A Panoramic View of Globular Cluster Systems in the Virgo and Coma Clusters

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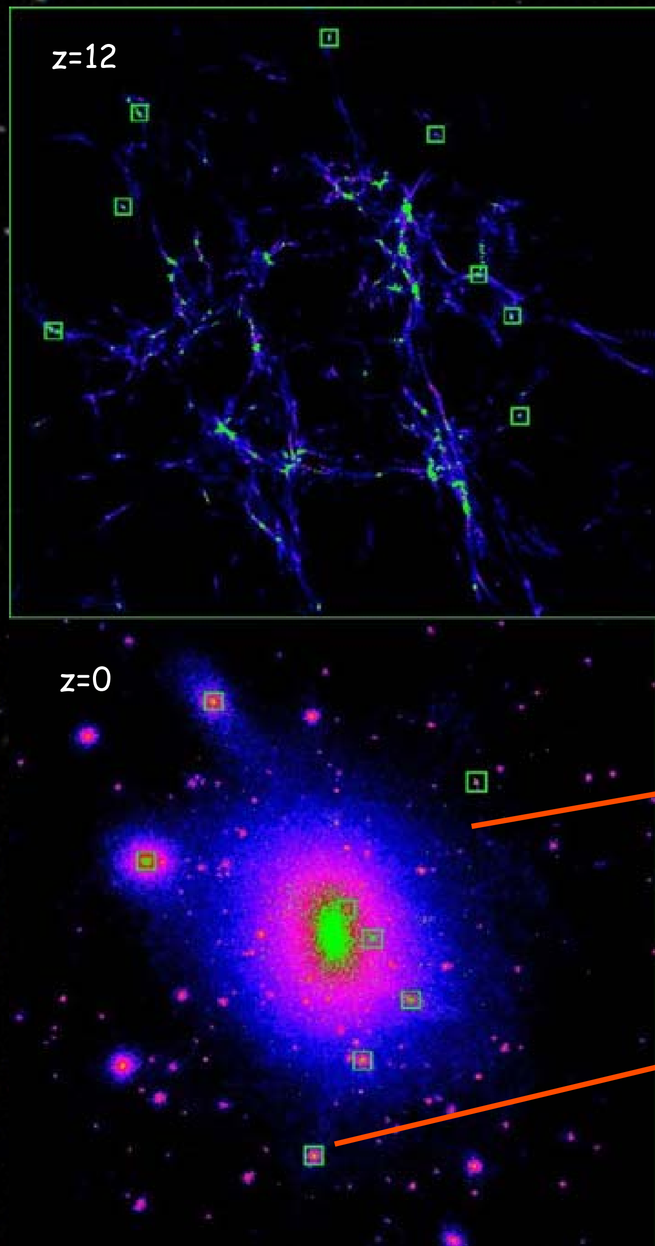
Globular Cluster Systems

- GCs form early in the evolution of galaxies
- Trace early, major epochs of star formation
- Simple stellar populations (mostly)
- Observable out to >100 Mpc, massive systems

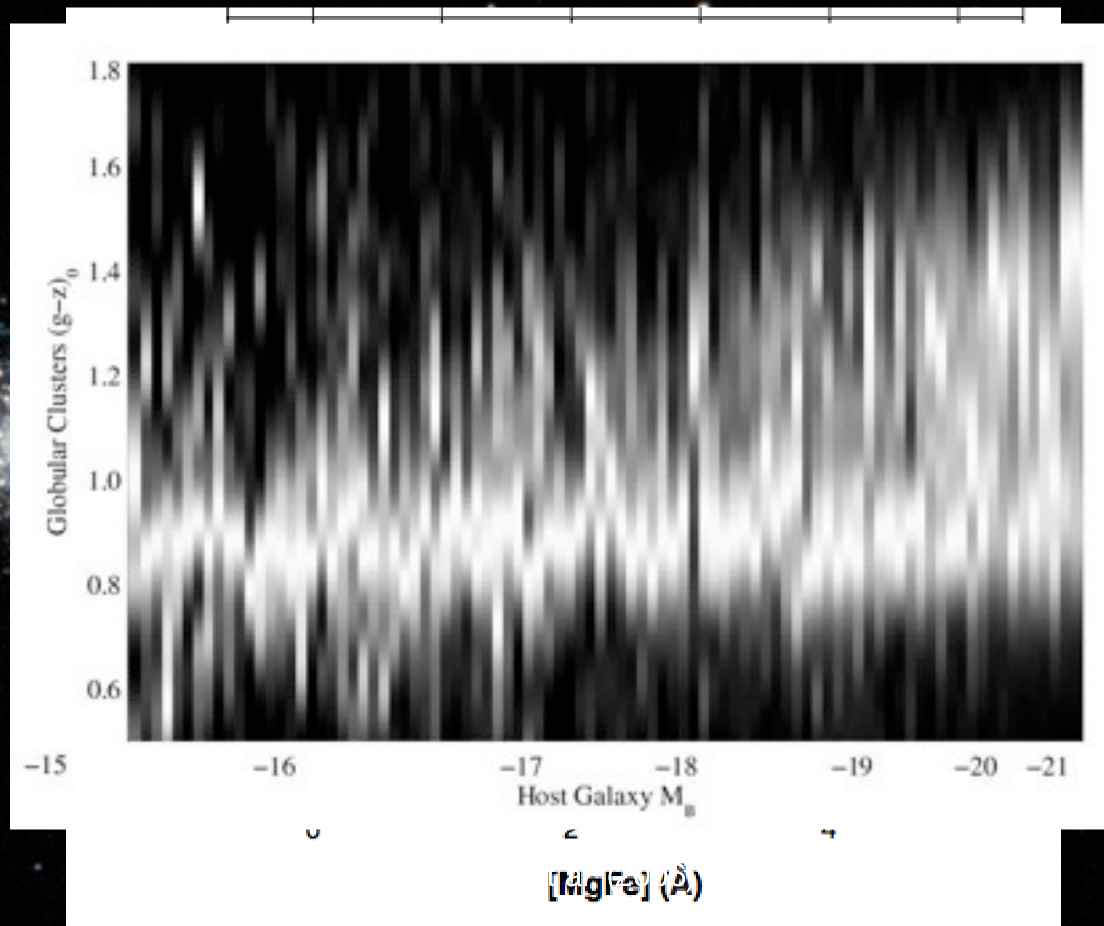


Moore et al (2006)

The Properties of Globular Cluster Systems

- Globular clusters are predominantly old (> 8 Gyr) and metal-poor

- Globular cluster color distributions in massive galaxies are often bimodal, unlike underlying field star metallicity distributions

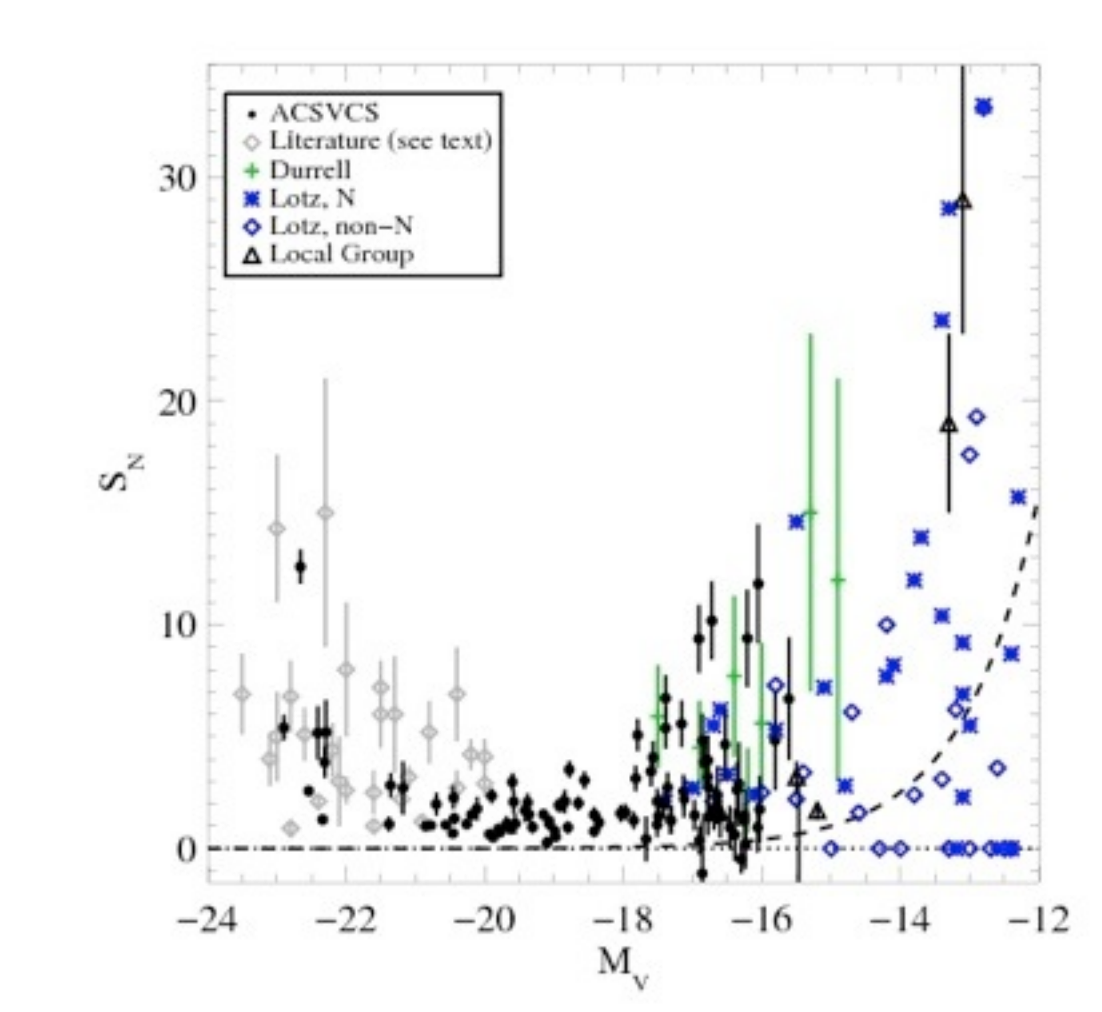


- Is color bimodality metallicity bimodality? See poster by Chies-Santos.
- Metallicity distributions of GC and field stars do not match.

The Properties of Globular Cluster Systems

Specific Frequency: number of GCs normalized to M_V=-15

$S_N = N_{GC} \, 10^{0.4(M_V+15)}$

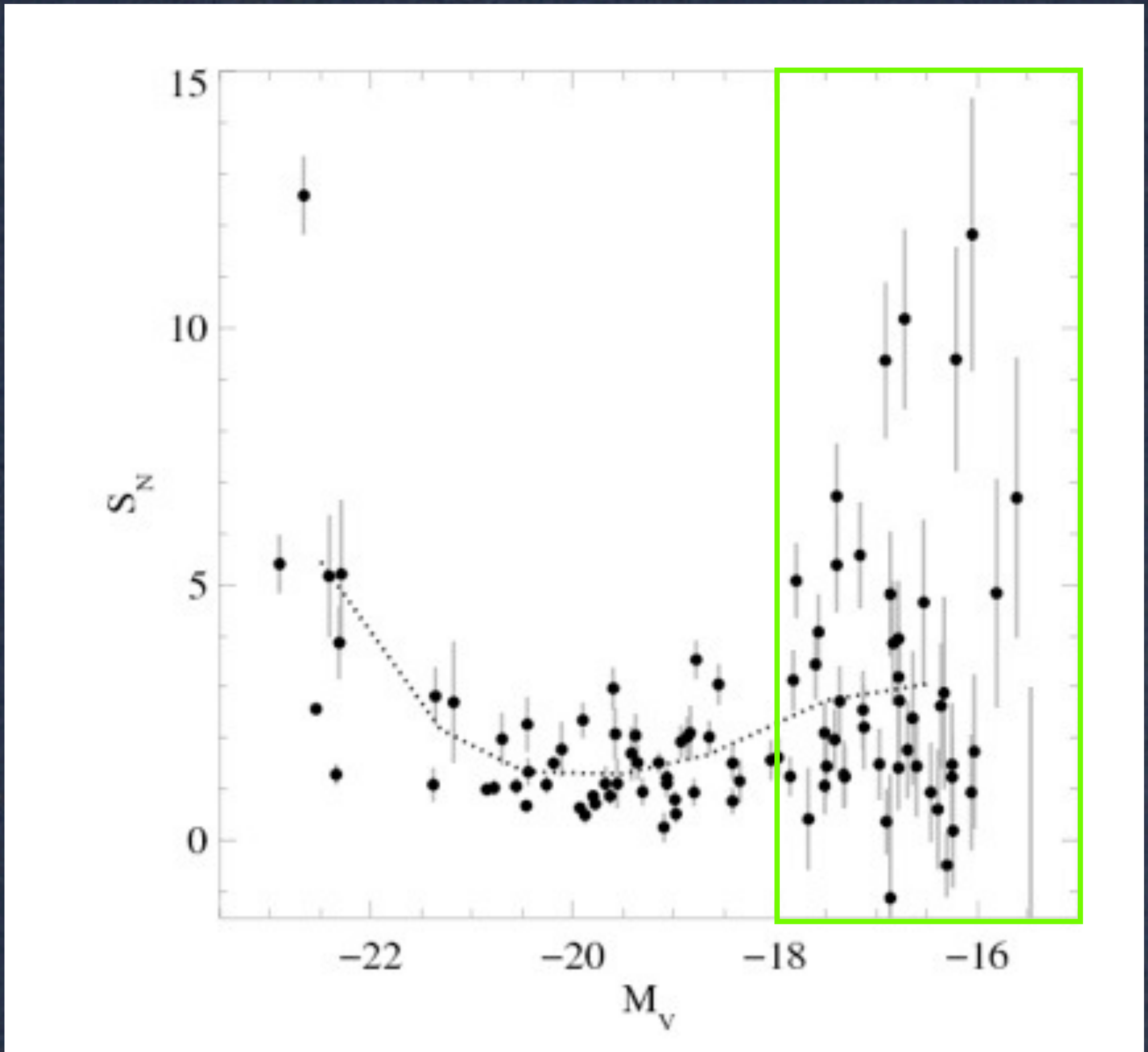


Peng et al. (2008)

Puzzle:

Globular cluster formation efficiency is not constant across galaxy mass

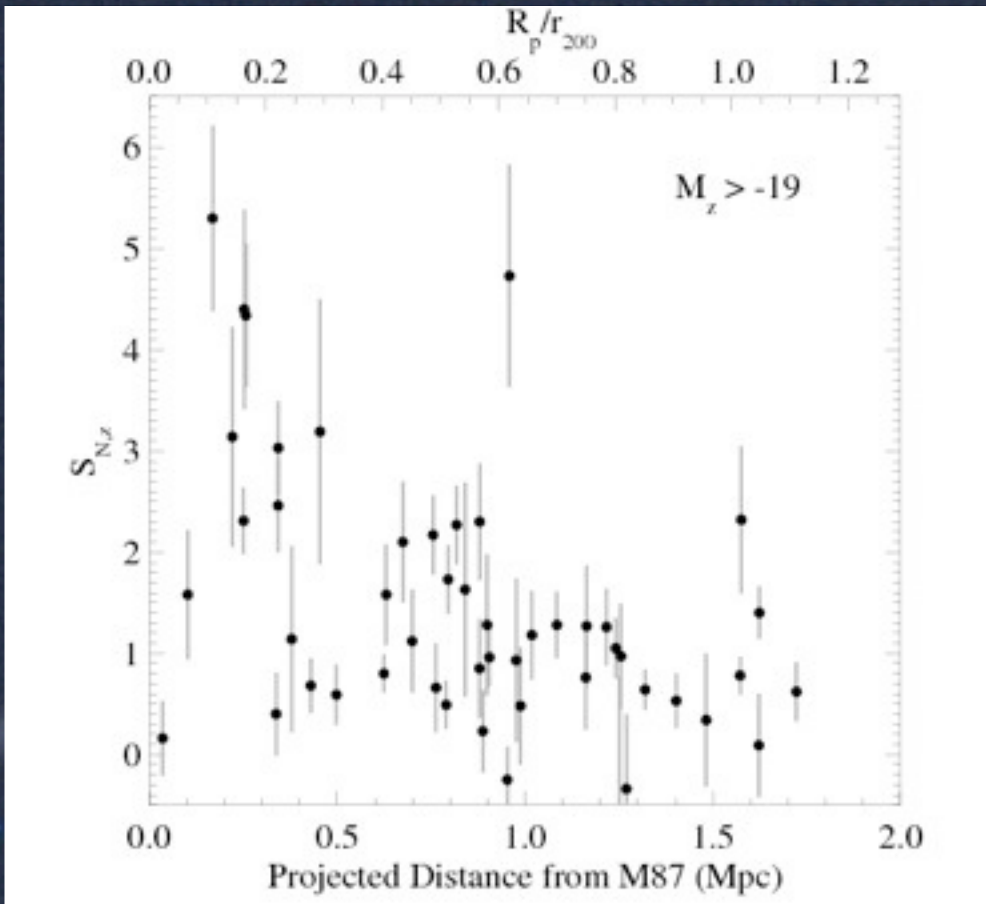
How does GC fraction behave across galaxy mass?



