Kinematics of Globular Cluster Systems of elliptical galaxies

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List of early-type galaxies with more than 117 GC velocities

NGC 1399	700	Schuberth et al. 2010
NGC 5128	605	Woodley et al. 2010
NGC 4636	238	Lee et al. 2010
	460	Schuberth et al. 2011
		(in the revision process)
NGC 4486	278	Côté et al. 2001
NGC 4472	263	Côté et al. 2003
	393	Zepf et al. 2010
NGC 1407	172	Romanowsky et al. 2009
NGC 4694	121	Hwang et al. 2008
NGC 3311	118	Richtler et al. 2011
		Misgeld et al. 2011
NGC 4374	287	Kumar et al. 2011 ???
NGC 1316	160	Kumar et al. 2011 ???

Globular cluster system kinematics?

Mass profile of the host galaxy
in combination with other tracers:
stellar light, PNe, X-rays

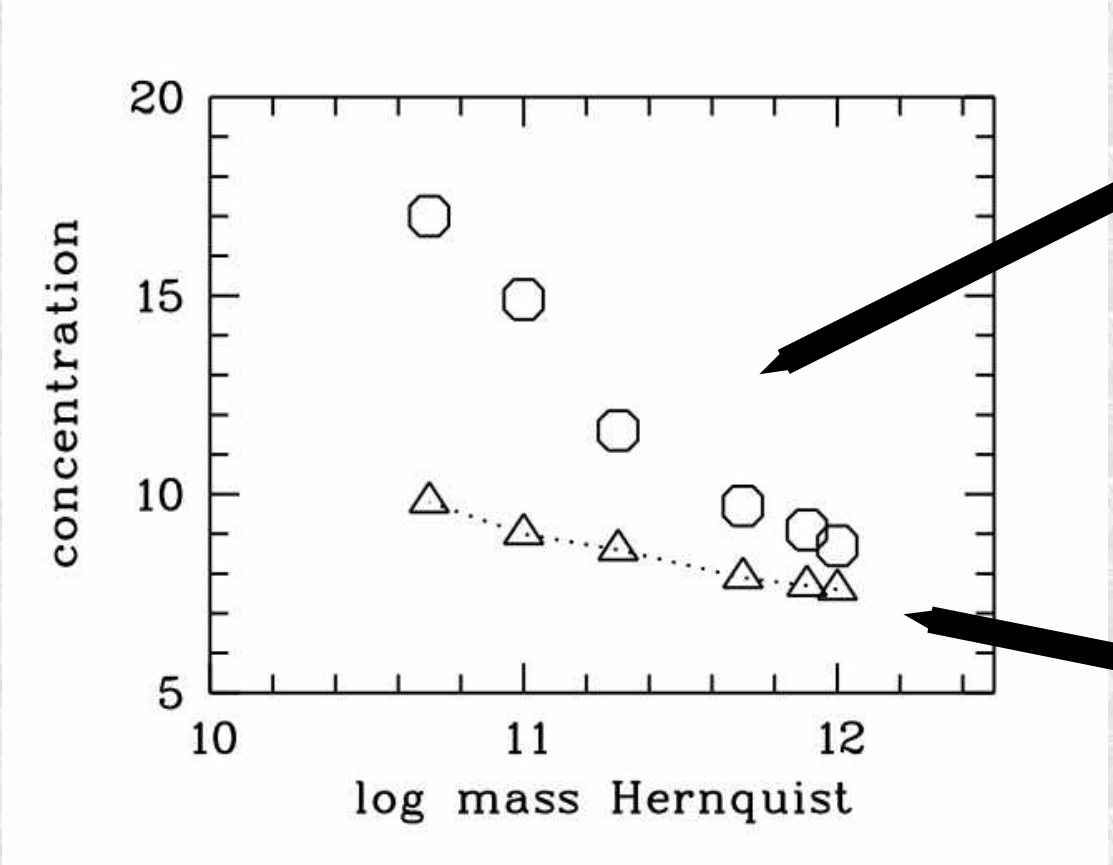
-> test LCDM predictions
-> test alternate gravity concepts

GC subpopulations
in combination with age, metallicity

Clues to their origin

Can we distinguish LCDM halos from, say,
MONDian phantom halos by using globular clusters ?

Concentration r_s/r_{virial} vs. mass of galaxy models



Phantom halos
Fitted with NFW profiles
(Richtler et al. 2011)

Cosmological halos
(Maccio et al. 2008)

A look onto the halo of M87

Huchra & Brodie 1987 - 10 GCs --> projected mass estimator

Murphy et al. 2011 stellar light + GCs (Côté et al. 2001 sample)
--> state-of-the-art-modeling

