The accretion history of the halo of M31 as probed by its globular cluster population

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PAndAS

The Pan-Andromeda Archaeological Survey (PAndAS)

P.I. Alan McConnachie

Motivations

• Use of Globular clusters as probes of the history of M31

– GCs form in major SF events that accompany galaxy formation and also wet mergers.

– And accretion of dwarfs will add the dwarfs GCs to the hosts population.

• With M31 we can also use analysis of resolved stellar pops to understand its history

– GCs can be used in concert with field stars

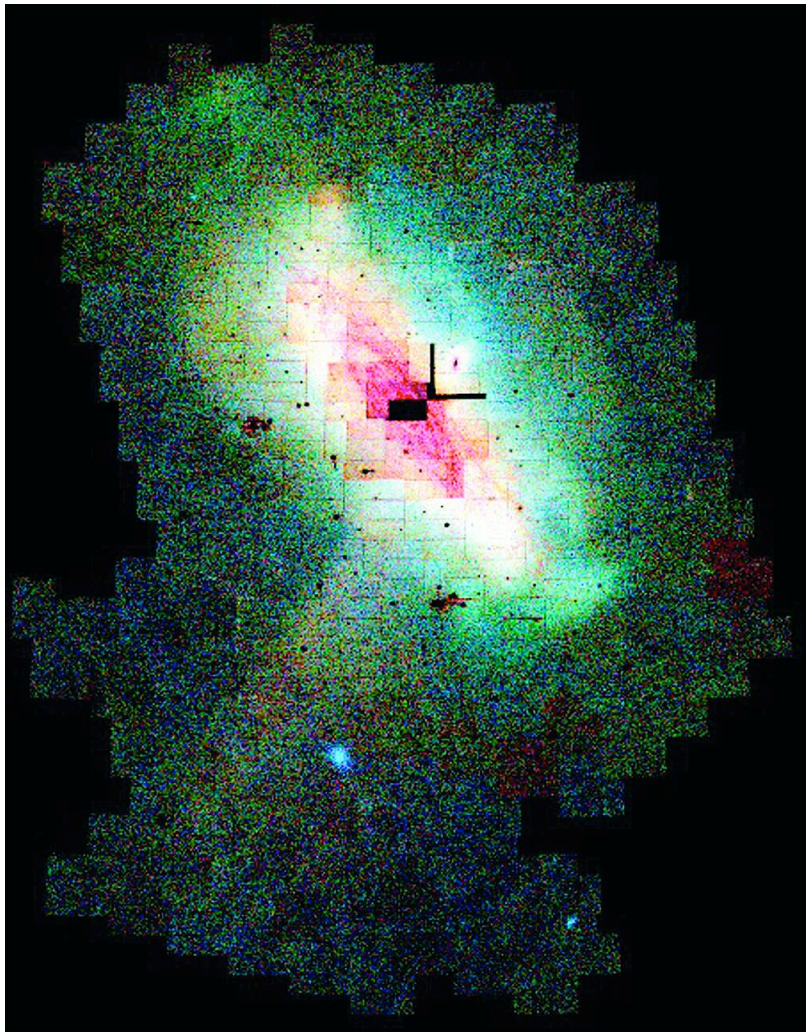
– If we can to tie GC population to history, might be able to use GCs (integrated properties) to understand more distant galaxies

INT-WFS survey area

INT-WFS was a wide-field survey in V and i', using INT/WFC.

> 40 square degrees

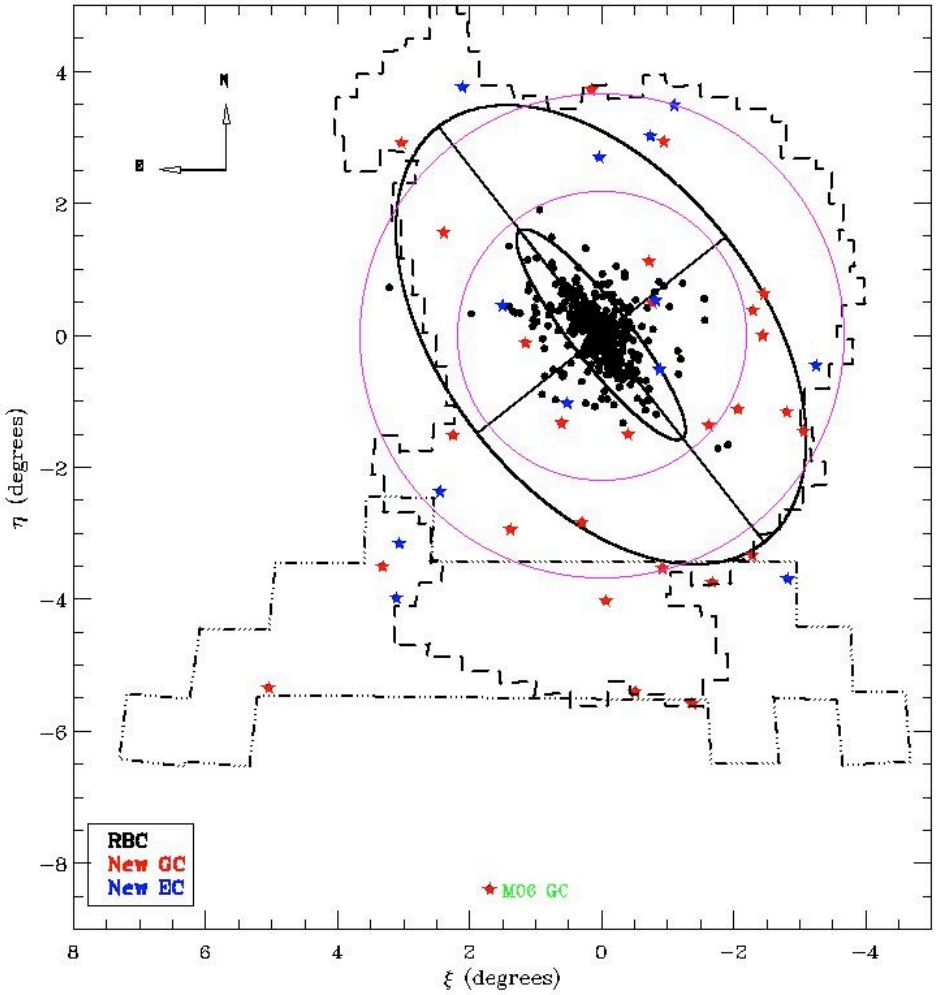
Superseded by the PAndAS survey



INT-WFS survey area

Early ‘sample’ comprised INT-WFS coverage, plus overlapping initial CFHT/ MegaCam fields.