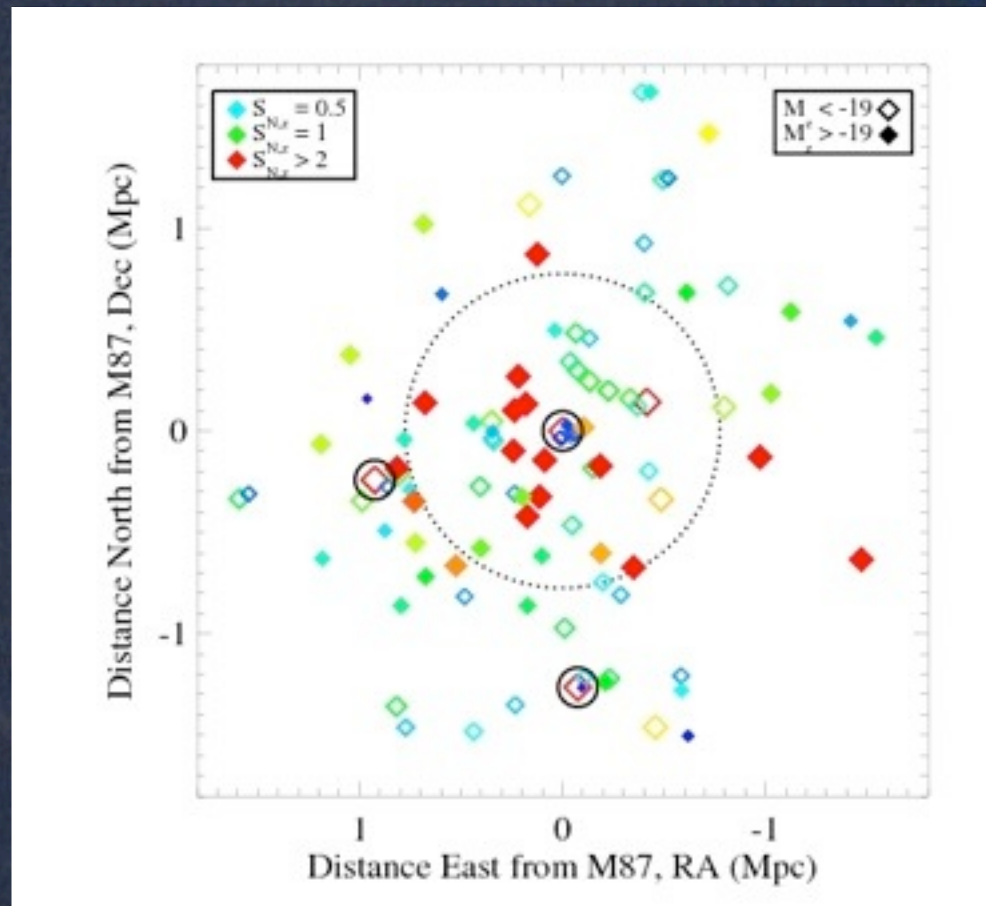
Peng et al. (2008)

- Narrow range of S_N at intermediate L
- High S_N values for both giants and dwarfs

Globular Clusters in dEs: The Role of Environment



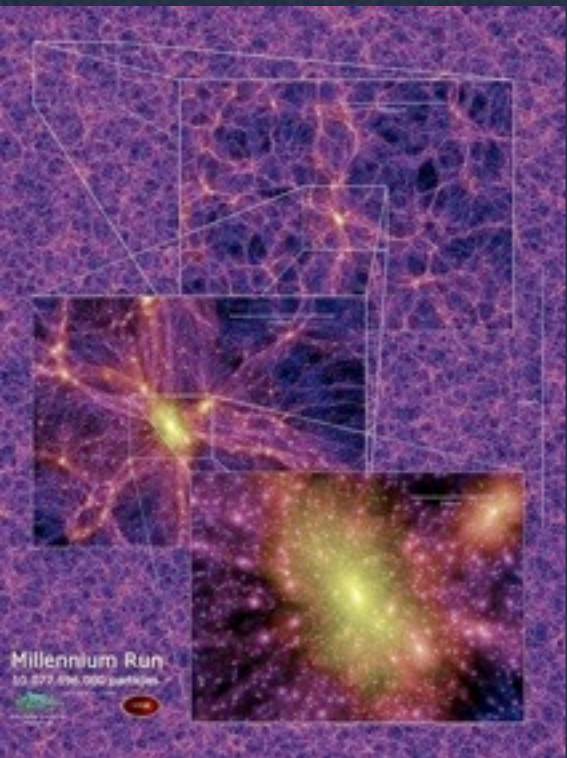
- Dwarfs only: $M_z > -19$
- S_N vs clustercentric distance

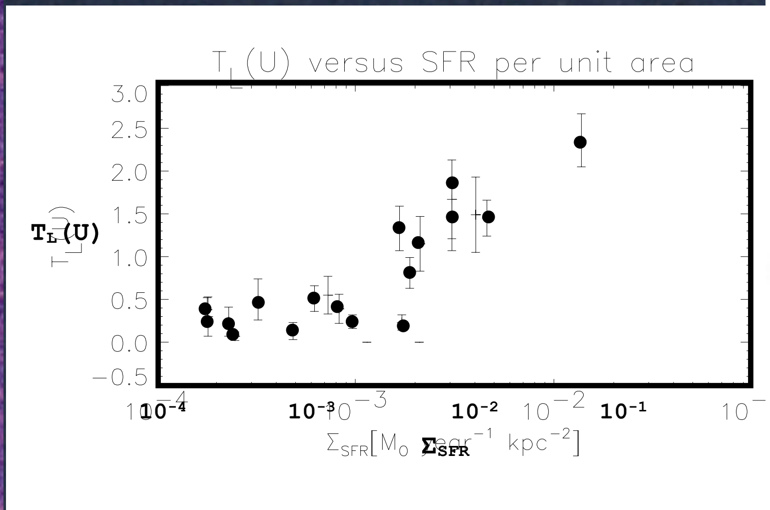


- dEs with high GC fractions are within $D_p < 1$ Mpc
- dEs within 100 kpc, stripped of GCs

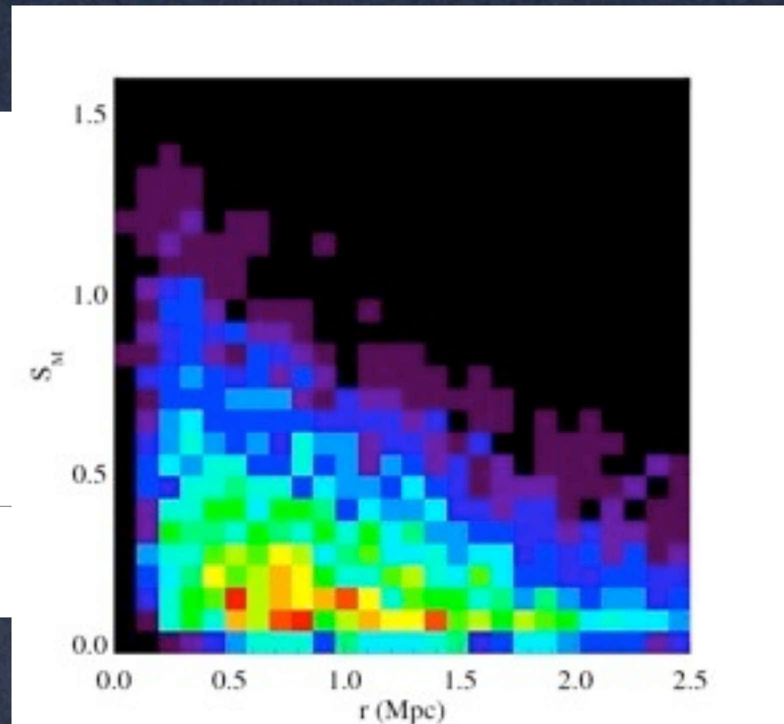
Peng et al. (2008)

The Millennium Simulation:
Early-type cluster dwarfs





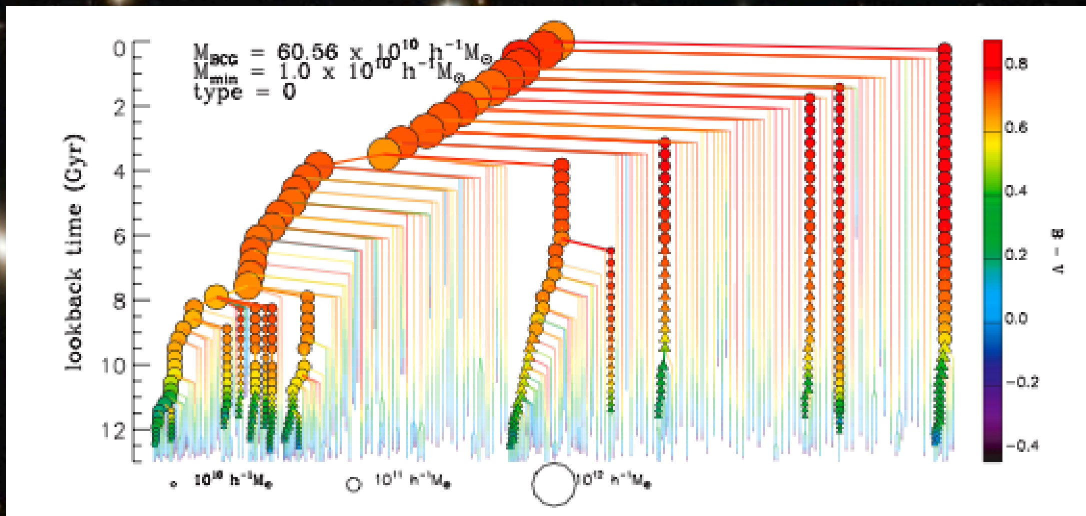
Larsen & Richtler (2000)

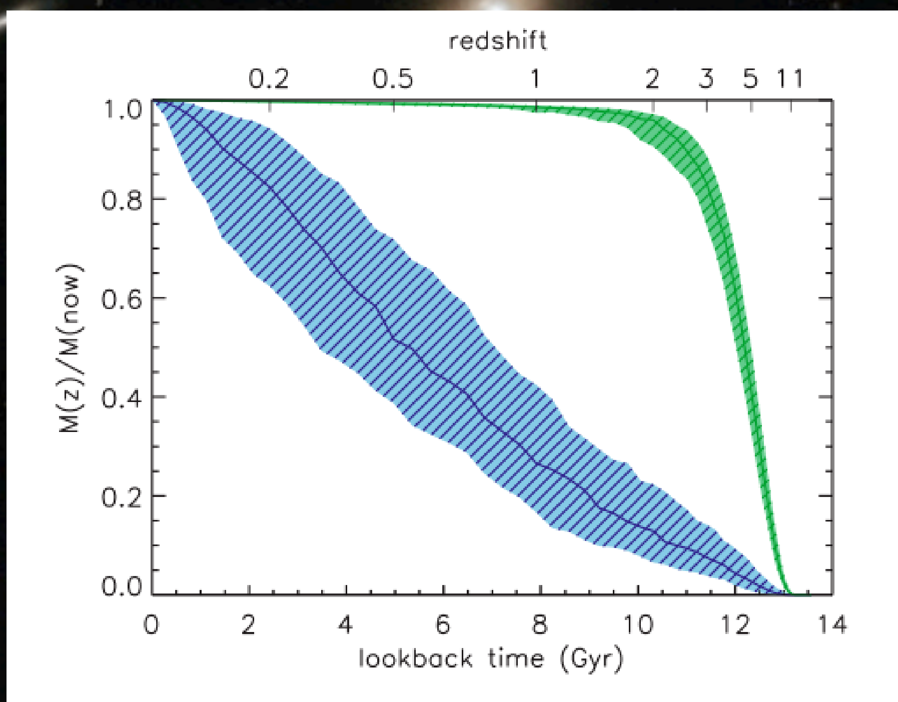


Peng et al. (2008)

Oldest dwarfs are at cluster center and formed GCs at high efficiency because low mass halos in denser environments collapse sooner and smaller.

The Evolution of Massive Galaxies



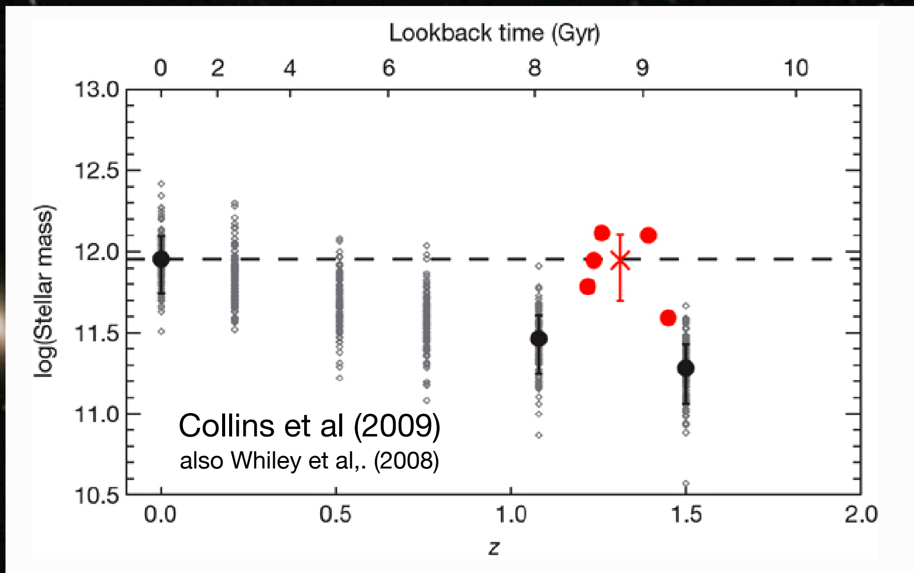


Simulations predict that Brightest Cluster Galaxies continue to grow in mass through dry mergers through z=0

BCG mass predicted to increase by a factor of 3-4 from z=1 to present

DeLucia & Blaizot (2007)

The Evolution of Massive Galaxies

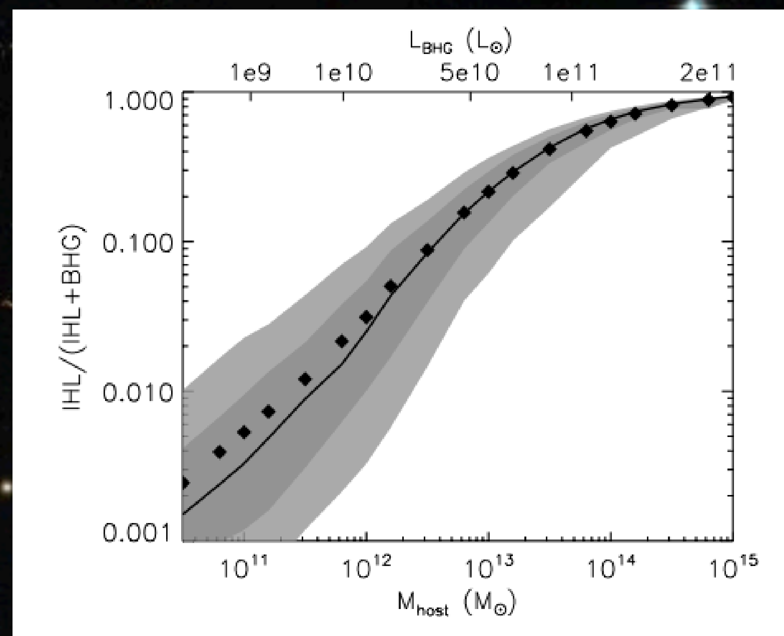


Observations show little mass evolution in BCGs with redshift

Observed masses of BCGs show only weak dependence on cluster mass

- In massive clusters, N-body simulations predict that “intracluster” light dominates the light of the BCG!