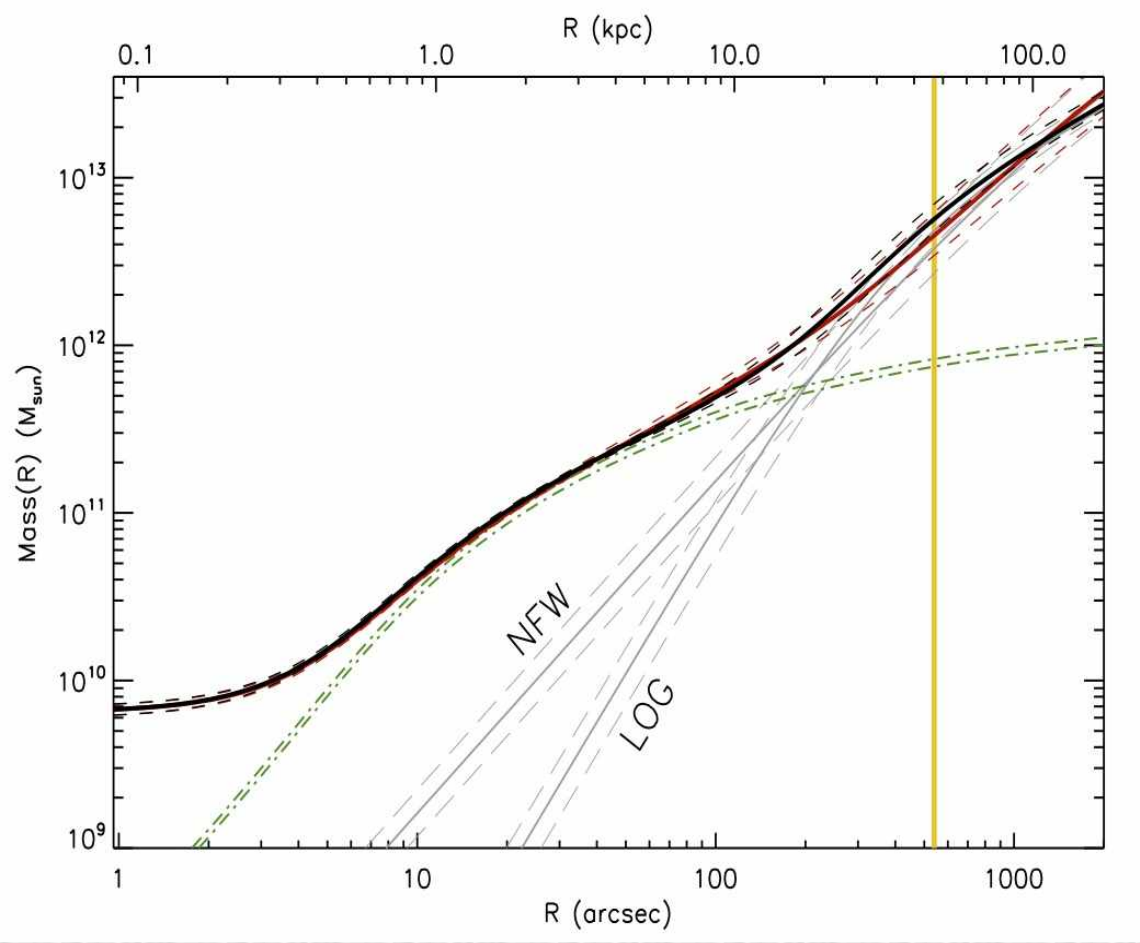
Huchra, Brodie: (6.1±2.2) 10^{12} $M_\odot$ inside 18.8 kpc

Murphy, Gebhardt, Adams: (1.6±0.3) 10^{12} $M_\odot$ inside 21.4 kpc
(logarithmic halo)

log-halo $$\rho(r) = \frac{v_0^2}{4\pi G} \frac{3r_0^2 + r^2}{(r_0^2 + r^2)^2}$$ cored halo

NFW-halo $$\rho(r) = \frac{\rho_s}{\left(\frac{r}{r_s}\right)\left(1 + \frac{r}{r_s}\right)^2}$$ cuspy halo

Murphy, Gebhardt, Adams 2011-Fig.12



Mvir = 1.6 10^{14} $M_{\odot}$

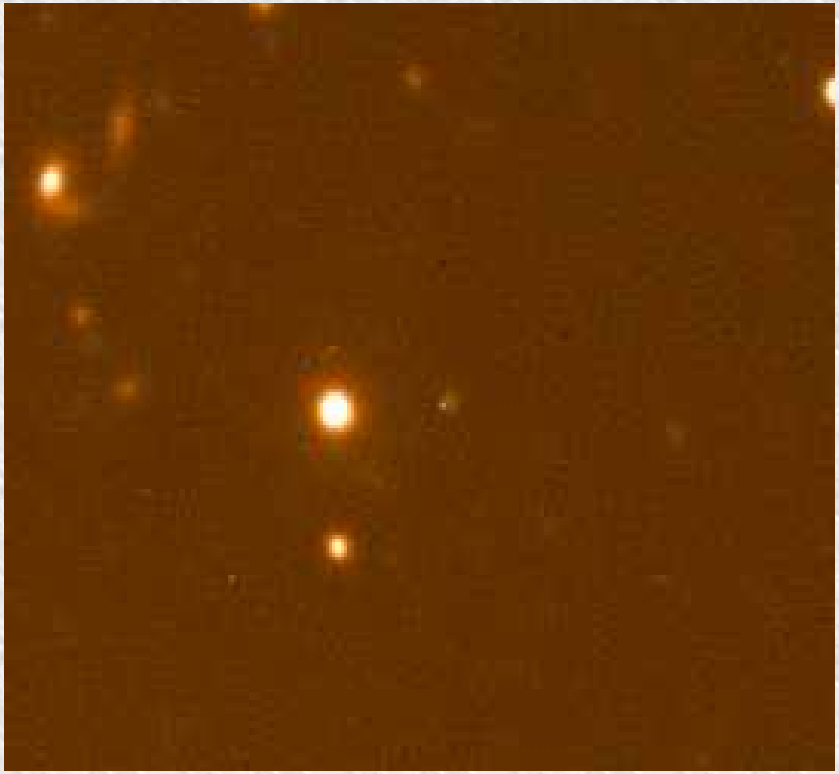
Rvir = 1.1 Mpc

c = 4.5 expected 4.1
(Maccio et al. 2008)