Provided cluster sample for Huxor et al. 2011

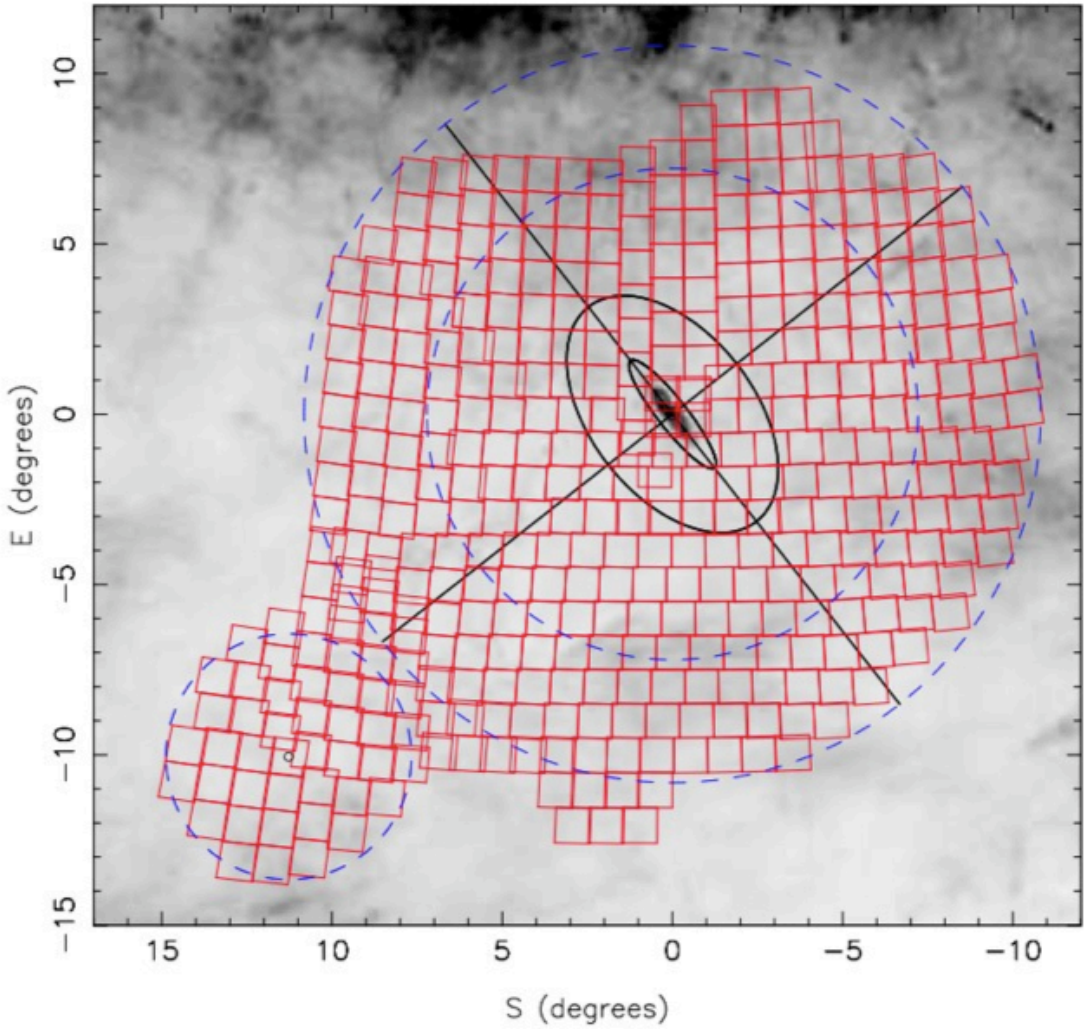


PAndAS survey area

PAndAS is a wide-field survey in g and i, using CFHT MegaCam.

Built on earlier INT-WFS related MegaCam programs (2002-2006)

PAndAS proper: a total of 226 hours (41 nights), giving a final coverage of ~400 square degrees