- Prediction: Strong correlation between ICL fraction and cluster mass



Purcell, Bullock & Zetner (2007)

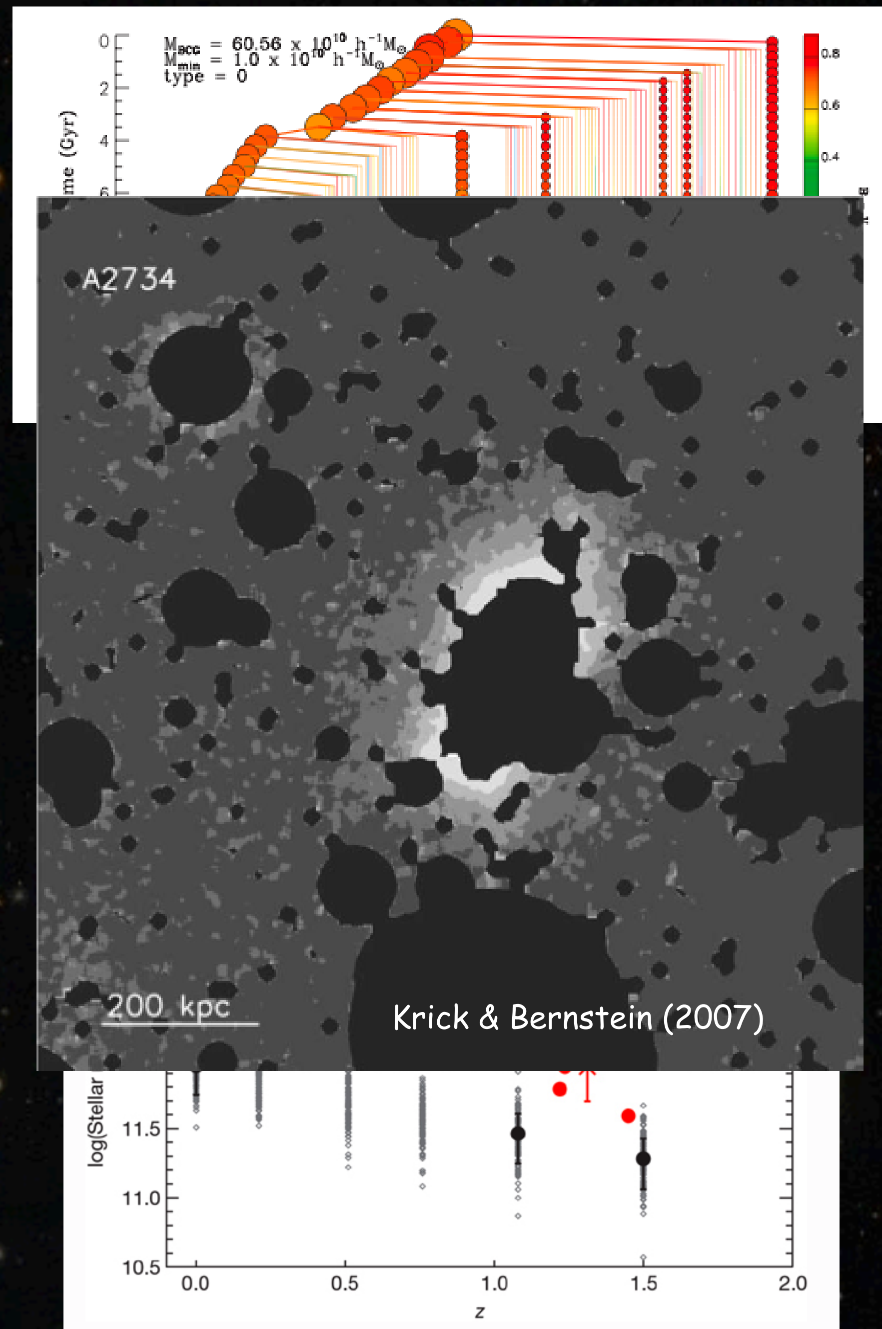
The Evolution of Massive Galaxies

Could intracluster light be the missing component?

ICL is notoriously difficult to observe

- Low surface brightness
- PN/Ly-alpha galaxy confusion

Intracluster Globular Clusters (IGCs) should accompany ICL, and can be easier to see

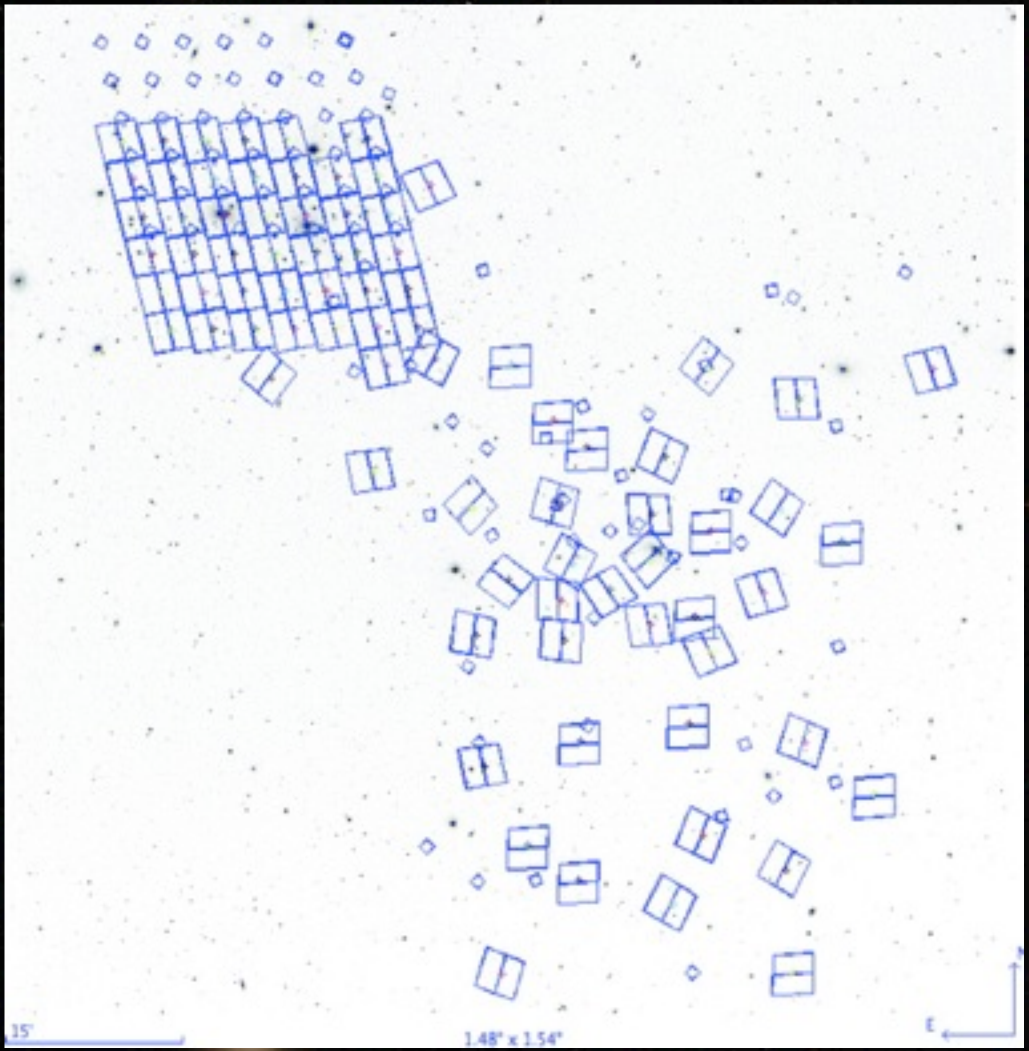


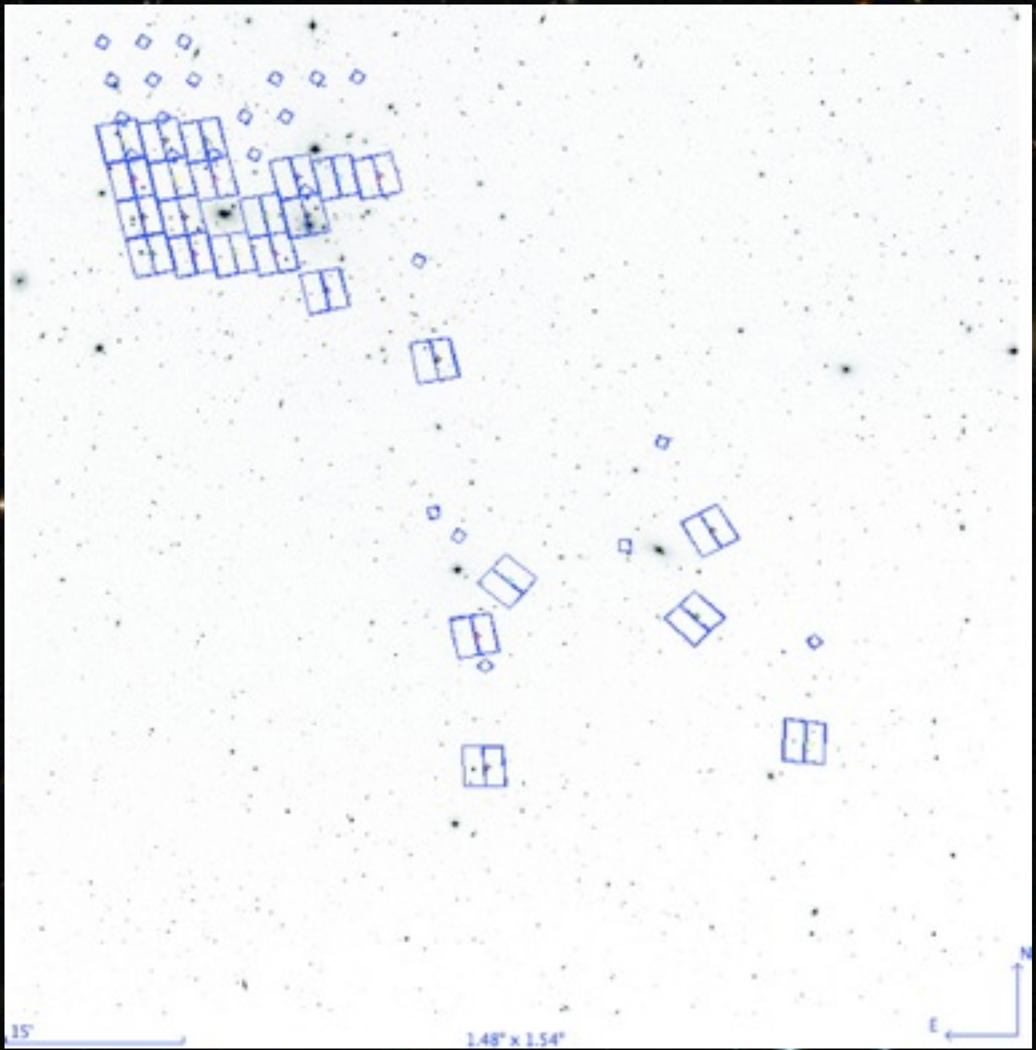
ICL, IGCs, and the Coma Cluster

- Nearest rich, dense cluster environment (100 Mpc)
- Previous evidence for intracluster light
- cD galaxy, NGC 4874

