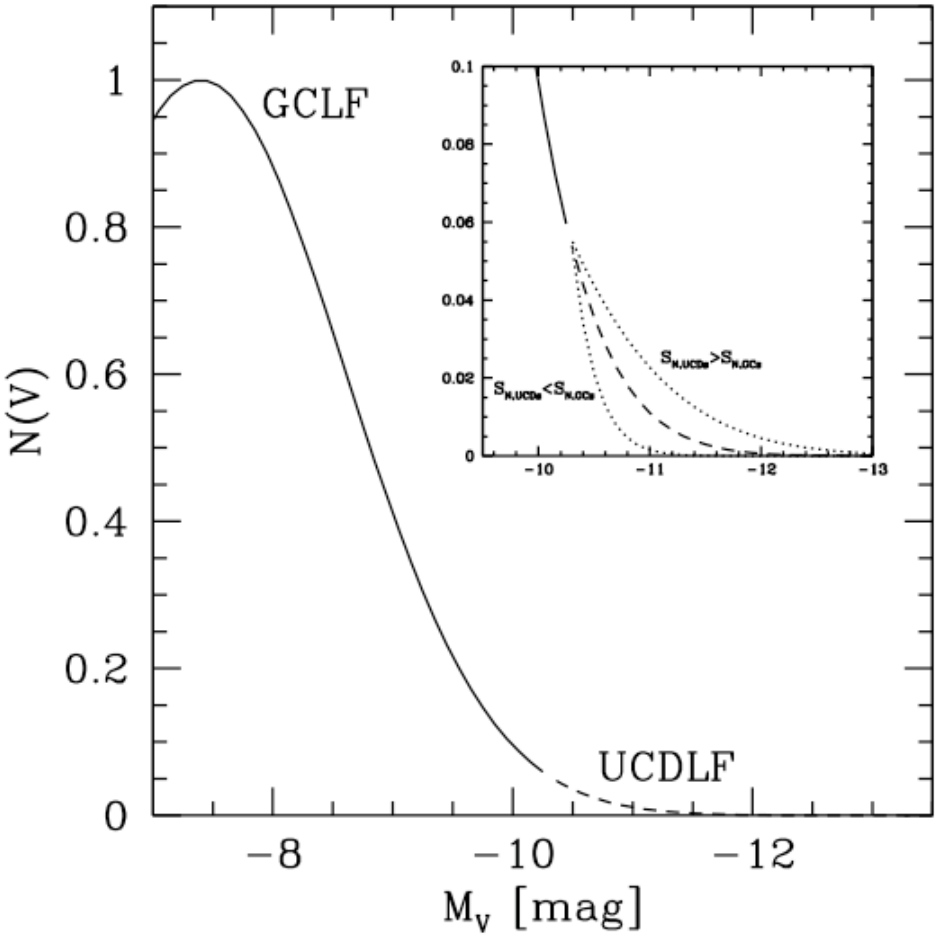
The UCD populations in comparison:

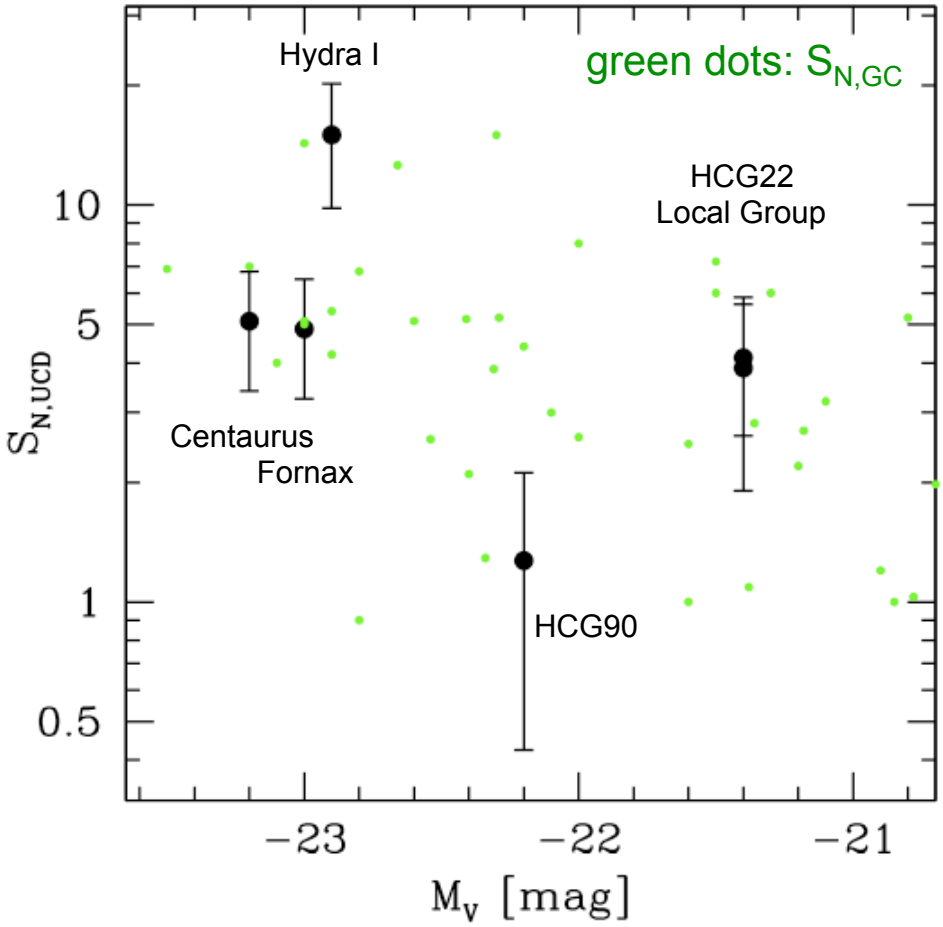
Cluster	D [Mpc]	R_c [kpc]	N_{UCD} all	N_{UCD} <100kpc	N_{UCD} <0.5R_c	$N_{>\omega Cen}$ all	$N_{>\omega Cen}$ <R_c	C_{UCD} <R_c
Fornax	20	100	59	34	20	154	106	~80%
Hydra I	42	350	38	31	26	65	56	<50%
Centaurus	46	220	28	20	22	(30)	(22)	<40%
Virgo	15	350	>28	>25	>20	?	?	?
Coma	100	270	>27	>20	>18	?	?	?

UCDs: $M_V < -11$ mag

>ωCens: $M_V < -10.4$ mag

The specific frequency of UCDs





$$S_{N,UCD} = N_{UCD} \times 10^{\,0.4 \times (\,M(V,host) - M(V,0)\,)} \times c_w$$

accounts for lost galaxy luminosity-width of GCLF relation

$S_{N,UCDs}$ follows $S_{N,GCs}$!!

Mieske, Hilker & Misgeld (2011, in prep.)

Summary

- `UCDs' are defined through their mass-size relation and enhanced dynamical mass-to-light ratios – roughly occurring at >2x$10^6 M_\odot$
- `UCDs' share properties of nuclear star clusters, e.g. the mass-size relation, but also are the "tip of the iceberg" of rich globular cluster systems → they are mostly of `star cluster origin'
- UCDs are mostly concentrated around major galaxies but also are found in the intra-cluster space, they do not follow the spatial distribution of nucleated dEs
- The specific frequency of UCDs follows that of GCs, i.e. a large UCD population is expected in rich globular cluster systems → the formation of UCDs is linked to that of GCs
- Still the studies of the UCD population in nearby clusters suffer from incompleteness effects – more spectroscopic surveys are needed