Some New GCs

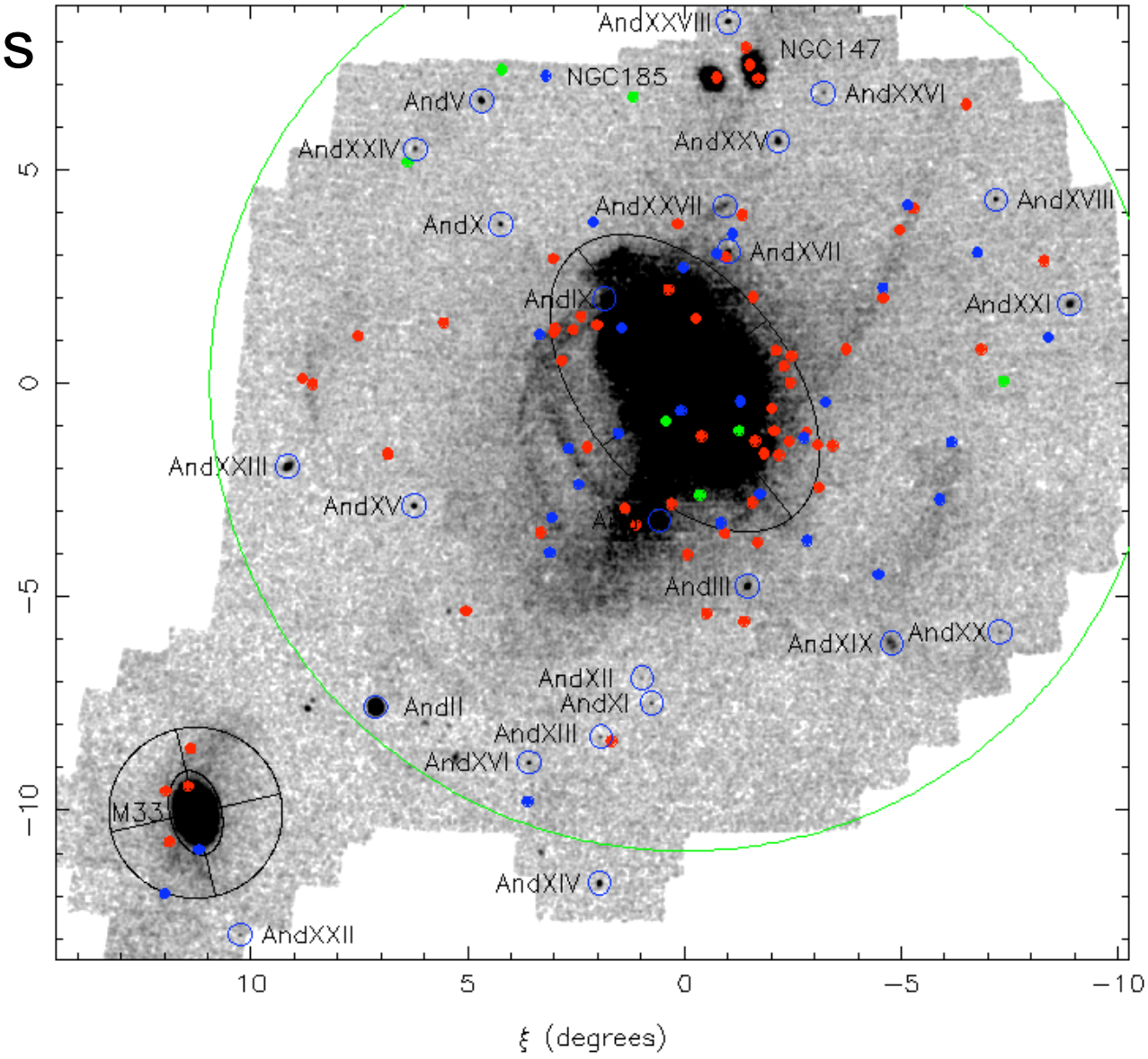
Red: compact GC

Blue: extended GC

Green: candidate GC

1. Clusters go to edge of survey
2. New GCs for N147/ N185
3. Association of clusters with stellar substructure

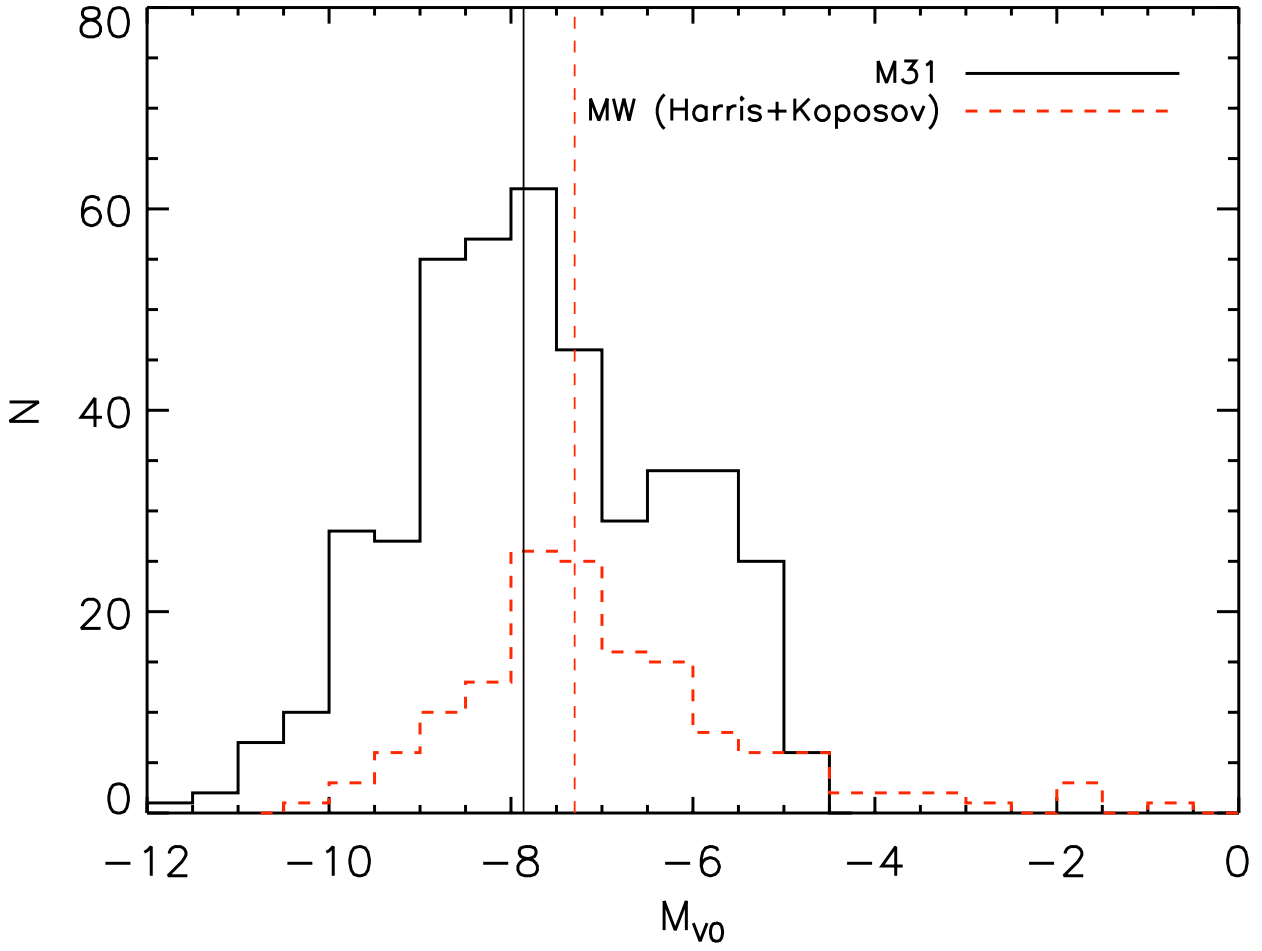
Latest photometry provisional, but excellent work by PhD student Cherie Fishlock



GC Luminosities

M31 appears to have a somewhat brighter peak than the MW But this is very dependent on the reddenings (from Fan++ 2010).

Suggestion of a second peak at M_{V0} ~ -6.0.



GC Luminosities

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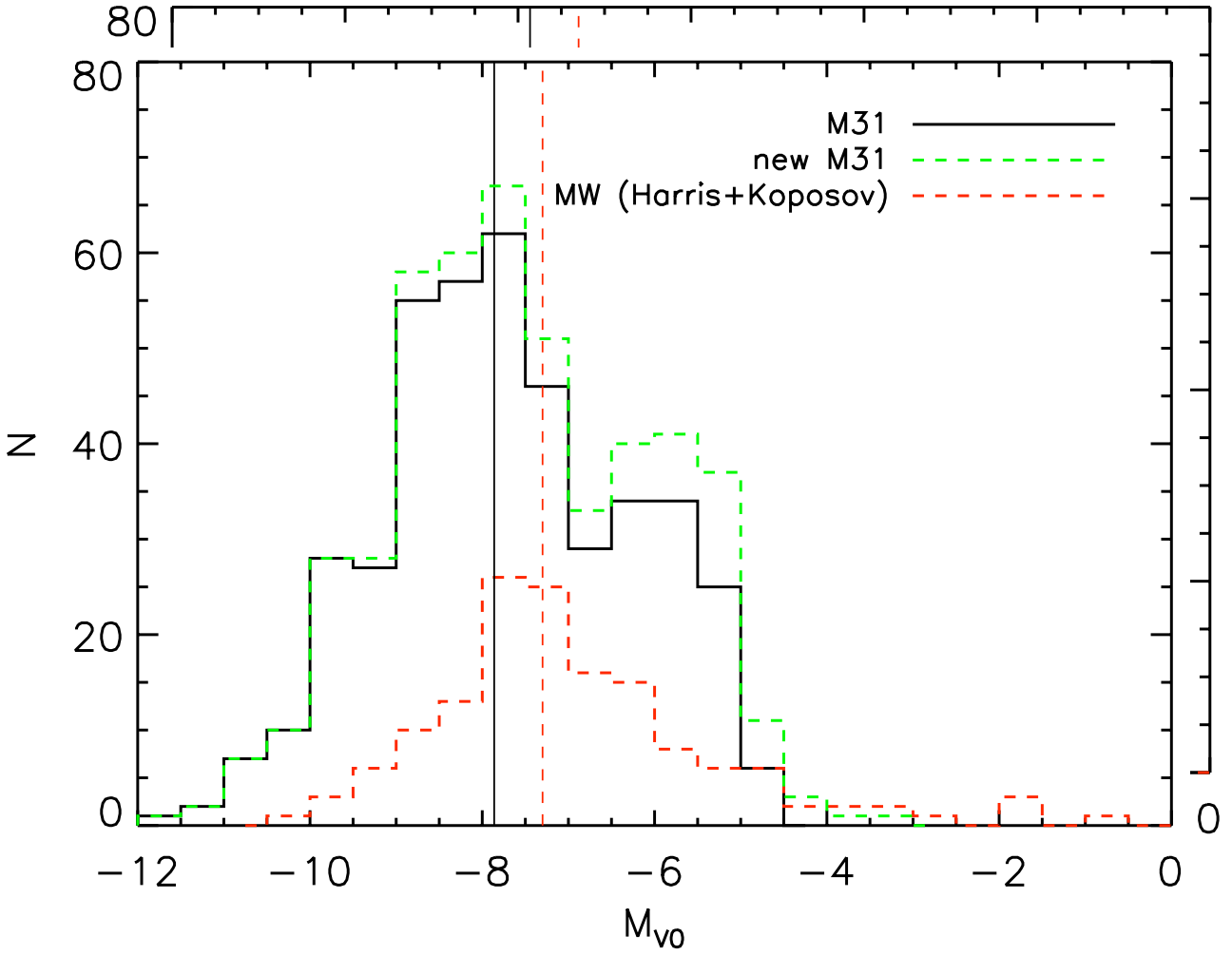
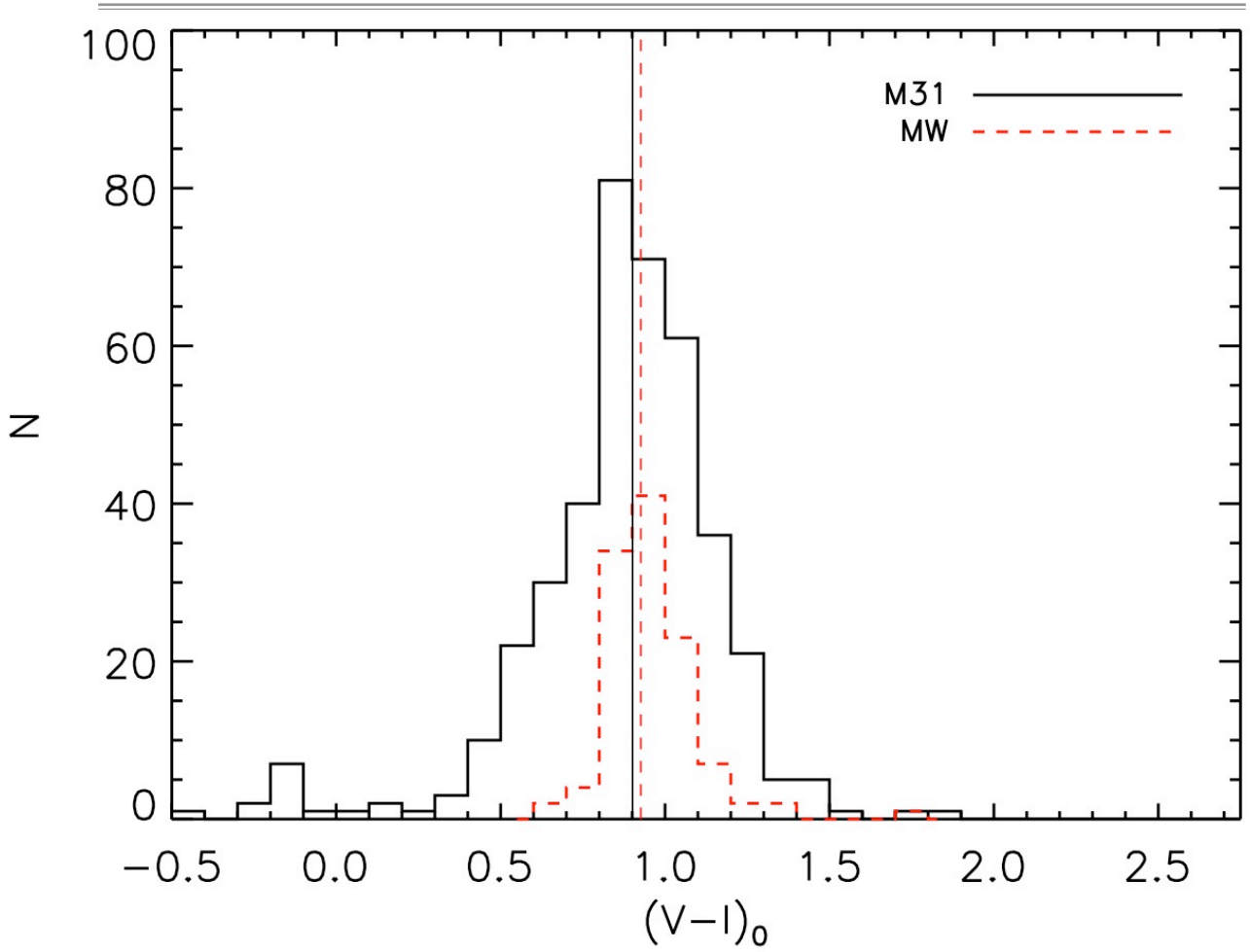
New data (with warning) strengthens second peak.