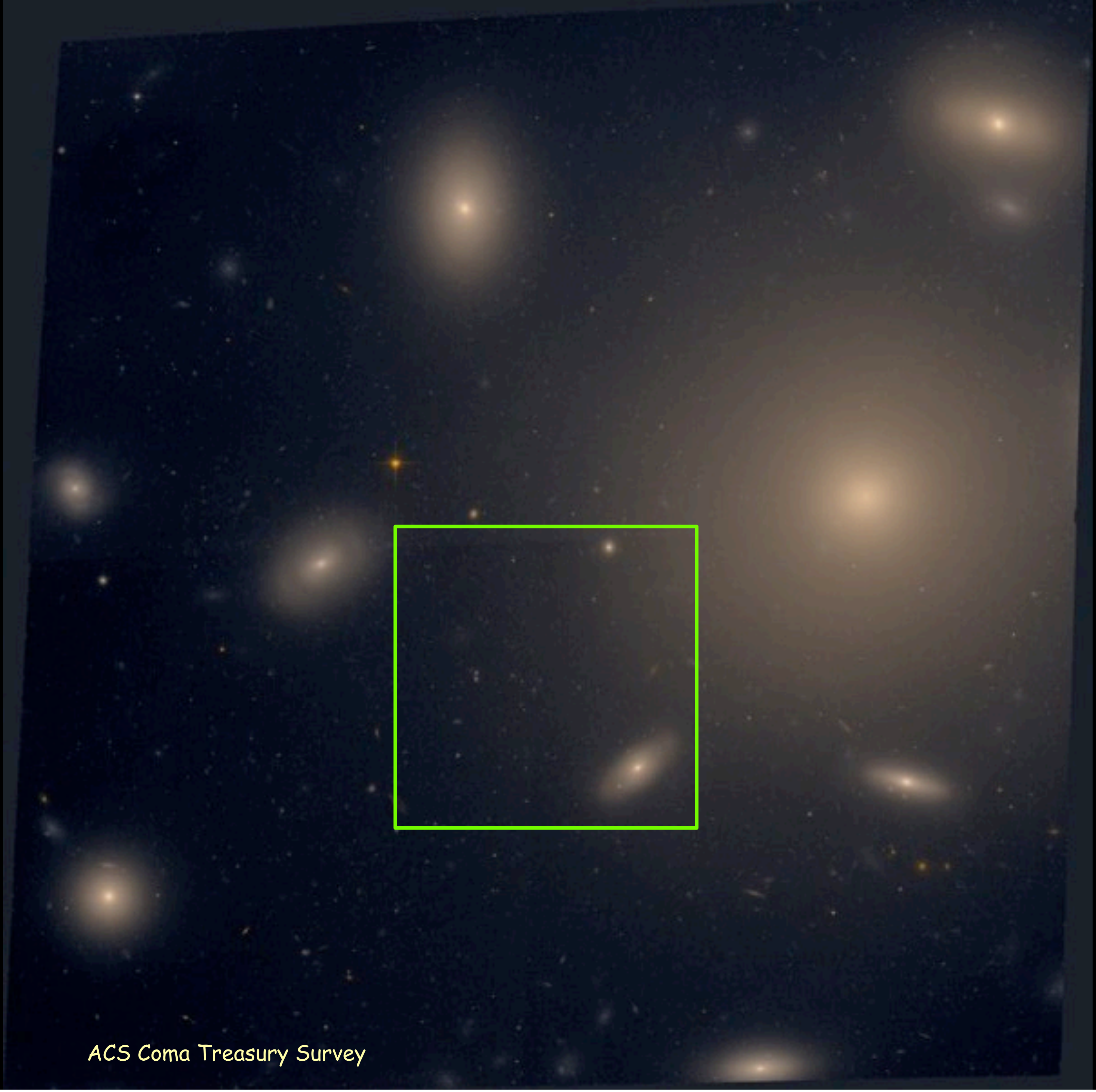
The HST/ACS Coma Treasury Survey

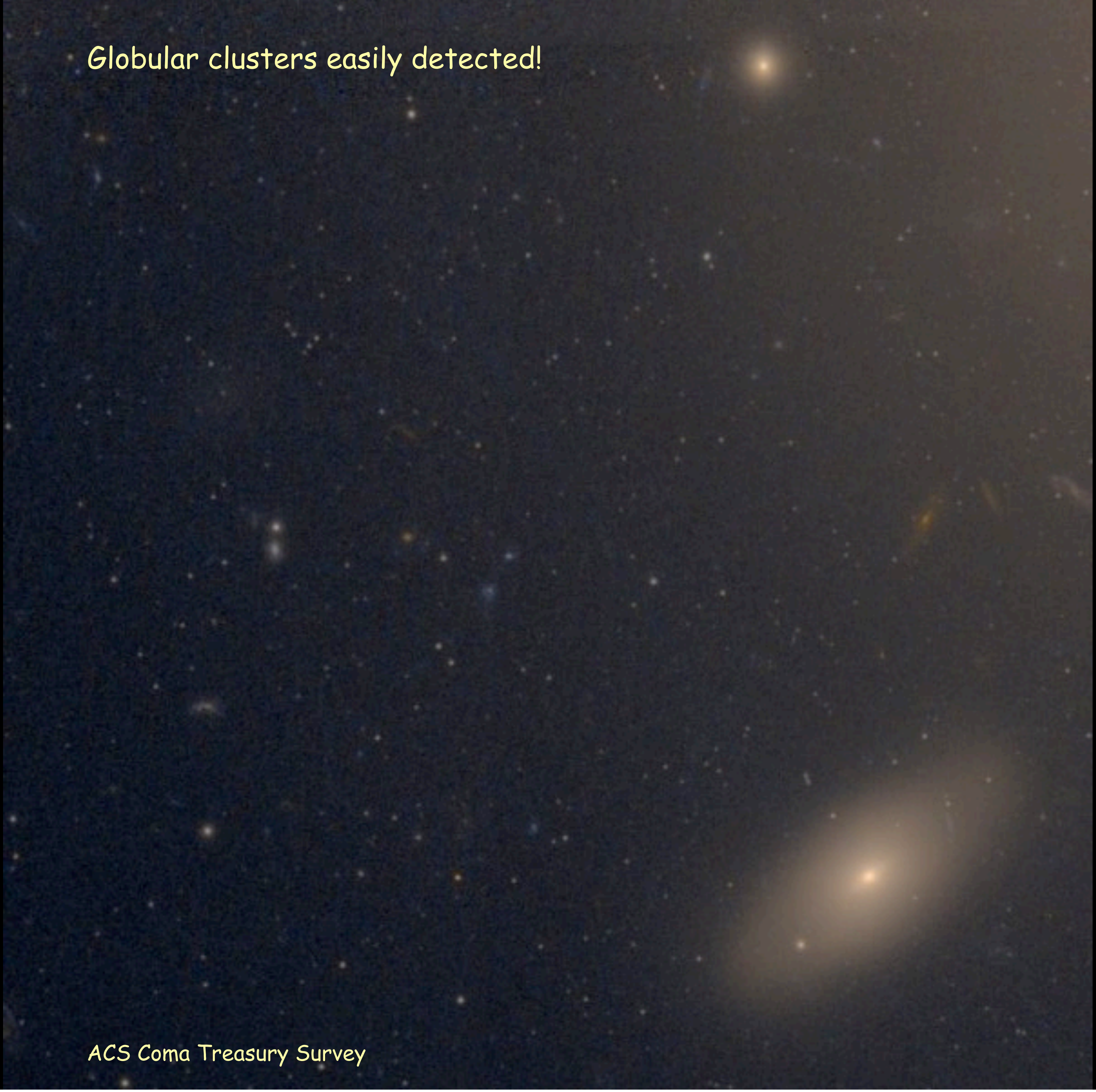
Carter et al (2008)



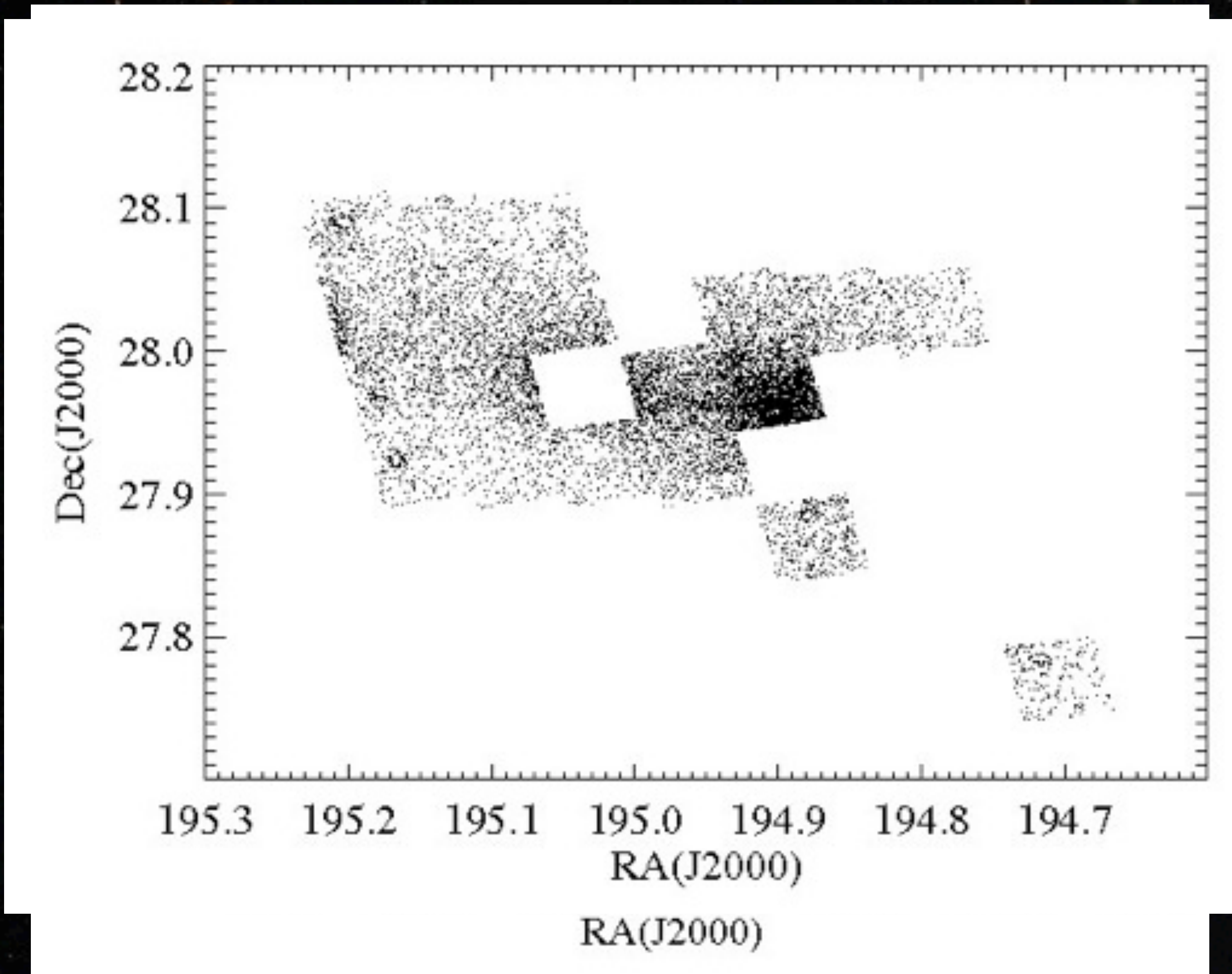


Can still do interesting GC and galaxy science!


ACS Coma Treasury Survey


Globular clusters easily detected!
ACS Coma Treasury Survey

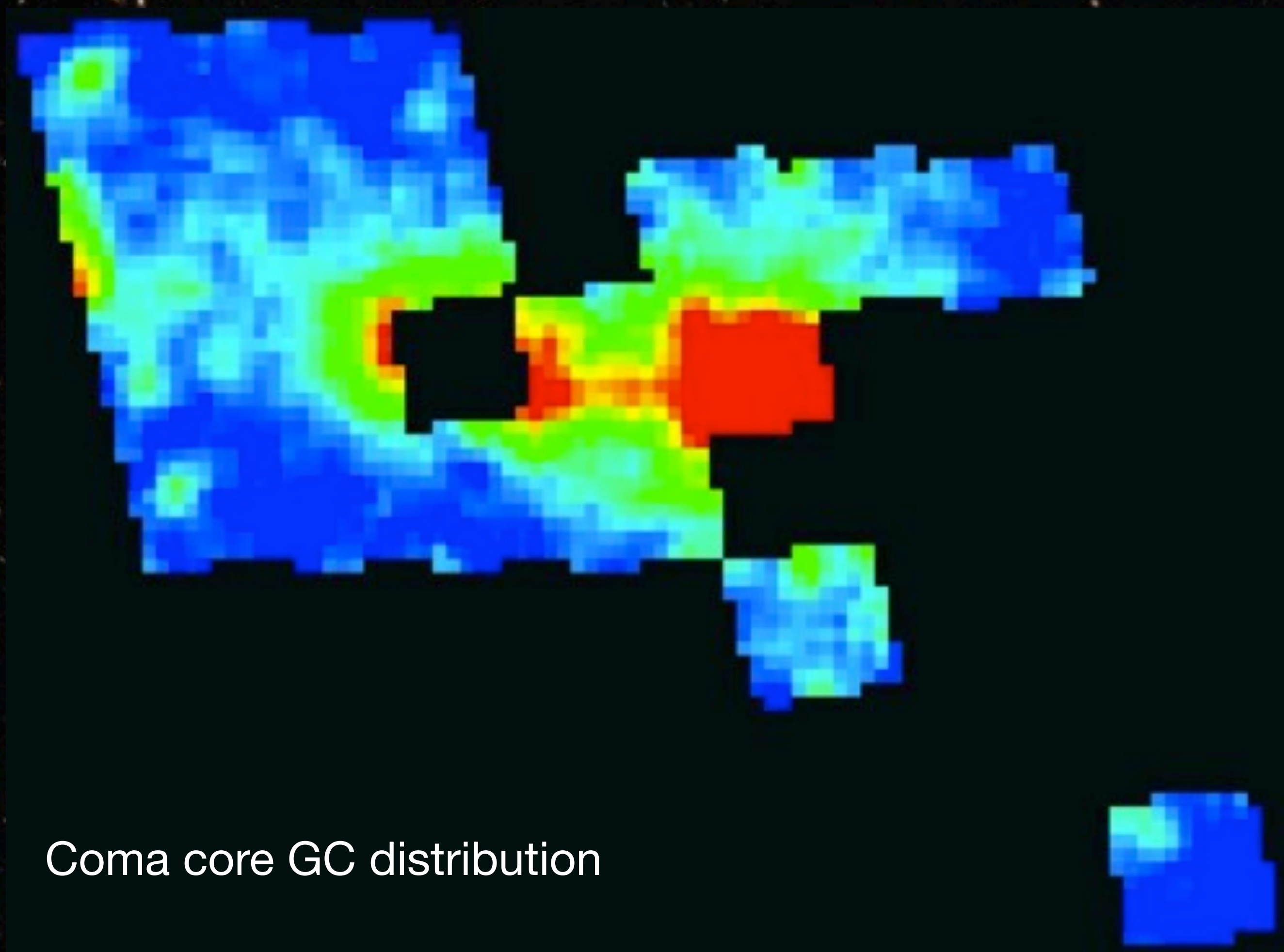
GC spatial distribution



- GCs are point sources (see Chiboucas et al. 2011, Price et al. 2009 for resolved UCDs)
- Entire cluster core is filled with GCs
- Intergalactic population
- Spatial structure in GCs

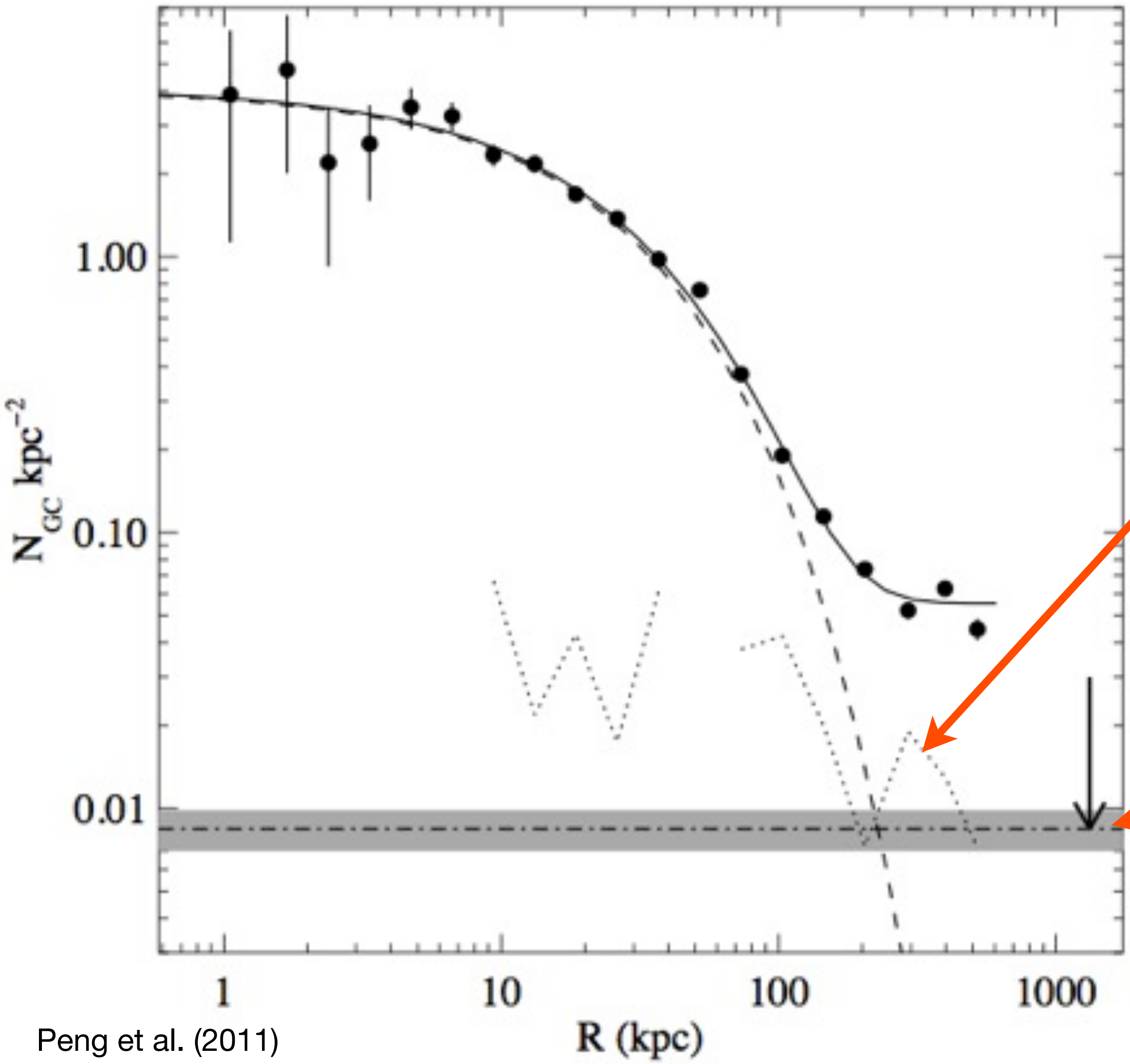
Peng et al. (2011)

GC spatial distribution in cluster core



- Spatial structure in GCs
- Intergalactic or just galactic?
- Model GC systems of Coma galaxies
- Statistically subtract from observations
- Mask aggressively