Cosmological cluster halo

-- NFW halo badly constrained, log halo fits better

NGC 1399 – central giant elliptical in the Fornax cluster

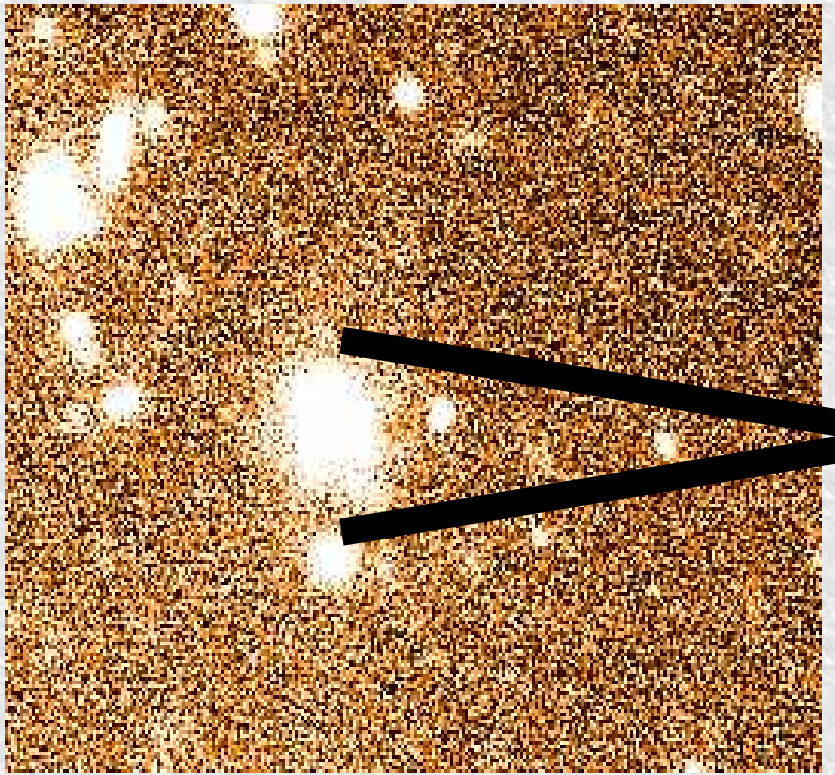


shallow exposure
--> globular cluster

$M_R \approx -11.4$

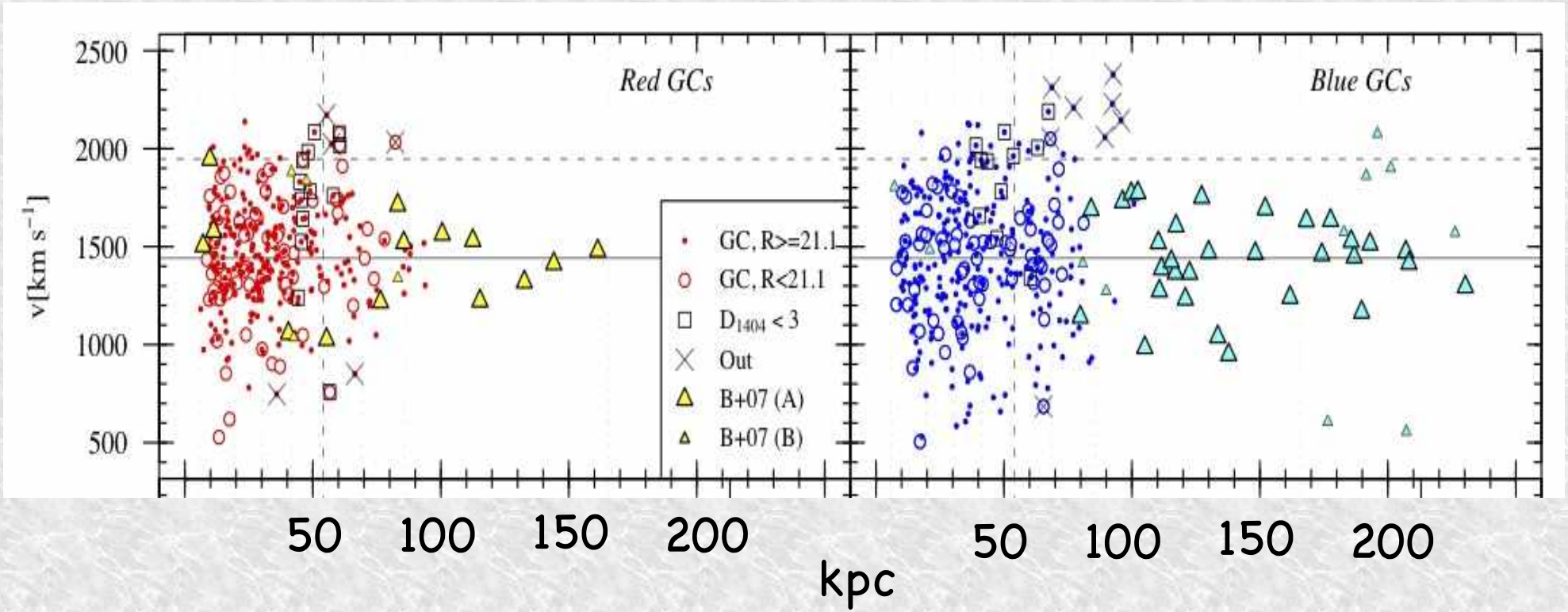
C-T1 ≈ 1.26

deep exposure
---> nucleus+ faint halo
with structure
diameter 0.6 kpc



The dark halo of NGC 1399

Schuberth et al. 2010 + Bergond et al. 2007 + stellar light (Saglia et al. 2000)