Colour

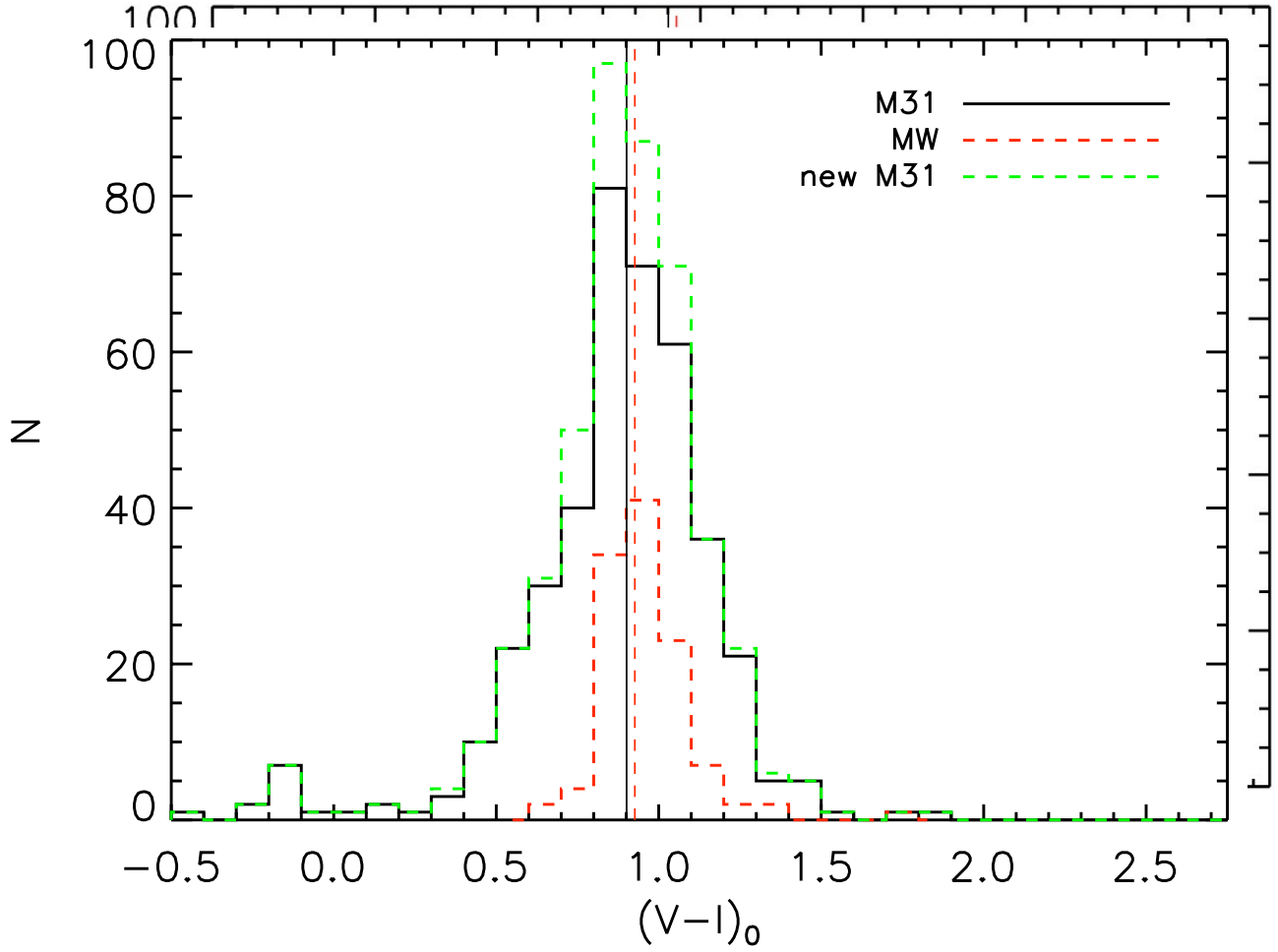
(V-I) colours very similar to the MW.



Colour

(V-I) colours very similar.