Radial Distribution of GCs



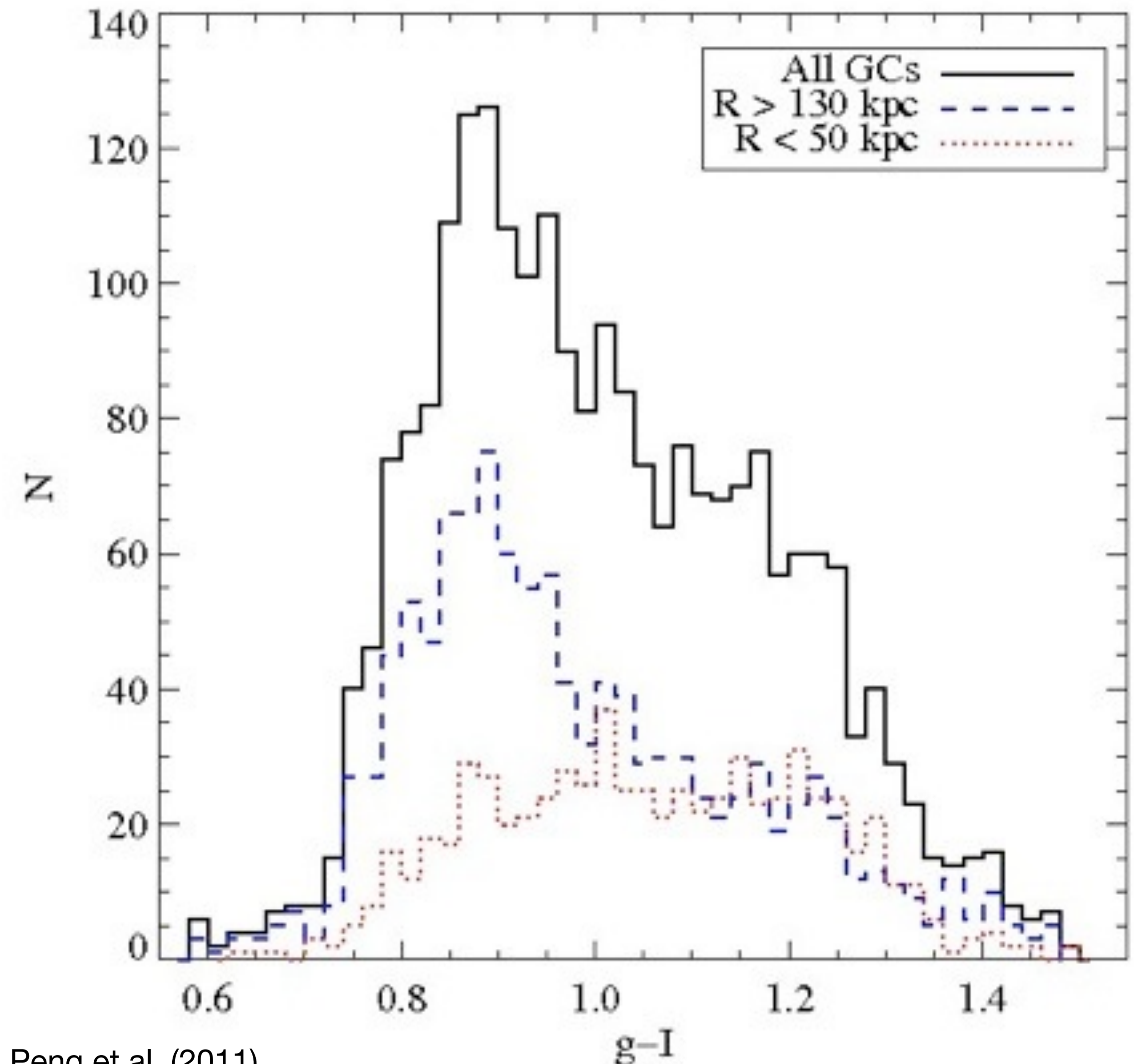
Peng et al. (2011)

- GC radial profile centered on NGC 4874
- Galaxies masked and their GCs statistically subtracted
- Sersic + constant fits well
- Intergalactic GC density is well above background level

~70% of GCs in N4874+IGC system are IGCs, ~30-45% of GCs in the core are IGCs
Consistent with ICL measurements (Gonzalez et al) and simulations (Purcell et al)

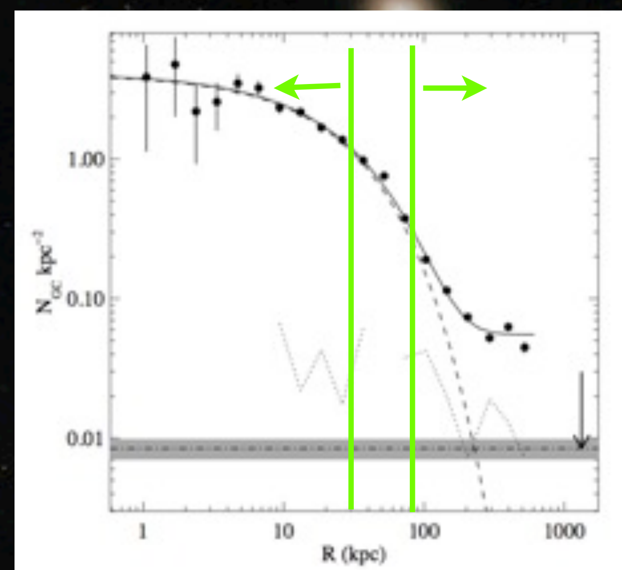
- N_{GC} (R<520kpc) = 70,000
- "Sersic" GCs = 22,000
- "Intergalactic" GCs = 47,000
- S_N (Sersic) = 9
- Implied ICL: 27 mag/arcsec^2
- ~2500 disrupted dEs at M_V=-16

GC Color Distributions



Peng et al. (2011)

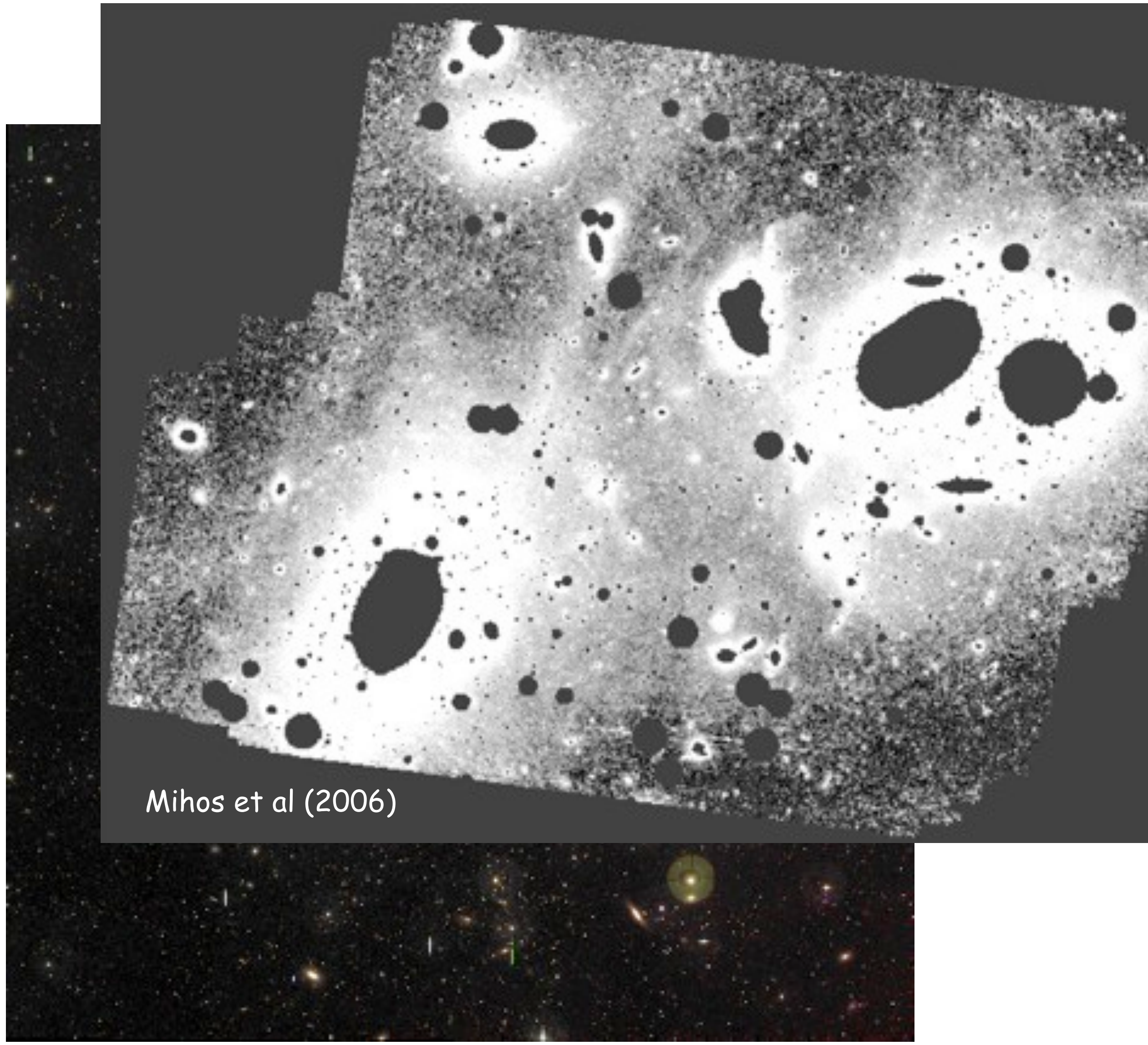
- Distribution of all GCs (I<25) show typical bimodality
- GCs outside of 130 kpc (IGCs) dominated by blue GCs, ratio 4:1
- GCs within 50 kpc not very bimodal, show equal numbers of red and blue GCs.



IGCs in the Virgo Cluster?

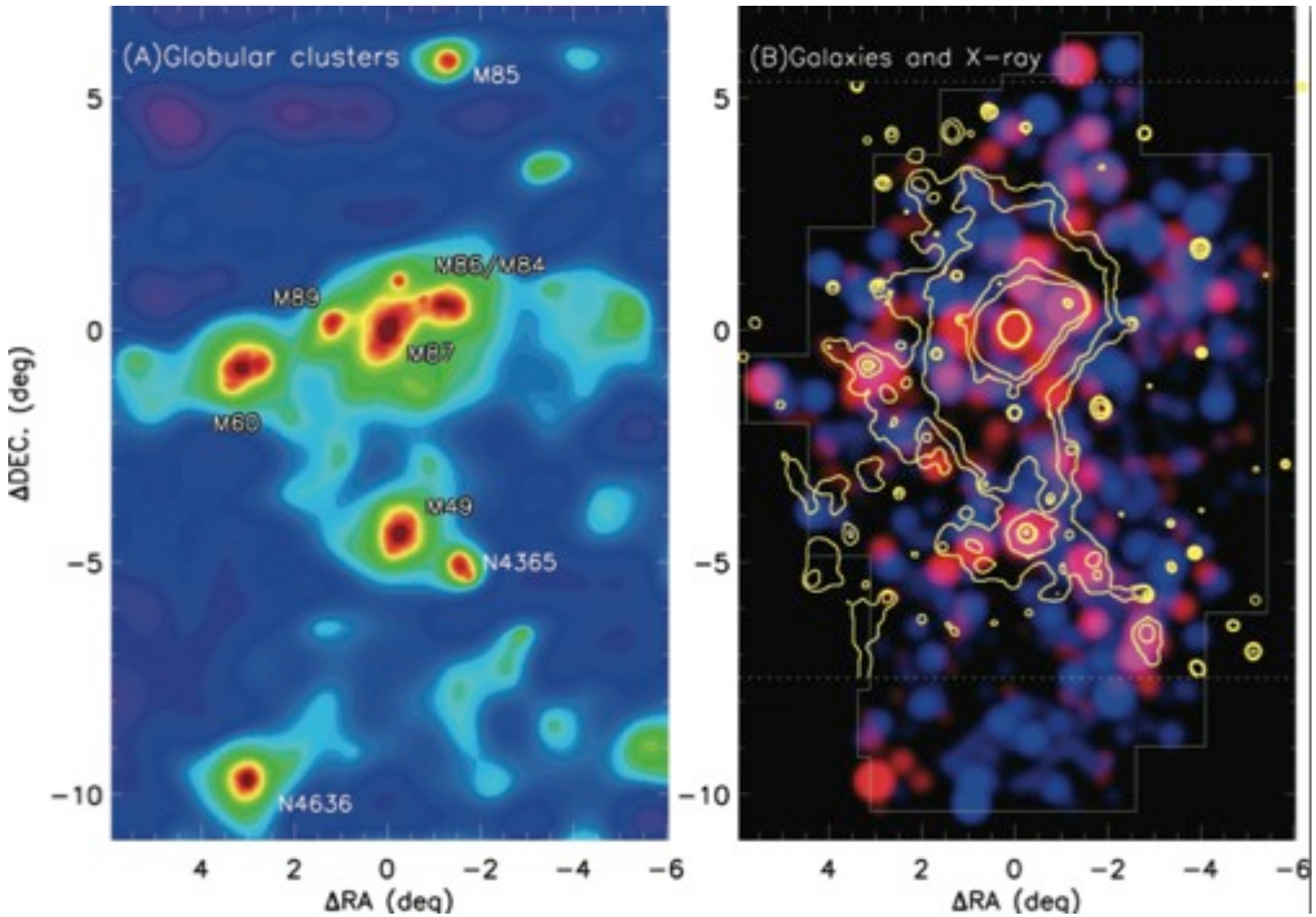
ICL observations

- LSB light (Mihos)
- Planetary nebulae (Arnaboldi, Okamura, Feldmeier)



- Best galaxy cluster for GC observations

IGCs in the Virgo Cluster?

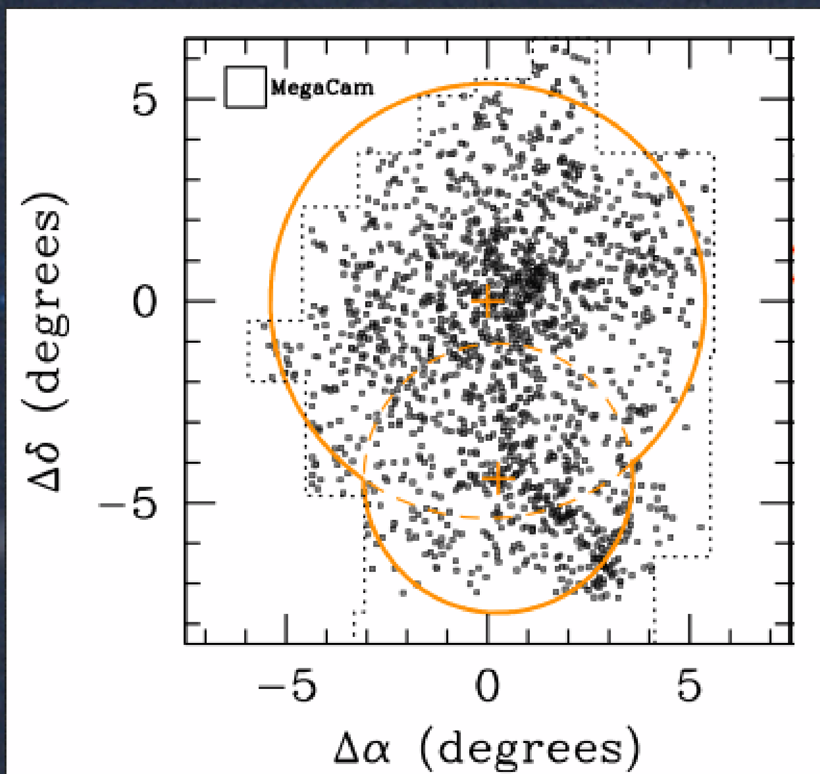


Reported detection of IGCs in Virgo using SDSS (g~22)