Spherical Jeans models

Mvir = 5.6 10^{12} $M_\odot$

Rvir = 370 kpc

c = 26, expected 5.7

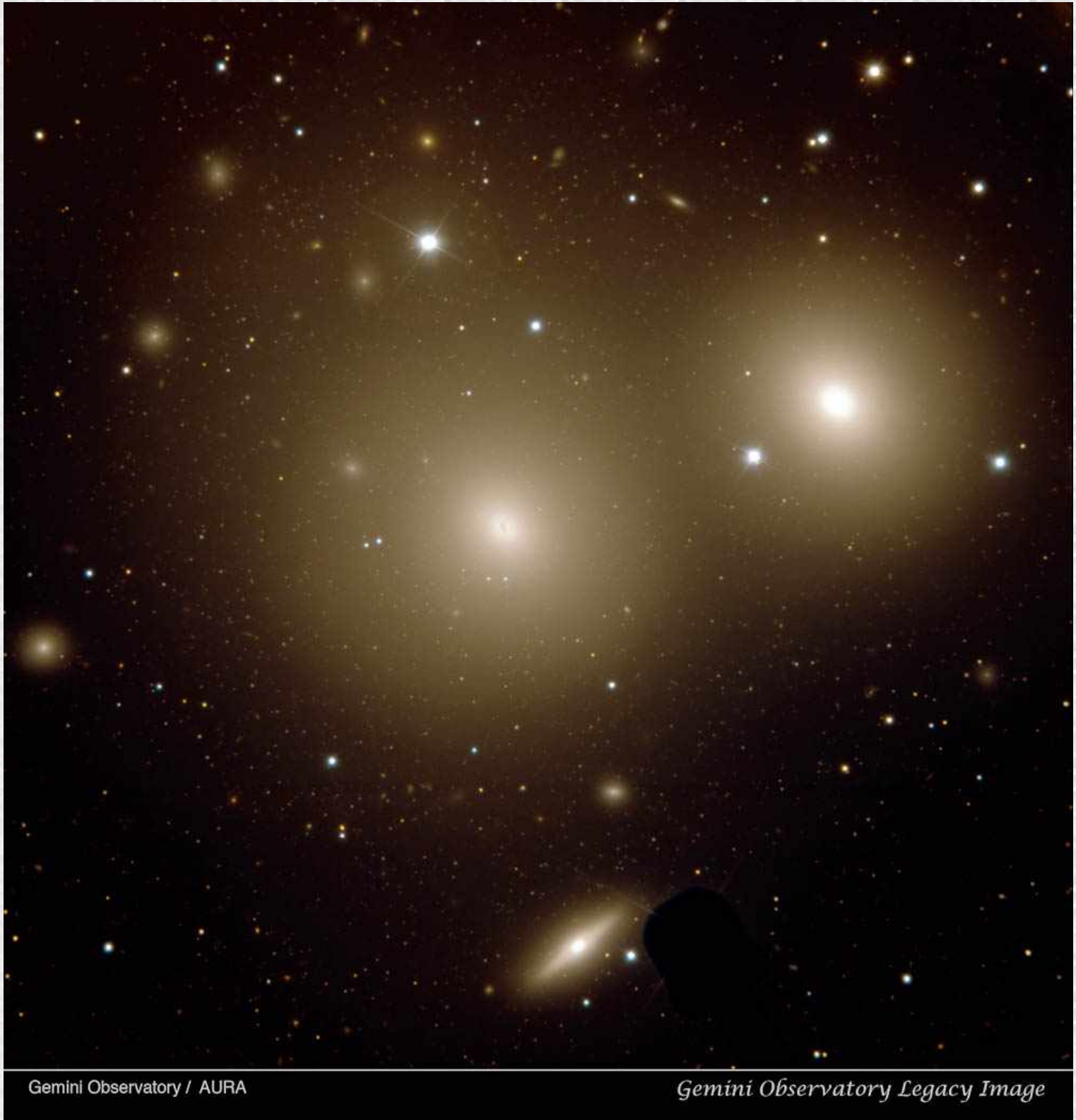
not cosmological

Mvir = 1.7 10^{13} $M_\odot$

Rvir = 536 kpc

c = 10.7. expected 5.1

not cosmological



Gemini Observatory / AURA

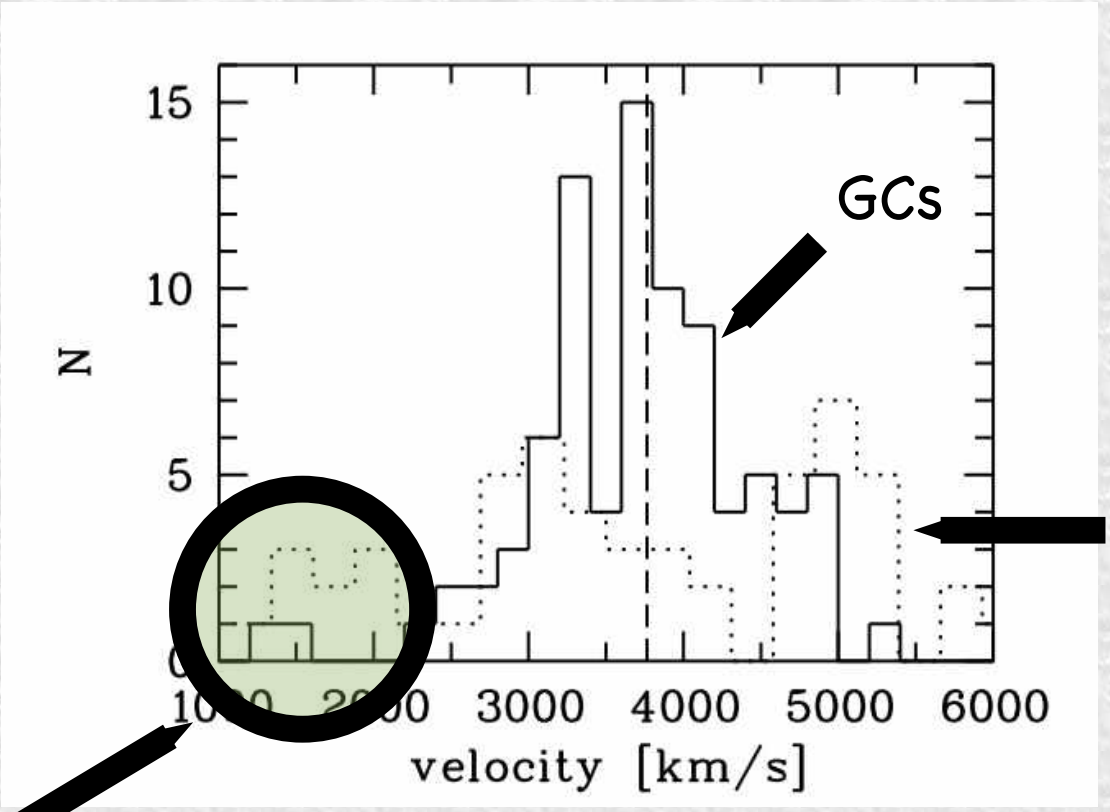
Gemini Observatory Legacy Image