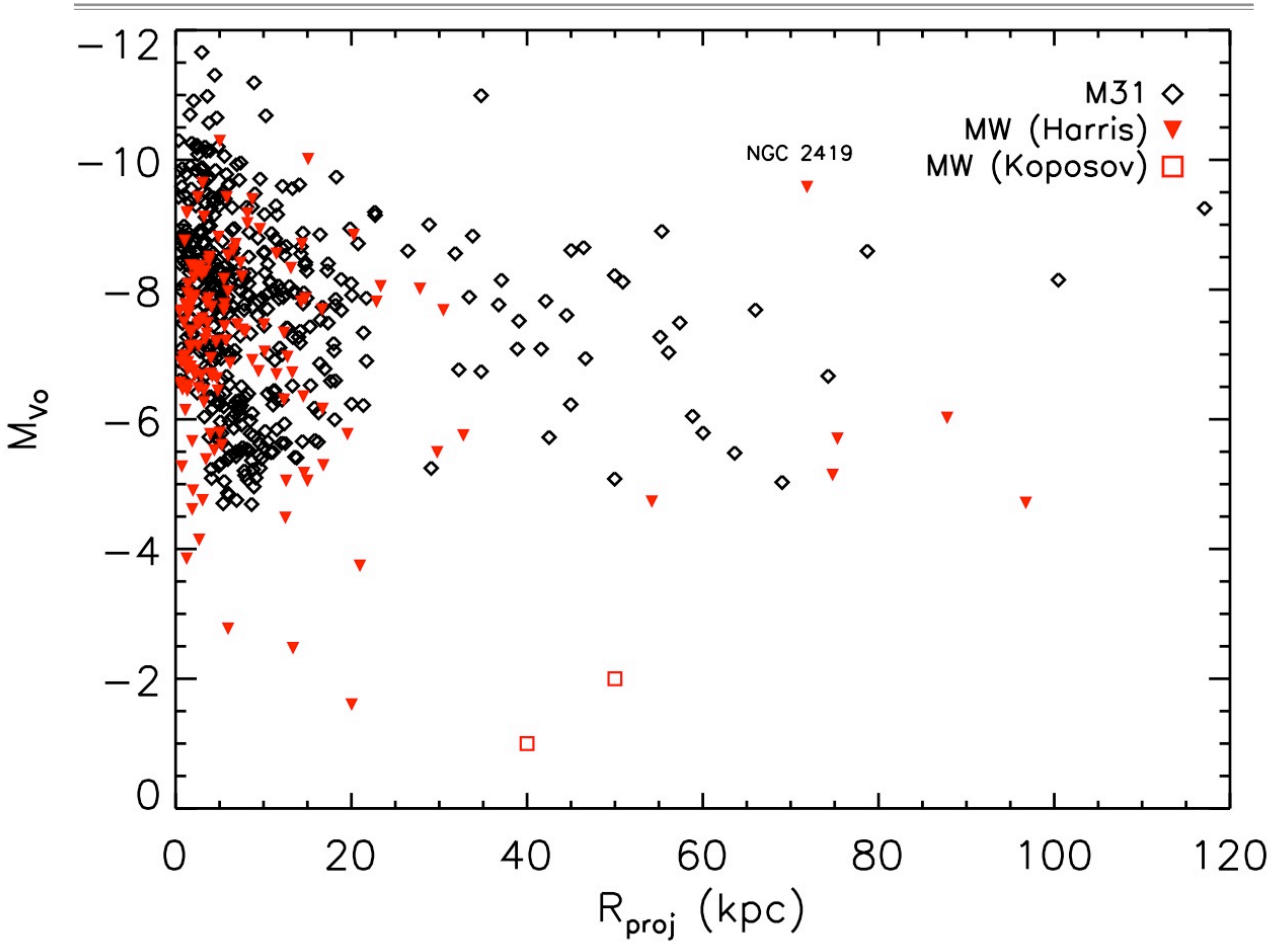
New data concurs



Luminosity against distance to host

M31 has a population of luminous GCs in the outer halo. The only MW counterpart is the unusual cluster NGC2419

We miss the very faint clusters in M31 (M_{V0} > -4)



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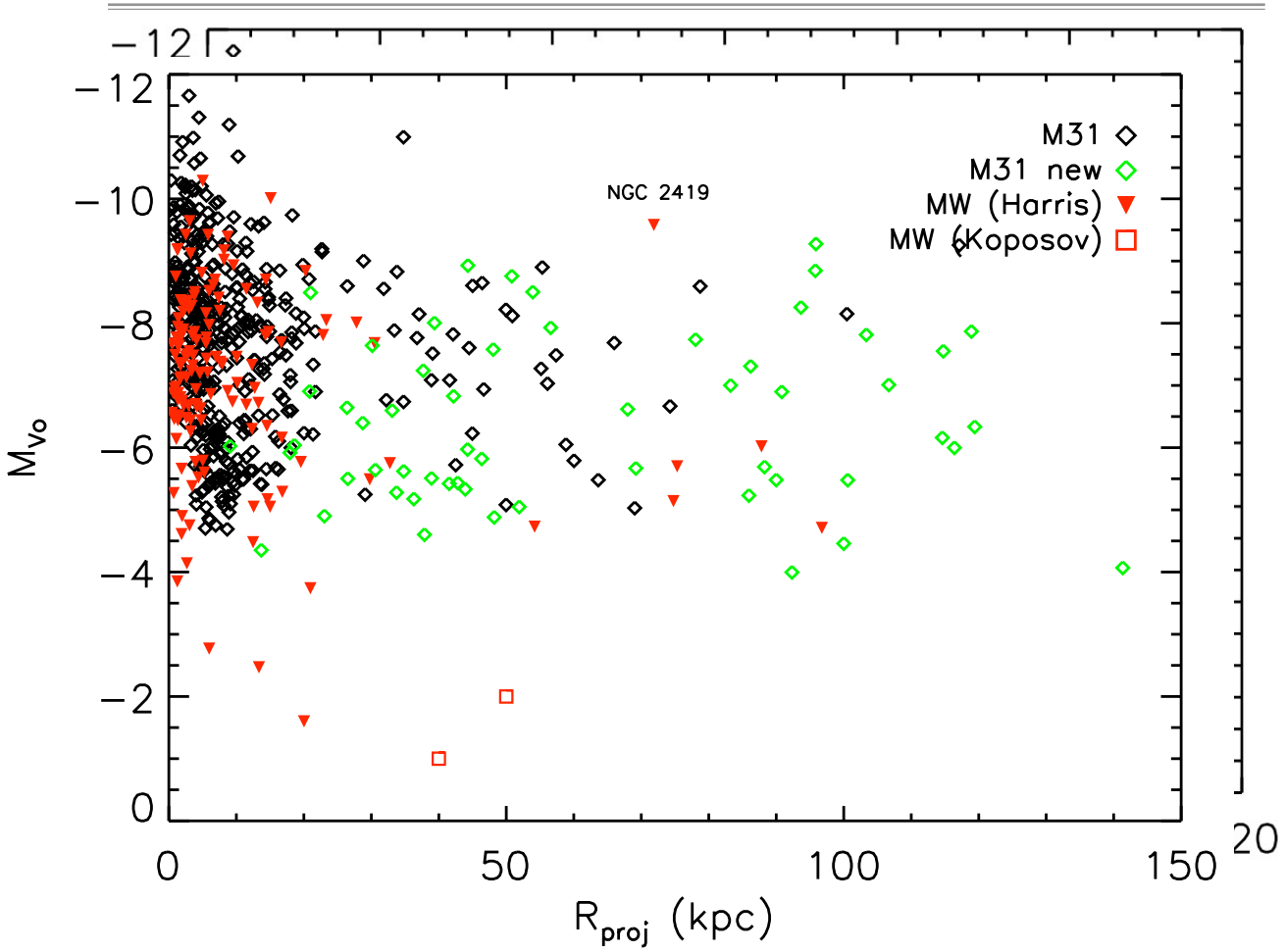
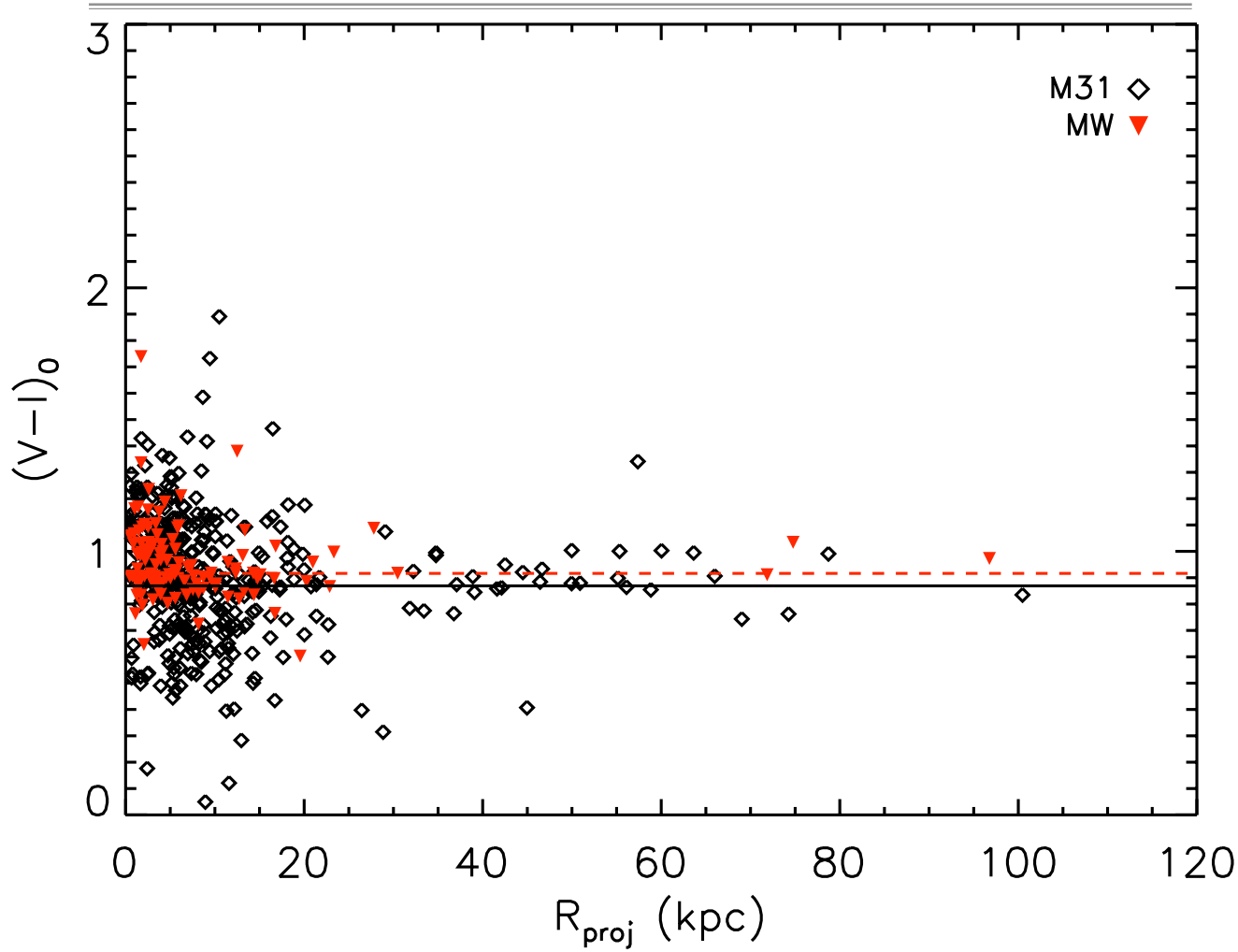
New data follows same pattern.