Lee, Park & Hwang 2011

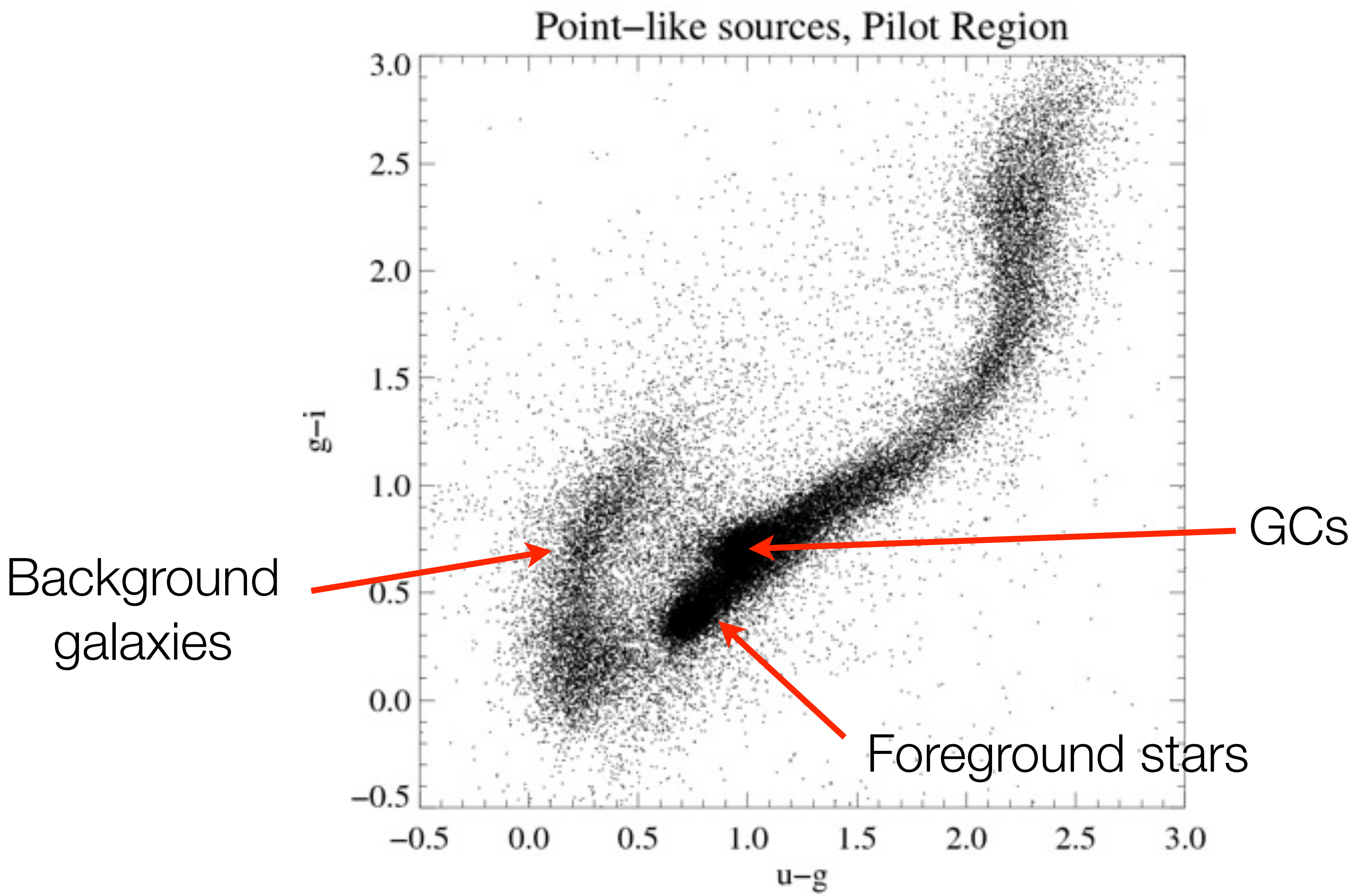
THE NEXT GENERATION VIRGO CLUSTER SURVEY

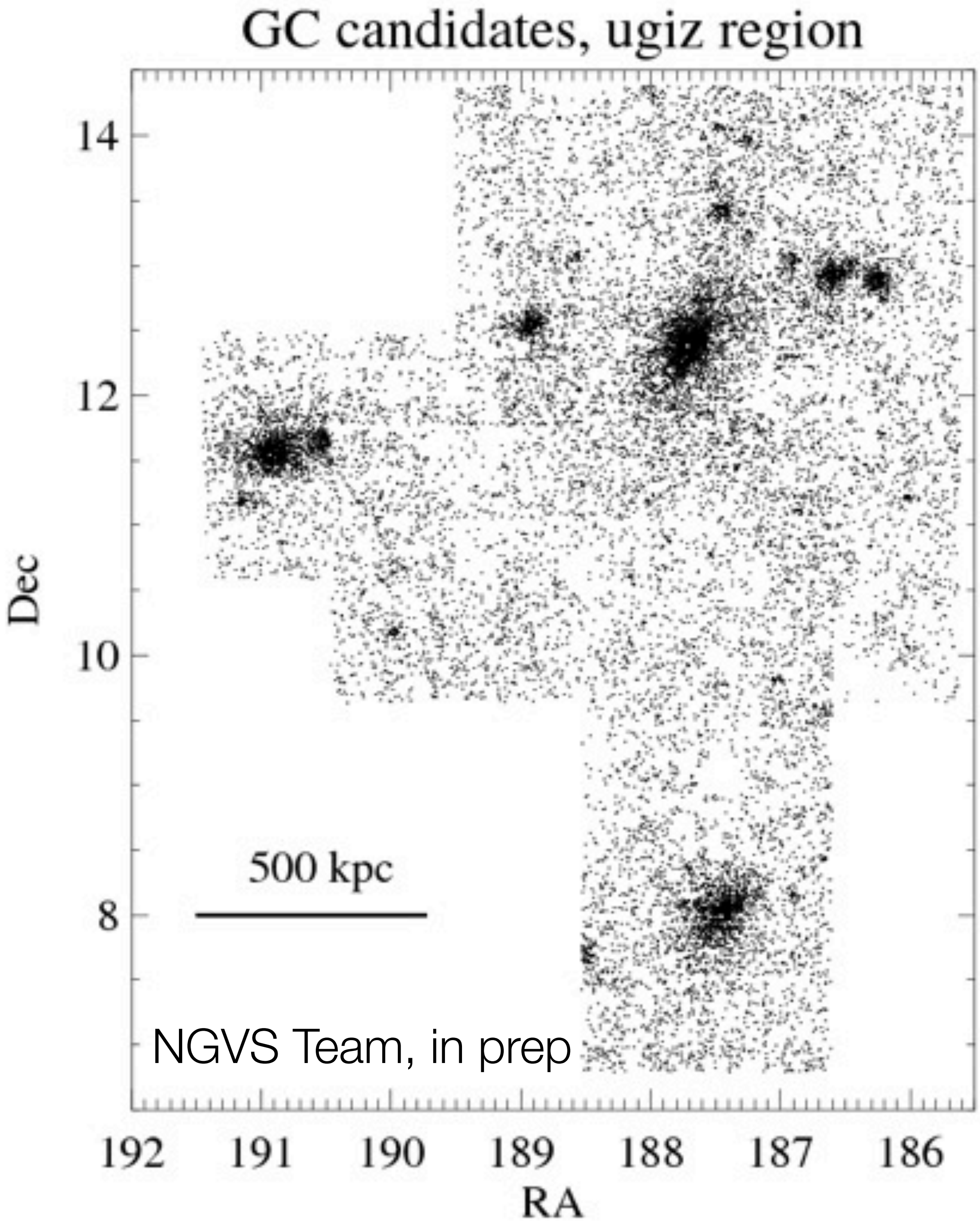
- CFHT Large Program (2009-2012)
- 104 sq. deg in ugriz
- u*g'~26, r'i'z'~25
- PI: L. Ferarrese
- Galaxies, globular clusters, foreground halo, background clusters



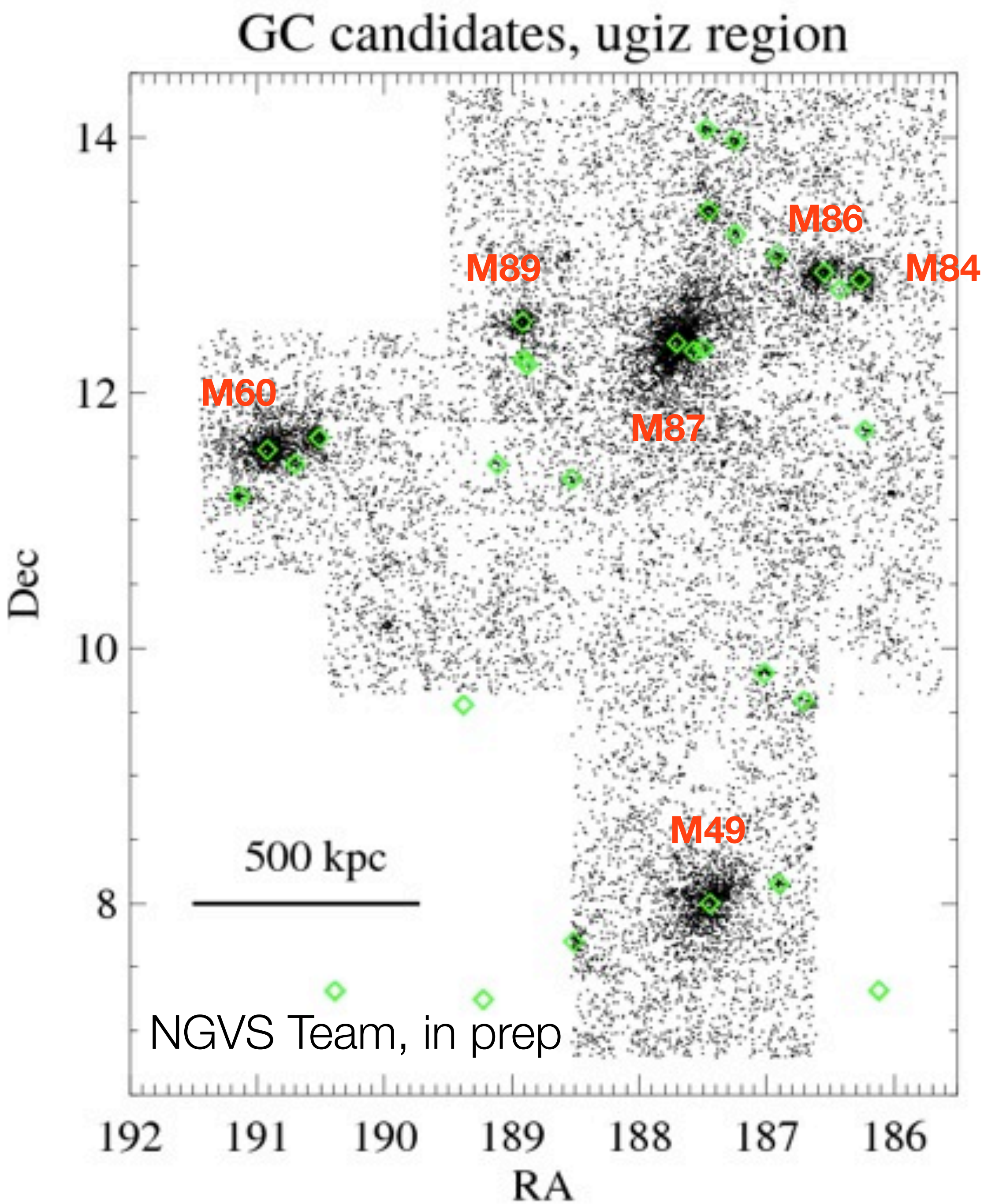
Nelson Caldwell
Patrick Côté
Jean-Charles Cuillandre
Patrick Durrell
Laura Ferrarese
Stephen Gwyn
Andrés Jordán
Chengze Liu
Yang-Shyang Li
Lauren MacArthur
Alan McConnachie