The case of NGC 3311 – central galaxy of Hydra I – 50 Mpc

Misgeld et al. 2011, Richtler et al. 2011

118 globular clusters – UCD's $M_V < -11$ (VIMOS)

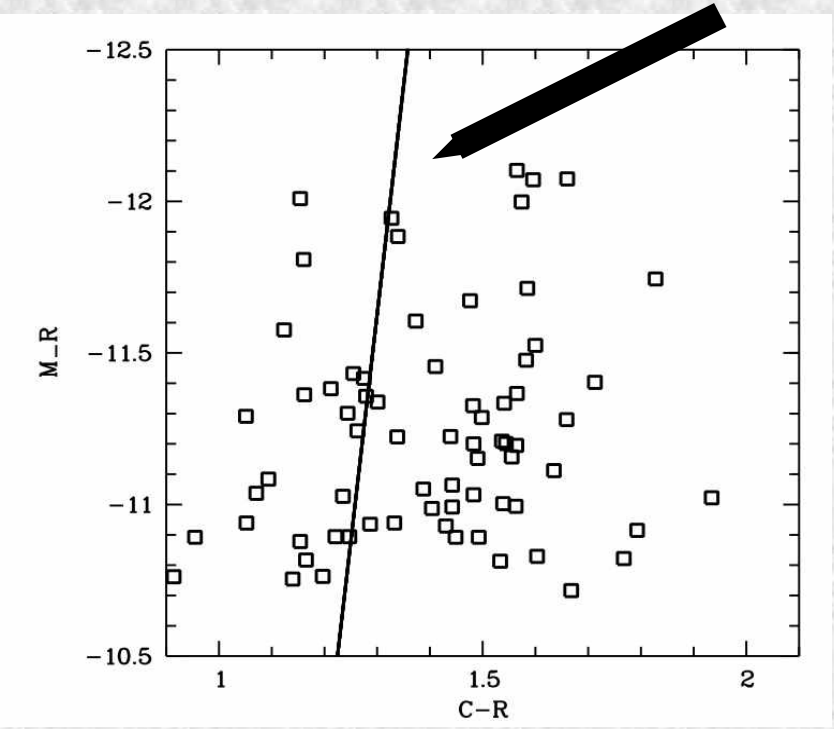
Cluster population or galaxy population?



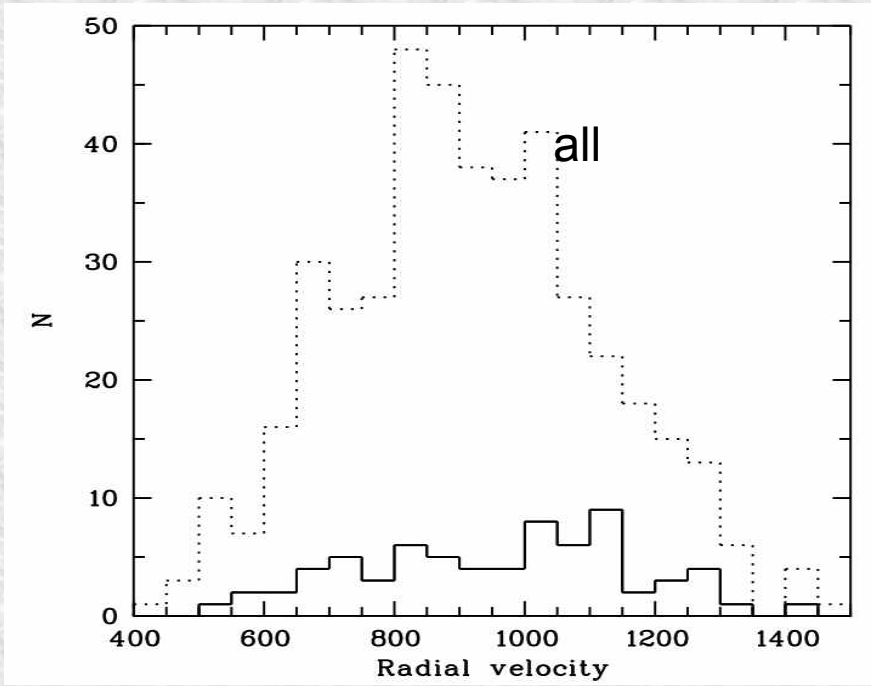
Planetary nebulae
Ventimiglia et al. 2011