Colour against distance to host

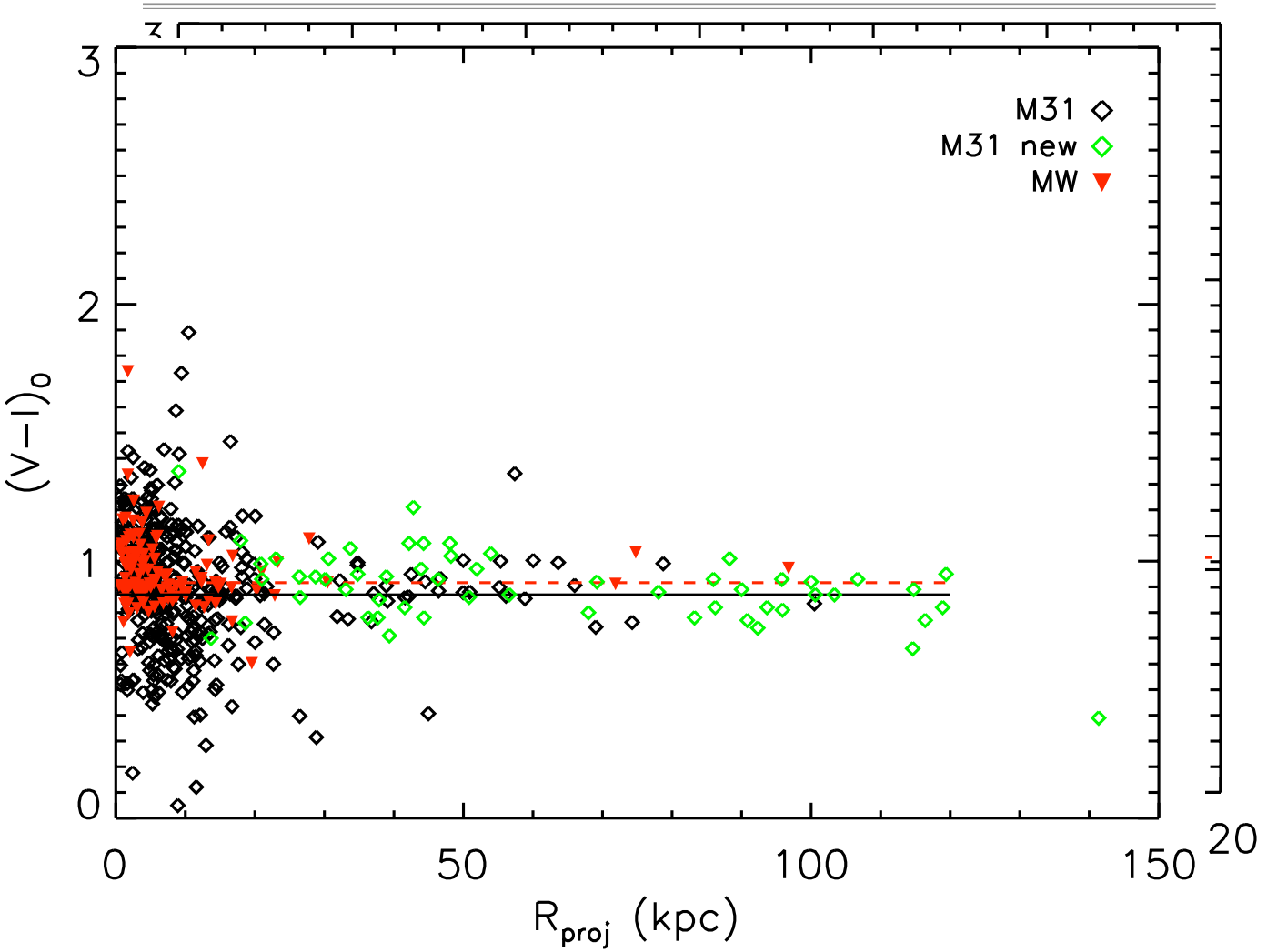
Colors in outer halo are uniformly blue, and similar to the MW halo.



Colour against distance to host

Colors in outer halo are uniformly blue, and similar to the MW halo.