Globular cluster selection

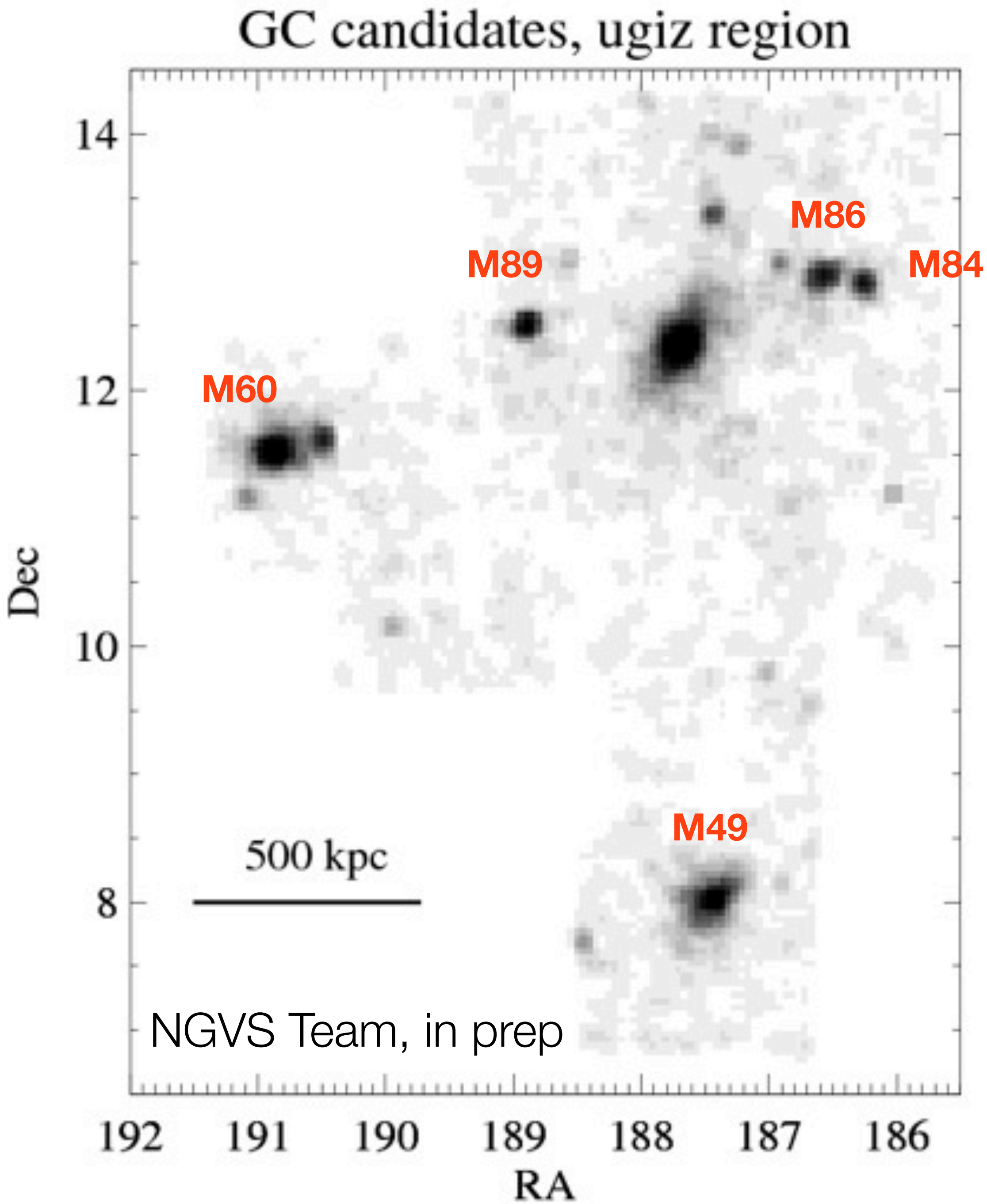




Virgo globular cluster spatial distribution



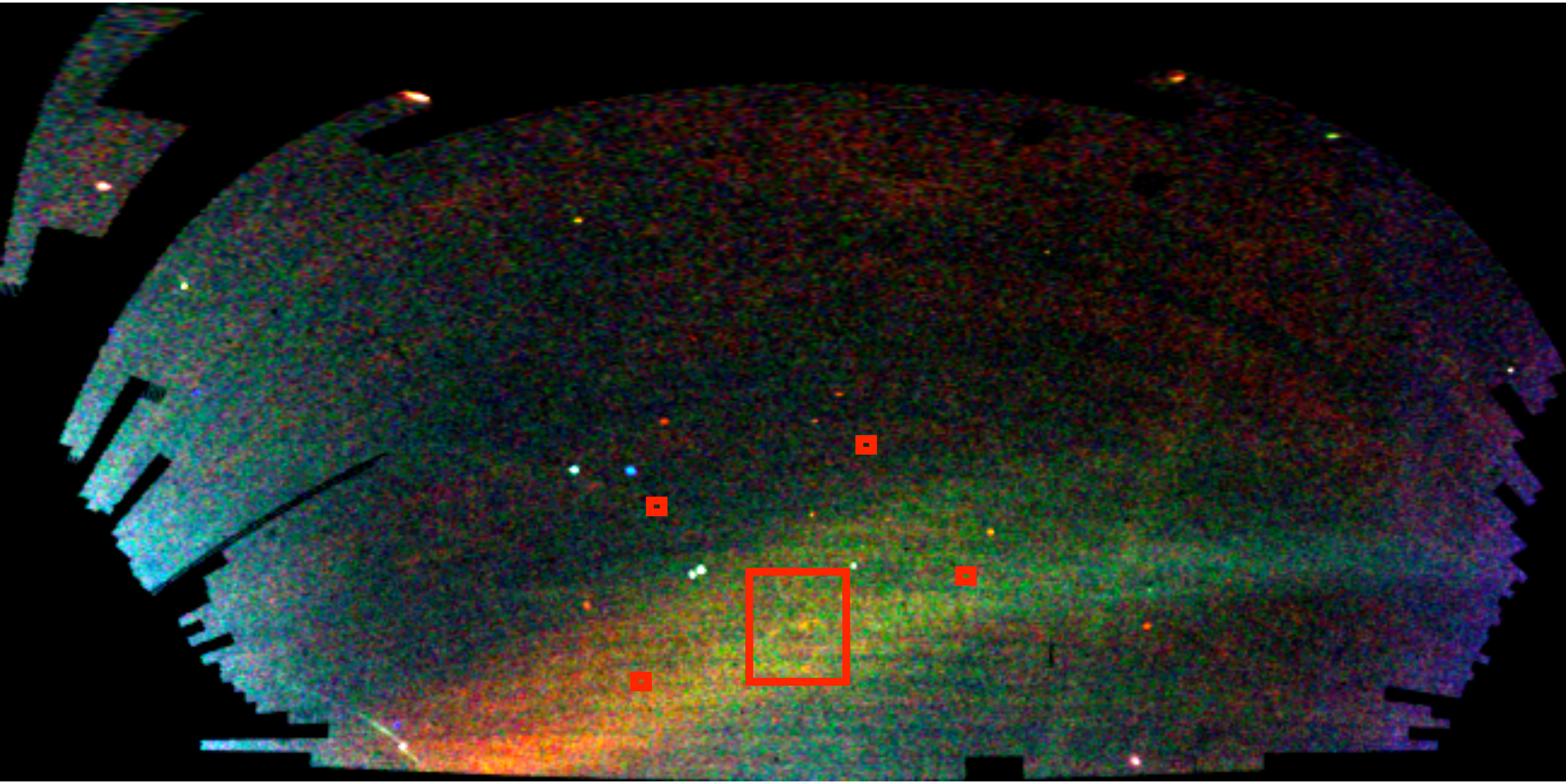
Virgo globular cluster spatial distribution



Virgo globular cluster spatial distribution

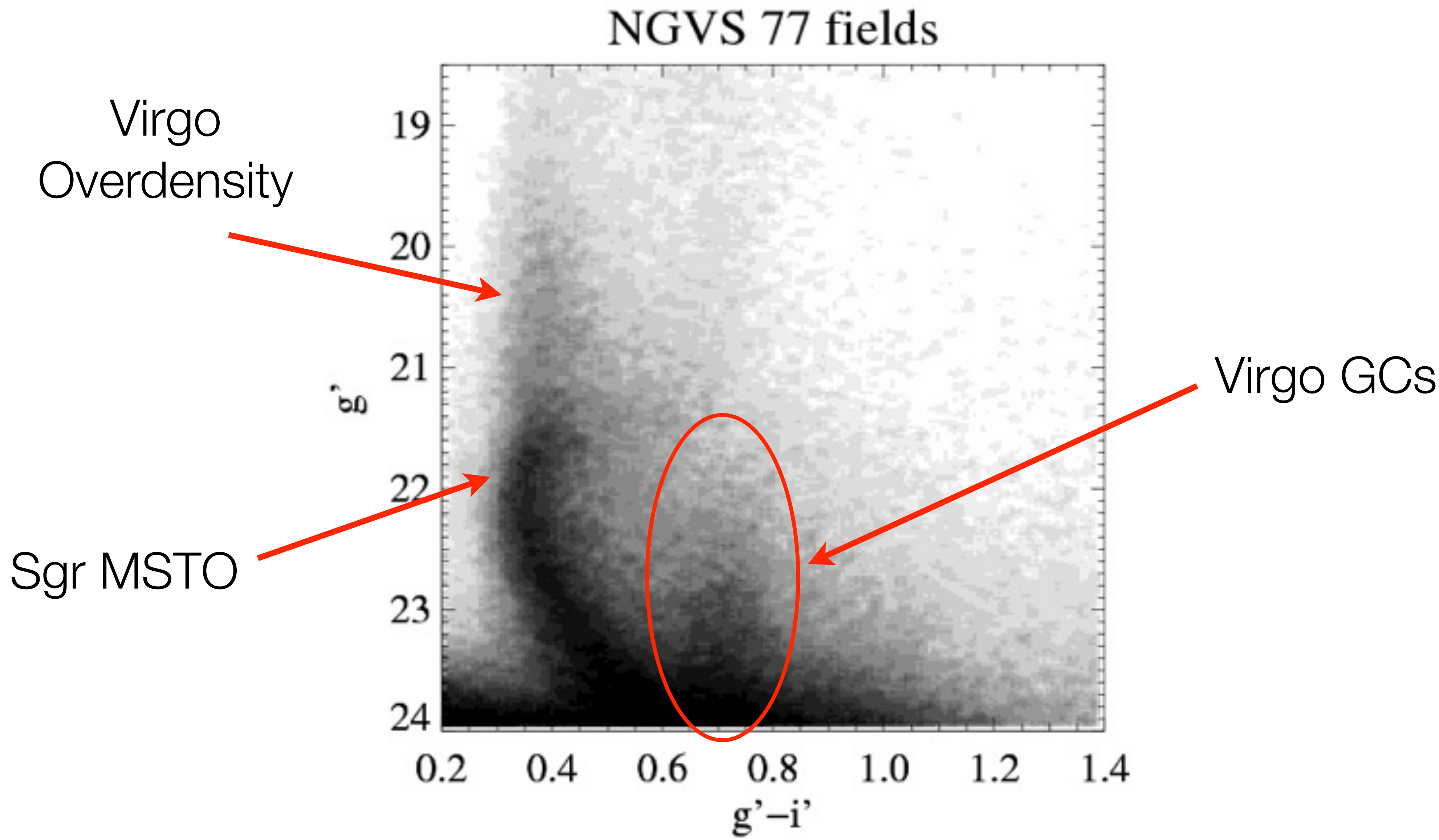
Can we estimate the IGC fraction in Virgo?

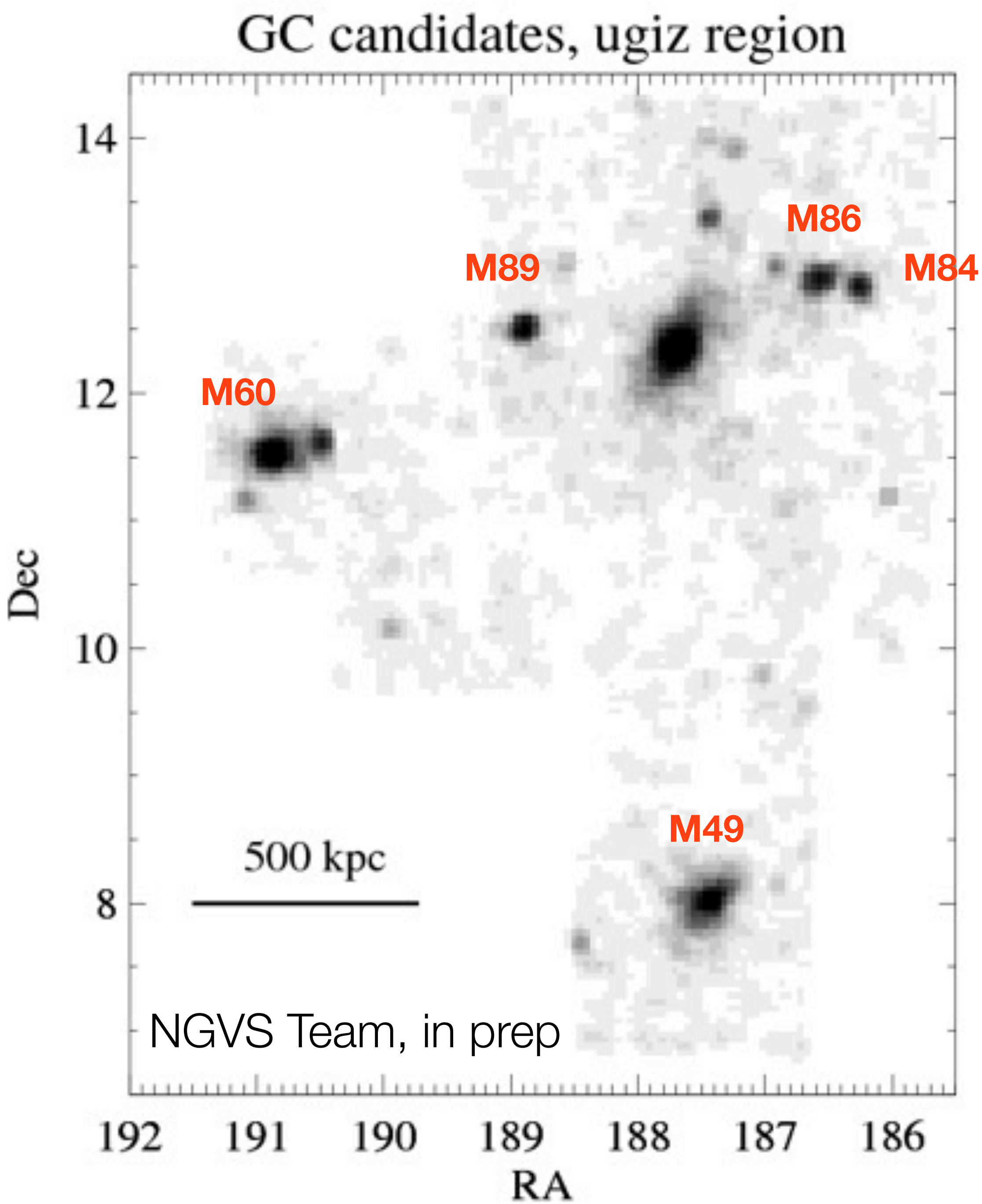
Virgo and the Galactic Foreground



V. Belokurov

Virgo and the Galactic Foreground

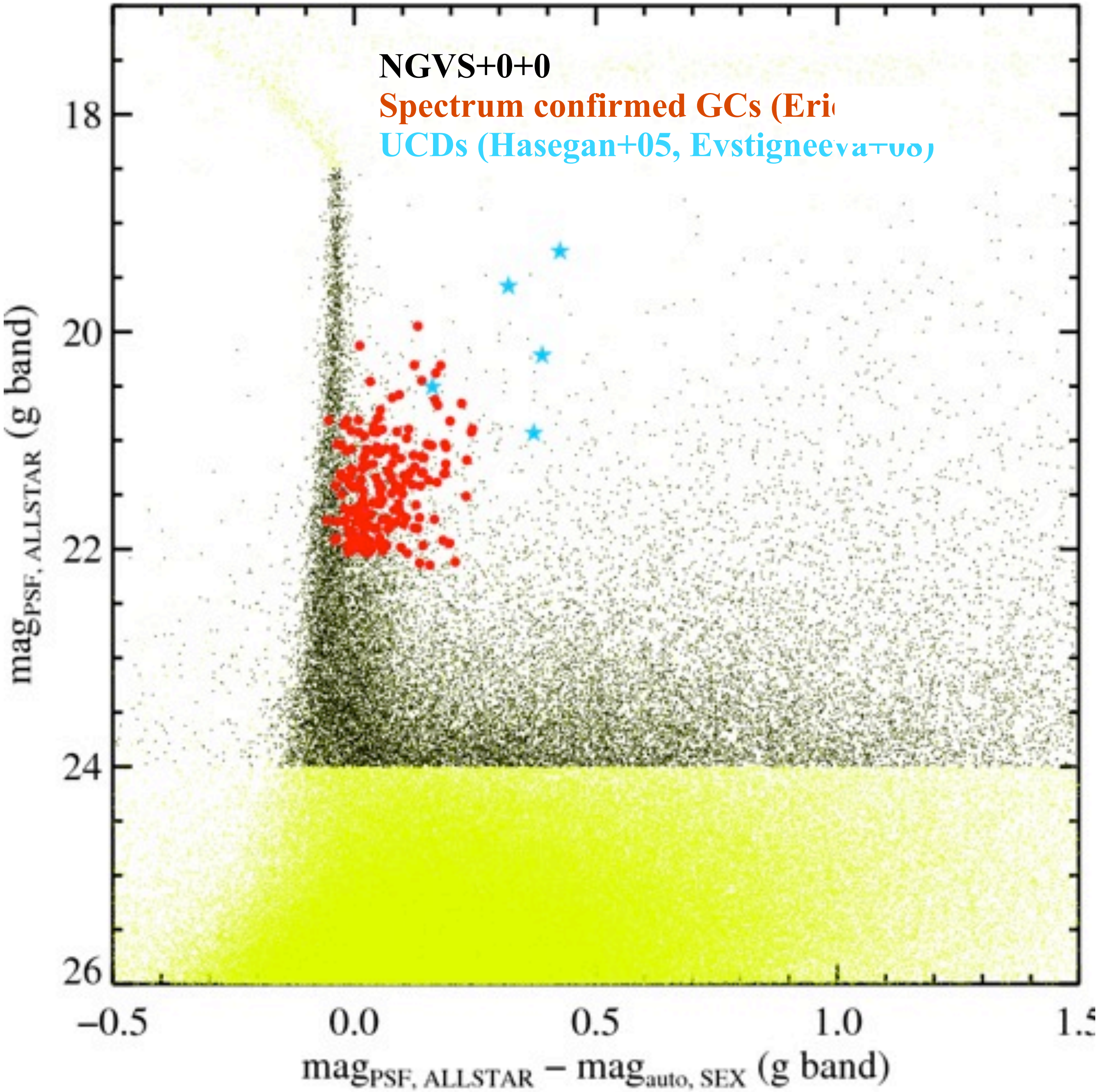




Preliminary IGC fraction ranges from ~0-40% depending on chosen background region.