Brief interlude: NGC 4636 Schuberth et al. 2011

Magnitude-color relation for dwarf galaxies (Smith-Castelli et al. 2008)



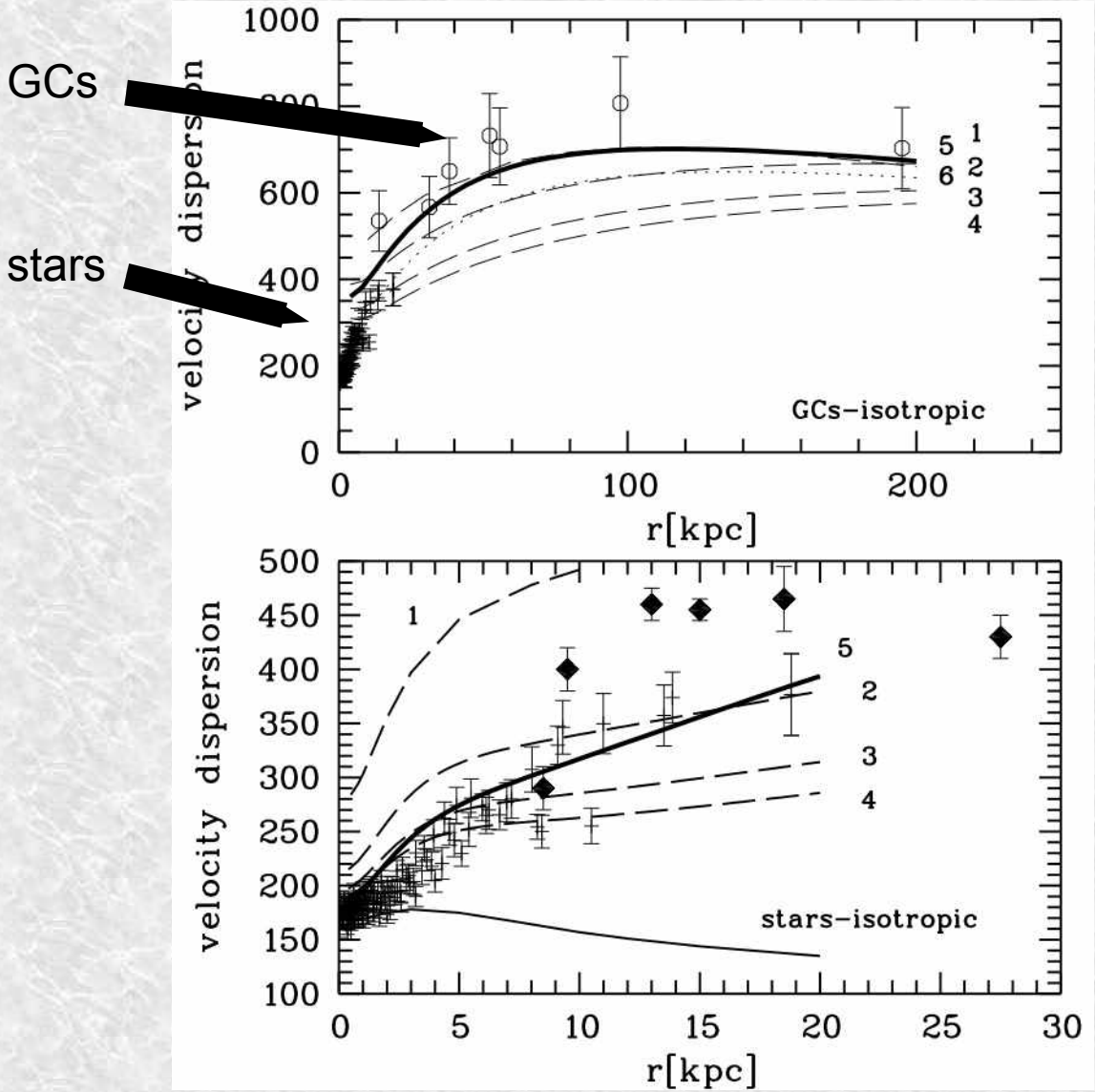
CMD for bright clusters



Velocity histogram for bright clusters

Galaxy cluster environment for producing UCDs not necessary !

NGC 3311 – find a halo which accounts for both GC and stellar Kinematics (long-slit, R. Salinas)