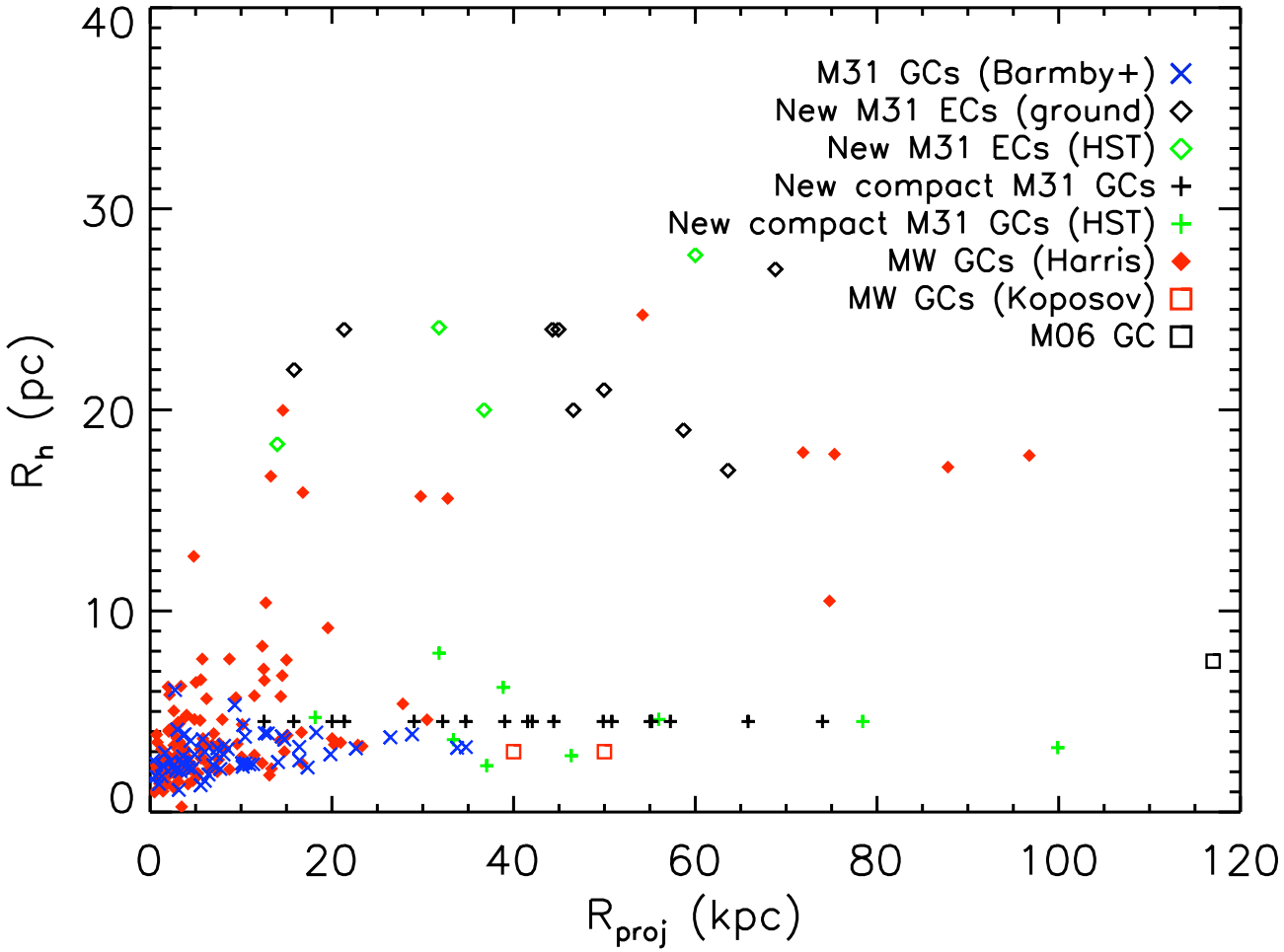
New data consistent witl this result, with hints tha that more metal-rich population starts < 50 kpc.



Half-light radii

M31 and MW appear quite different. MW has no compact GCs at large $R_{proj.}$

Suggestion of bimodal distribution in R_{eff} in M31 halo with few from 8 - 15 pc. Compact vs Extended?



Half-light radii

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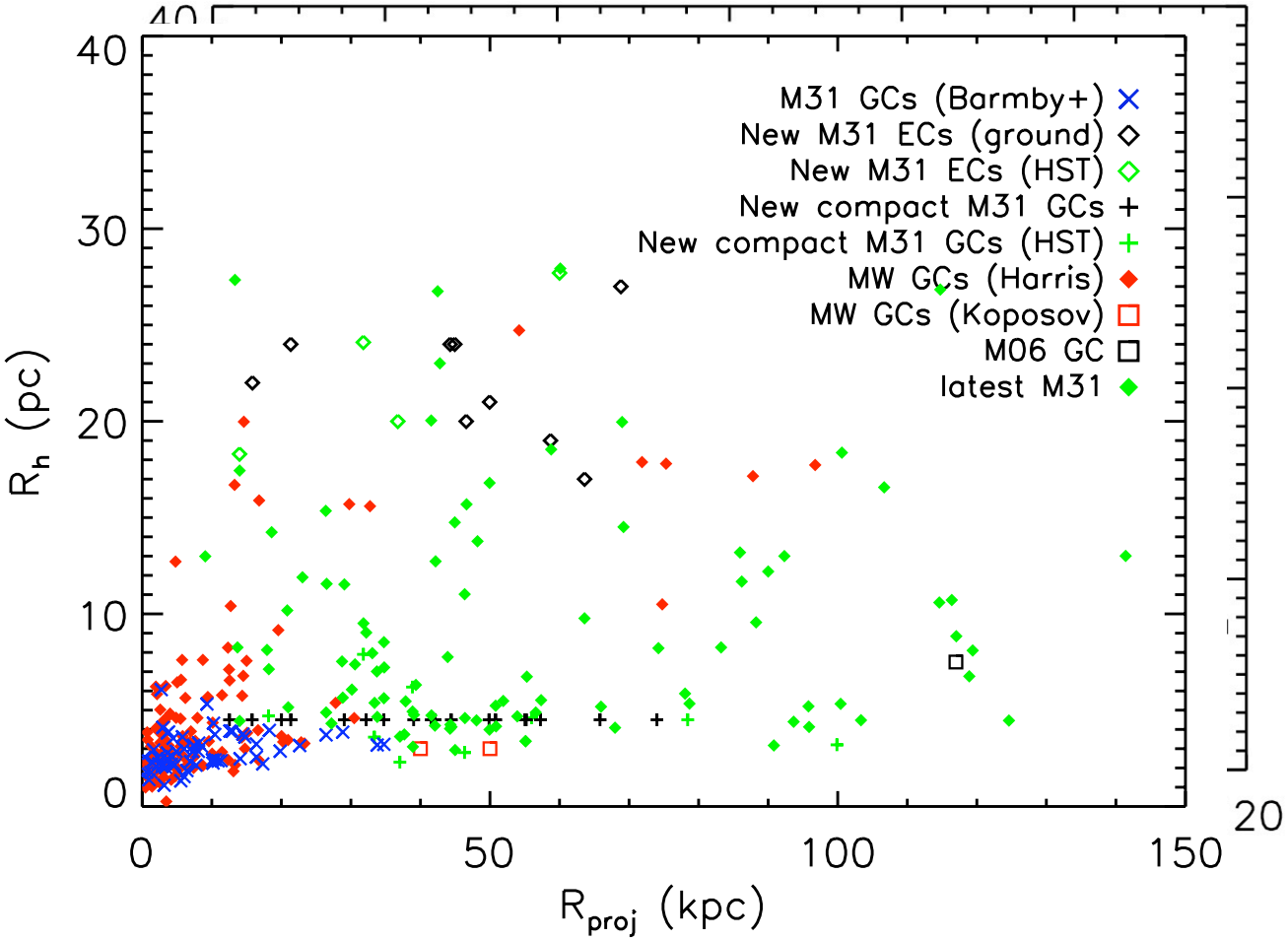
Suggestion of bimodal distribution in R_{eff} in M31 halo with few from 8 - 15 pc. Compact vs Extended?

New data reveals many extended clusters, but fills in gap in R_{eff}.