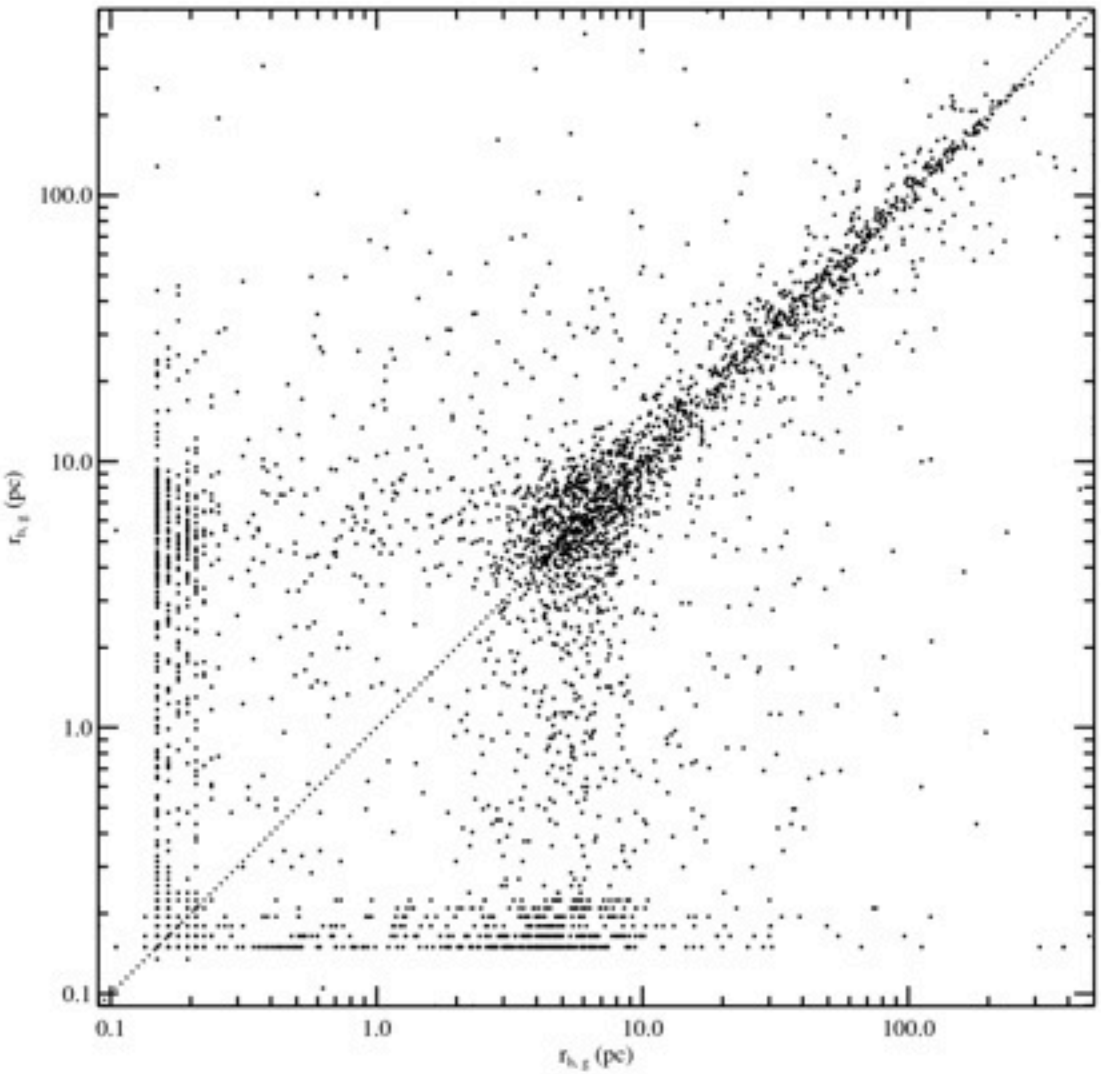
Need careful treatment of Galactic foreground.

Resolving Virgo GCs in the NGVS

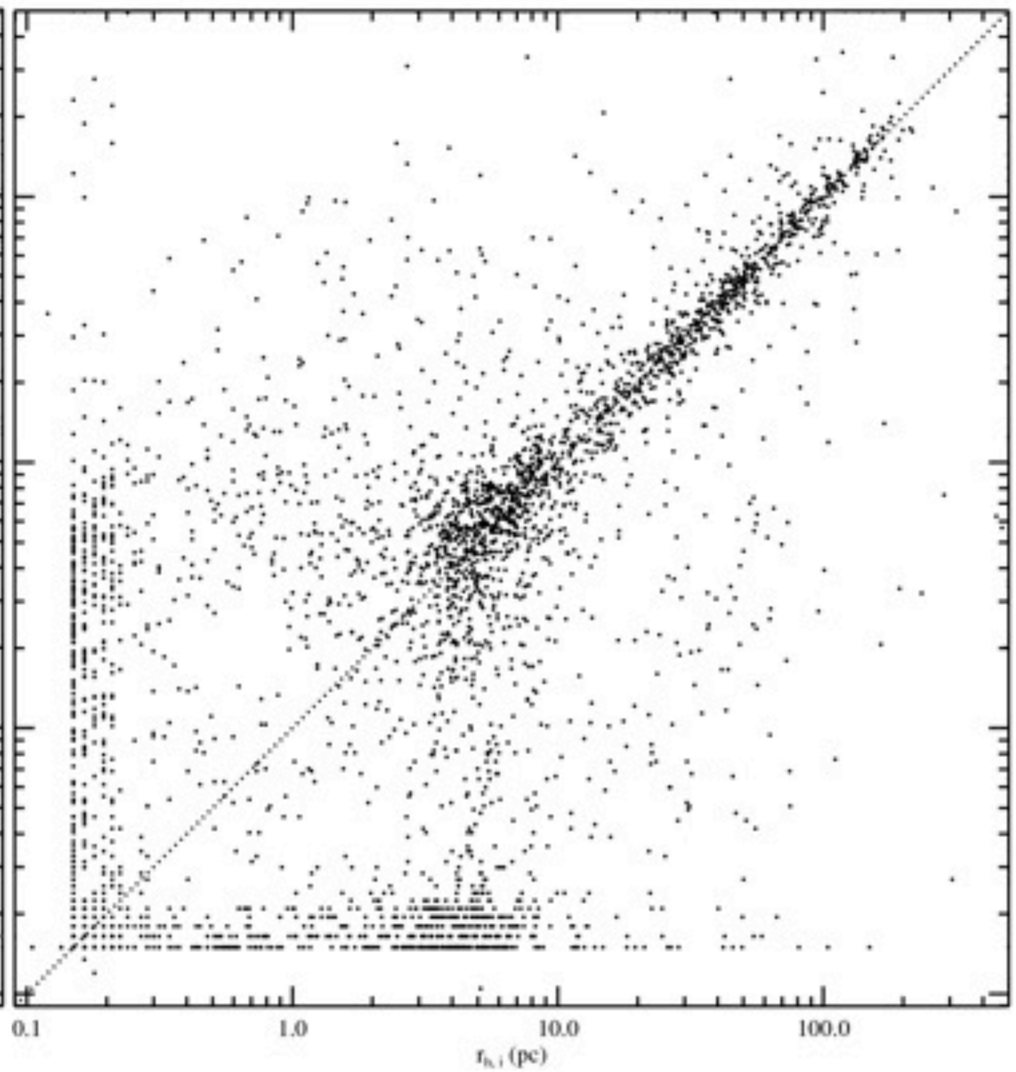


Overlap regions

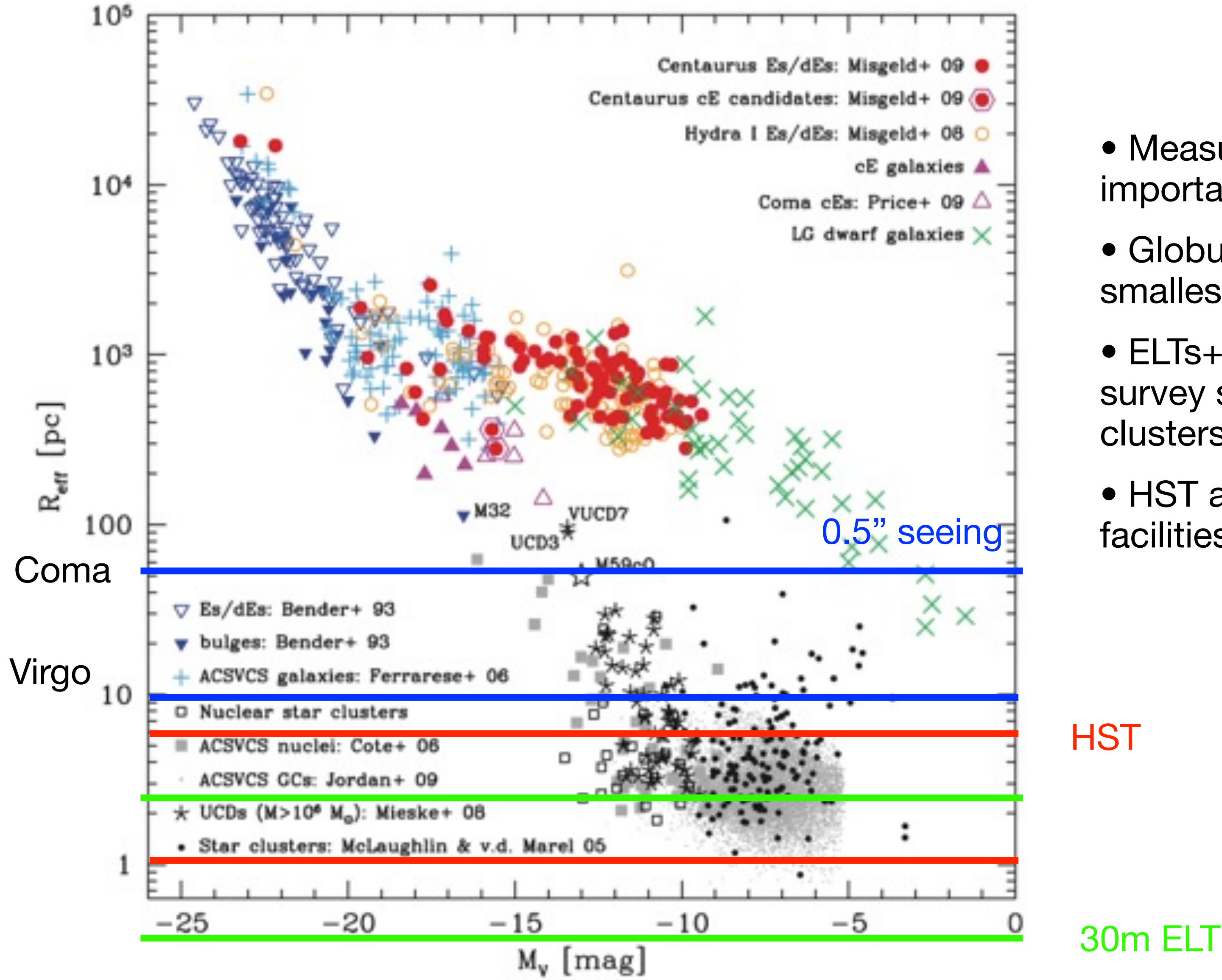
r_h in g band



r_h in i band



Globular Cluster Systems

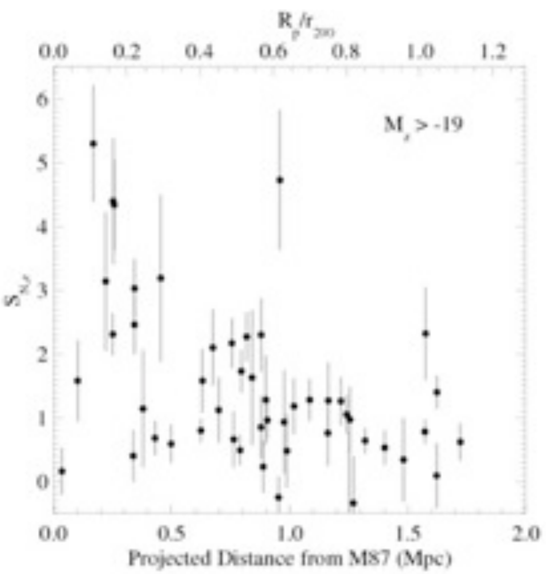


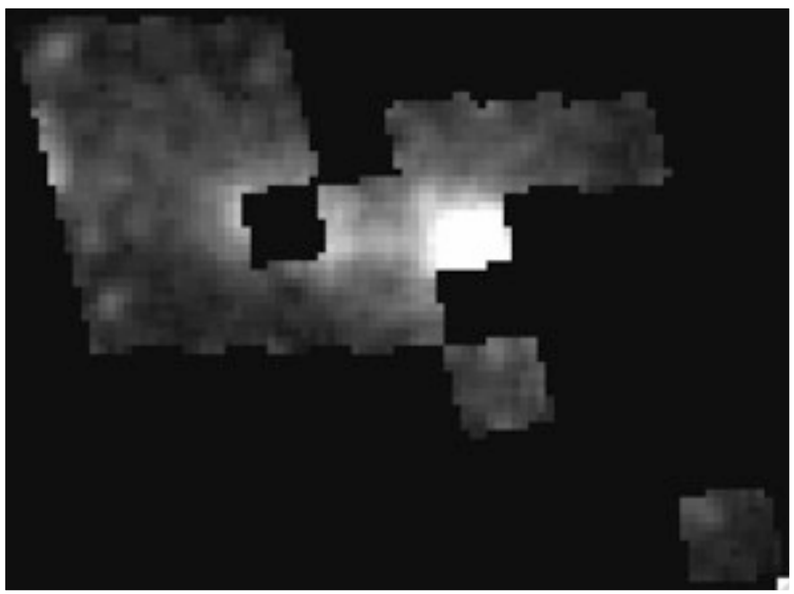
Misgeld & Hilker (2011)

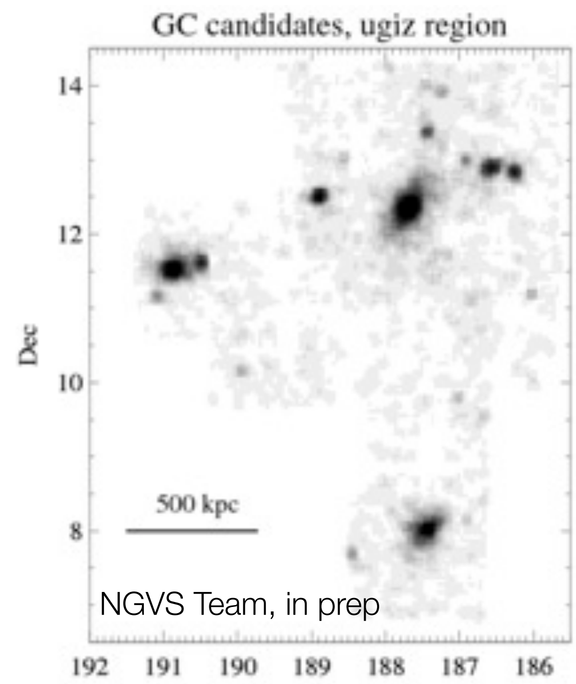
- Measuring sizes of stellar systems is important for understanding them
- Globular clusters are among the smallest stellar systems
- ELTs+AO may not significantly improve survey speed for GCs in nearby galaxy clusters for certain applications
- HST and current ground-based facilities can already do a lot

Summary

1. Panoramic observations of nearby galaxy clusters provide a new view on GCs and the intracluster stellar component, showing history of intense formation and interaction.
2. dEs in dense environments show enhanced GC formation, contribute GCs to larger halos.
3. A large population of intergalactic GCs (~47,000) in Coma core. The ratio of IGC component to total central system (N4874+IGC) ~70% within ~0.5 Mpc. IGC fraction of all GCs is ~30-45%. Consistent with simulations of ICL production through dry merging and stripping of satellite galaxies.
4. IGCs are dominated by blue/metal-poor GCs, with a ratio 2:1.
5. Virgo population of IGCs is now spectroscopically confirmed. Total fraction still uncertain, but likely has a lower fraction than in Coma.
6. Ability to resolve systems with r_h>5-10 pc over the entire Virgo cluster will be uniquely powerful for some time.







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List of Symposia selected for 2012

3 June 2011

1) Symposia to be held during the General Assembly (Beijing):
The Executive Committee and Division Presidents have exceptionally selected 8 Symposia (instead of the usual 6).

1. **IAUS 288 — Astrophysics from Antarctica**
Contact: Michael Burton, Australia
m.burton@unsw.edu.au
2. **IAUS 289 — Advancing the physics of cosmic distances**
Contact: Richard de Grijs, China
grijs@kiaa.pku.edu.cn
3. **IAUS 290 — Feeding compact objects: Accretion on all scales**
Contact: Zhang Chengmin, China
zhangcm@bao.ac.cn
4. **IAUS 291 — Neutron stars and pulsars: Challenges and opportunities after 80 Years**
Contact: Richard Manchester, Australia
dick.manchester@csiro.au
5. **IAUS 292 — Molecular Gas, Dust, and Star Formation in Galaxies**
Contact: Martin Bureau, UK
bureau@astro.ox.ac.uk
6. **IAUS 293 — Formation, detection, and characterization of extrasolar habitable planets**
Contact: Nader Haghighipour, USA
nader@ifa.hawaii.edu
7. **IAUS 294 — Solar and astrophysical dynamos and magnetic activity**
Contact: Alexander Kosovichev, USA
sasha@sun.stanford.edu
8. **IAUS 295 — The intriguing life of massive galaxies**
Contact: Daniel Thomas, UK
daniel.thomas@port.ac.uk