Halo 5 – cored-halo

$$\rho(r)=\frac{\rho_0}{(1+r/r_s)(1+r^2/r_s^2)}$$

Halo 2 – NFW halo

Mvir = 4 10^{14} $M_\odot$

Rvir = 1.5 Mpc

c = 5.3

more or less cosmological

Extreme velocities in galaxy clusters

Hydra I - offsets by 2700 km/s
Fornax - offsets by 800 km/s

Assumptions: Doppler velocities(!!), full space velocity near pericenter

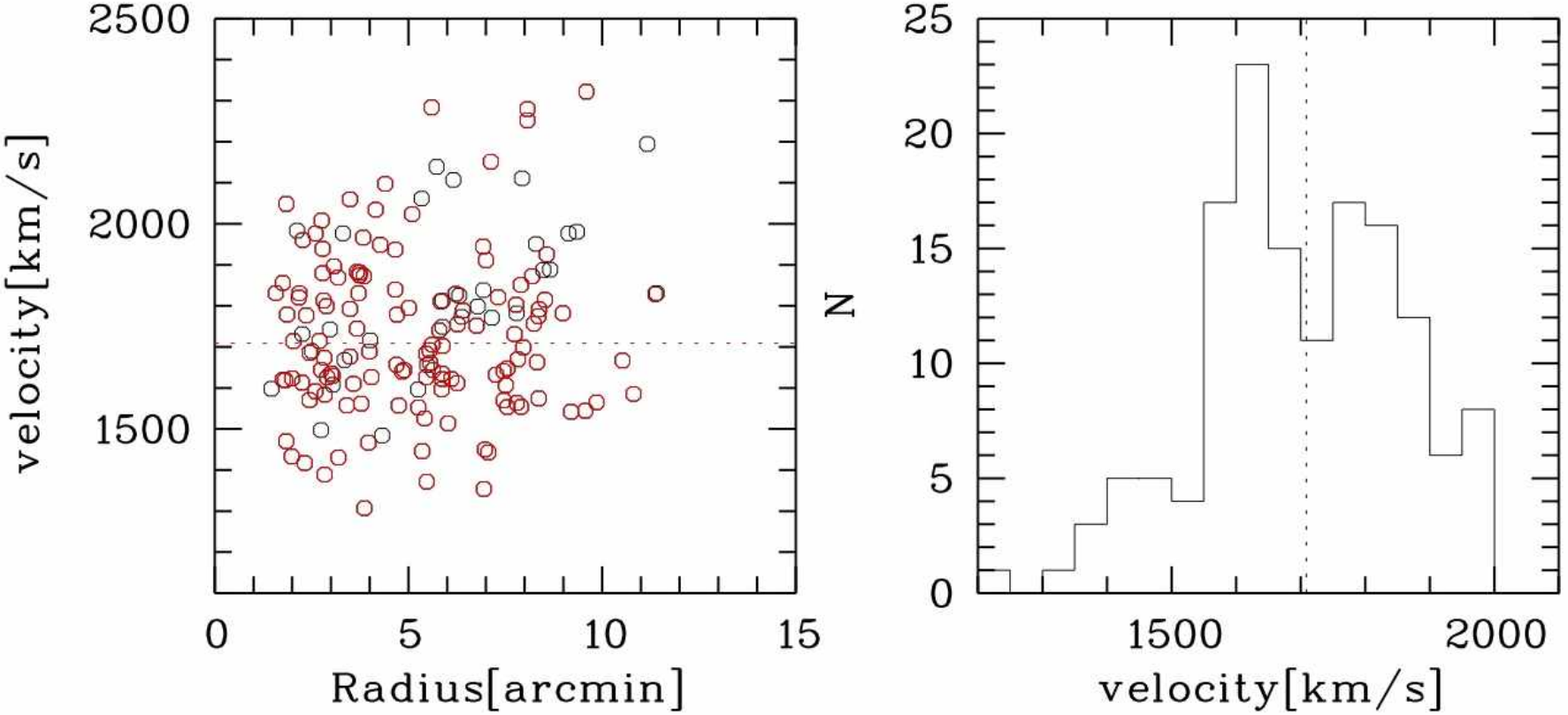
--> possible but with large apocenters
-- for Hydra object 1.2 Mpc, orbital period 2.9 Gyr
Mostly blue GCs --> intracluster population of unknown fraction, but must be significant!

NGC 1316 (Fornax A) – a 3 Gyr old merger remnant
Kinematics of 24 inner GCs (Goudfrooij et al. 2001)

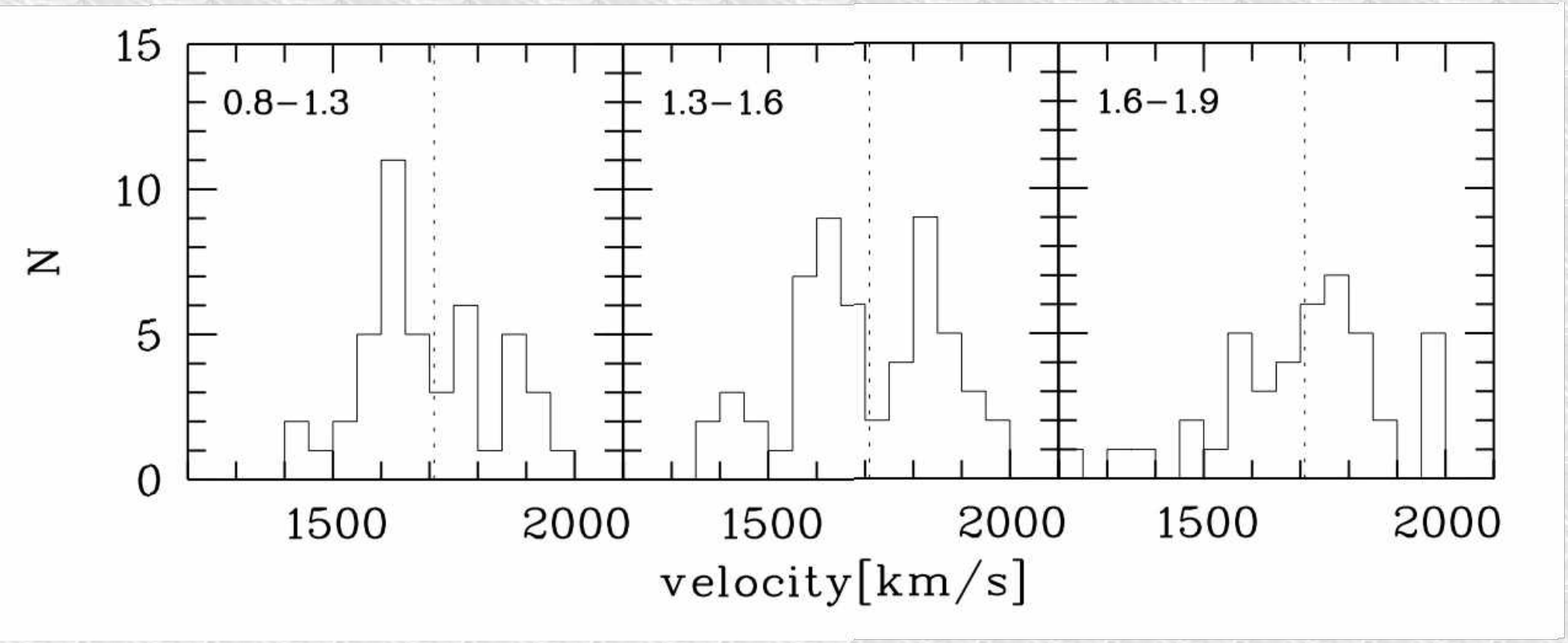
$3 < m/L_B < 6$

Dark halo?

160 radial velocities, 130 with Washington colors



Velocity histograms in 3 color bins



Old metal-poor
+ young (< 1 Gyr)

Intermediate age (2 Gyr)
Supersolar metallicity
+ old, intermediate
metallicity

Old metal-rich

Future objects

massive and less massive field ellipticals:

e.g. NGC 7507 (Salinas et al. 2011)

Long-slits --> intermediate-age

no or very little dark matter

group galaxies:

NGC 5846 , Antlia galaxies

NGC 7507 – an elliptical field galaxy without dark matter?

Summary of a hypothetical review

--- metal-rich red globular clusters share kinematic properties of the bulge population

---> formation in the starburst(s) forming the bulge

--- metal-poor clusters divided into subgroups

1) prior to starburst -> shares kinematical properties with metal-rich clusters

2) accretion --> higher velocity dispersion

--> shallower number density profile

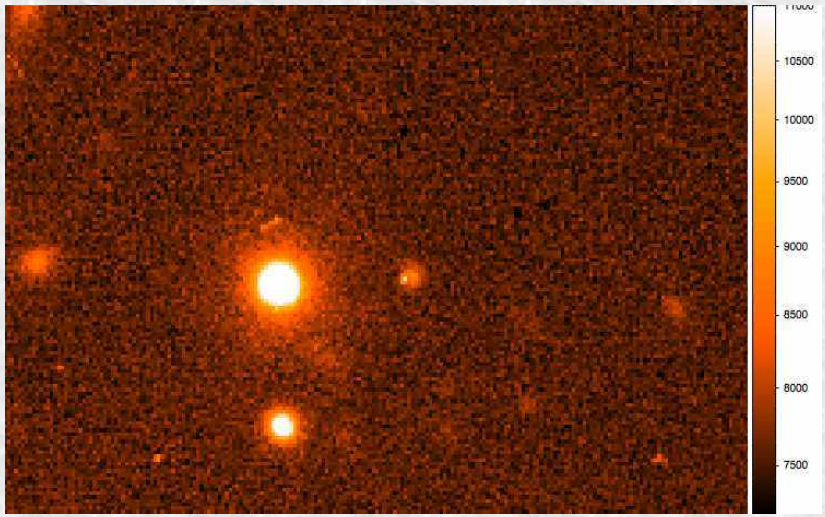
3) central galaxies -> intracluster population kinematically decoupled

dark halos: sometimes cosmological, sometimes not

Alternate gravity: ??????????????????????????

Globular Clusters?
Objects in the NGC 1399 system

78_12



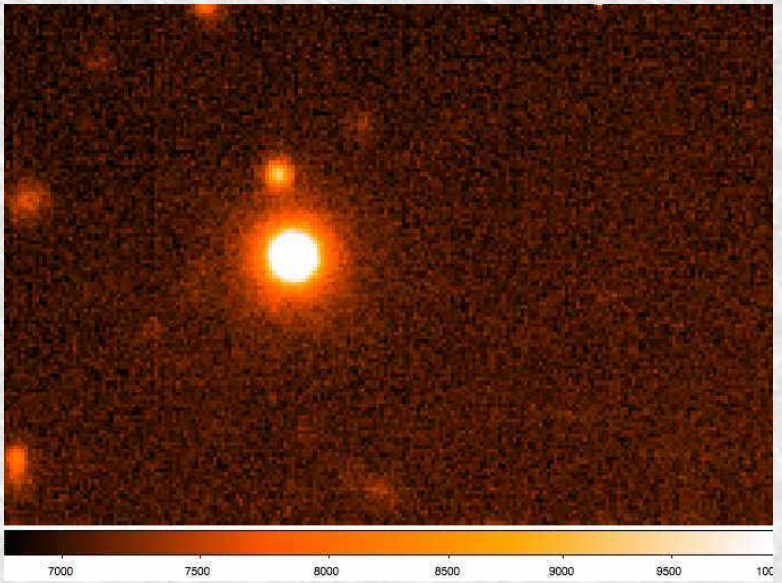
$M_R \approx -11.4$

C-T1 ≈ 1.26

Radius 250 pc

Nucleus with faint halo

80_115



$M_R \approx -11.5$

C-T1 ≈ 1.4

Radius 200 pc

Nucleus with faint halo