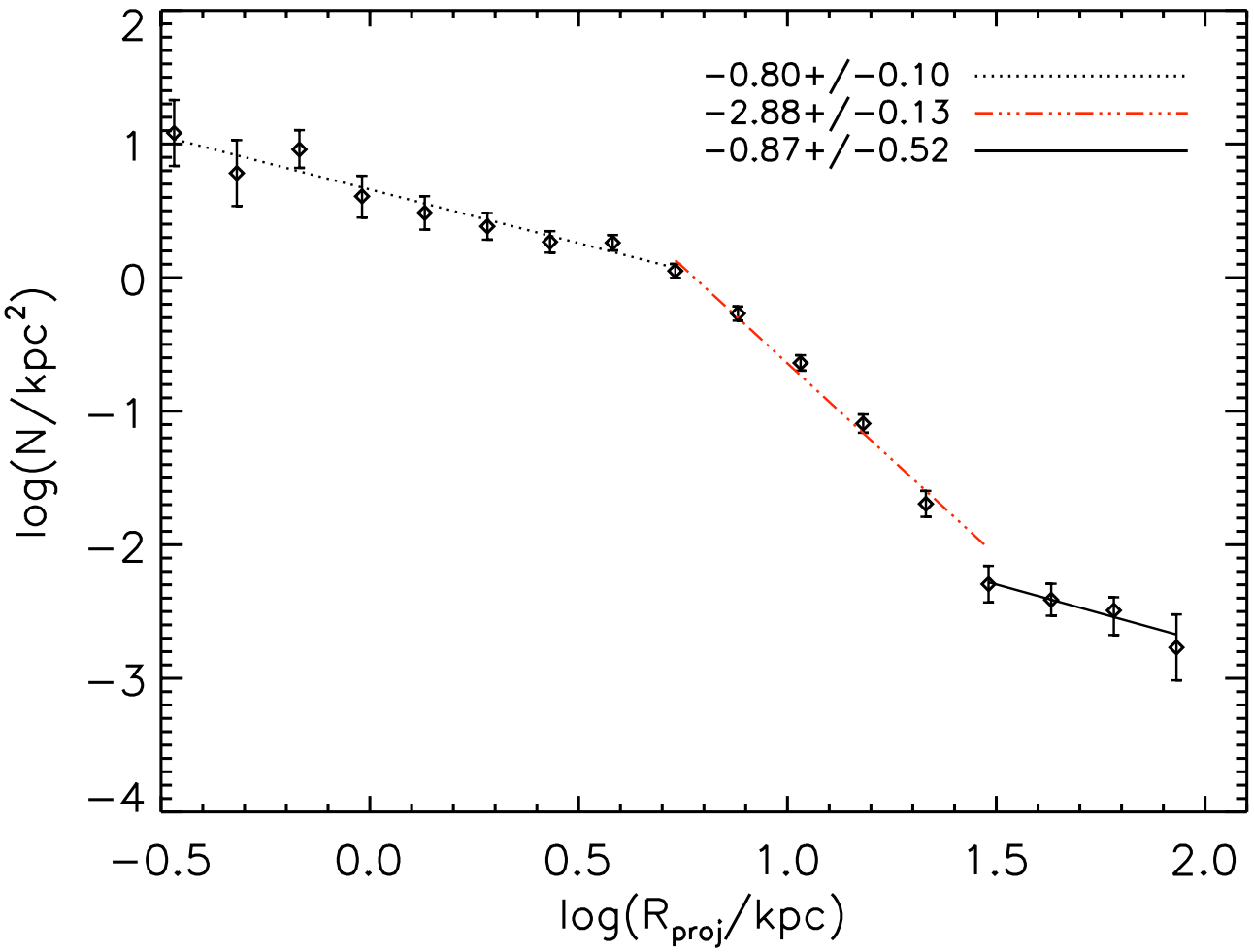


GC surface density profile

Using conventional $R^{1/4}$ fit, we see a break in the outer slope.

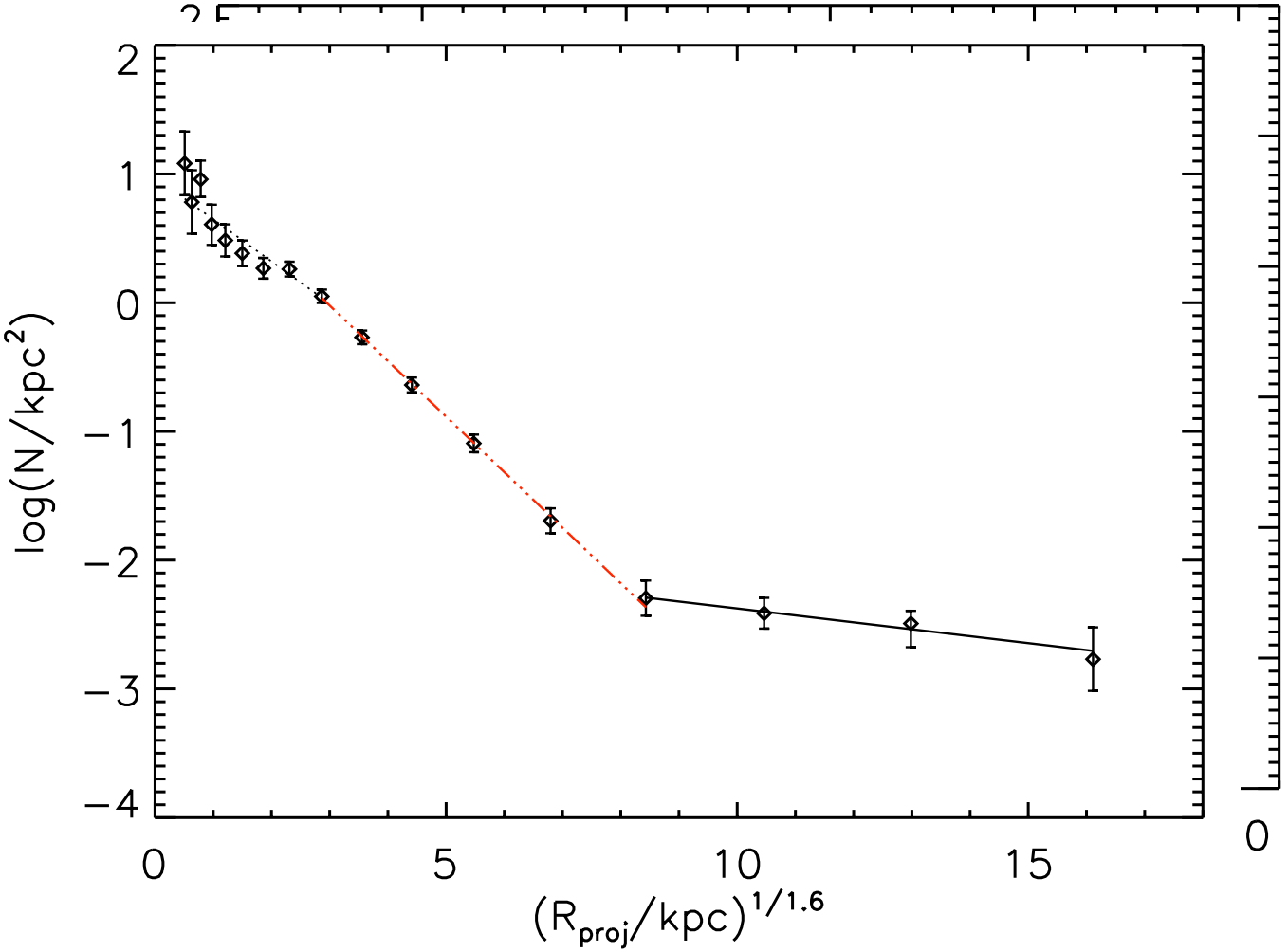
Not seen before.

[shallower inner slope known, and likely due to detection problems in central region, and cluster disruption]



GC surface density profile

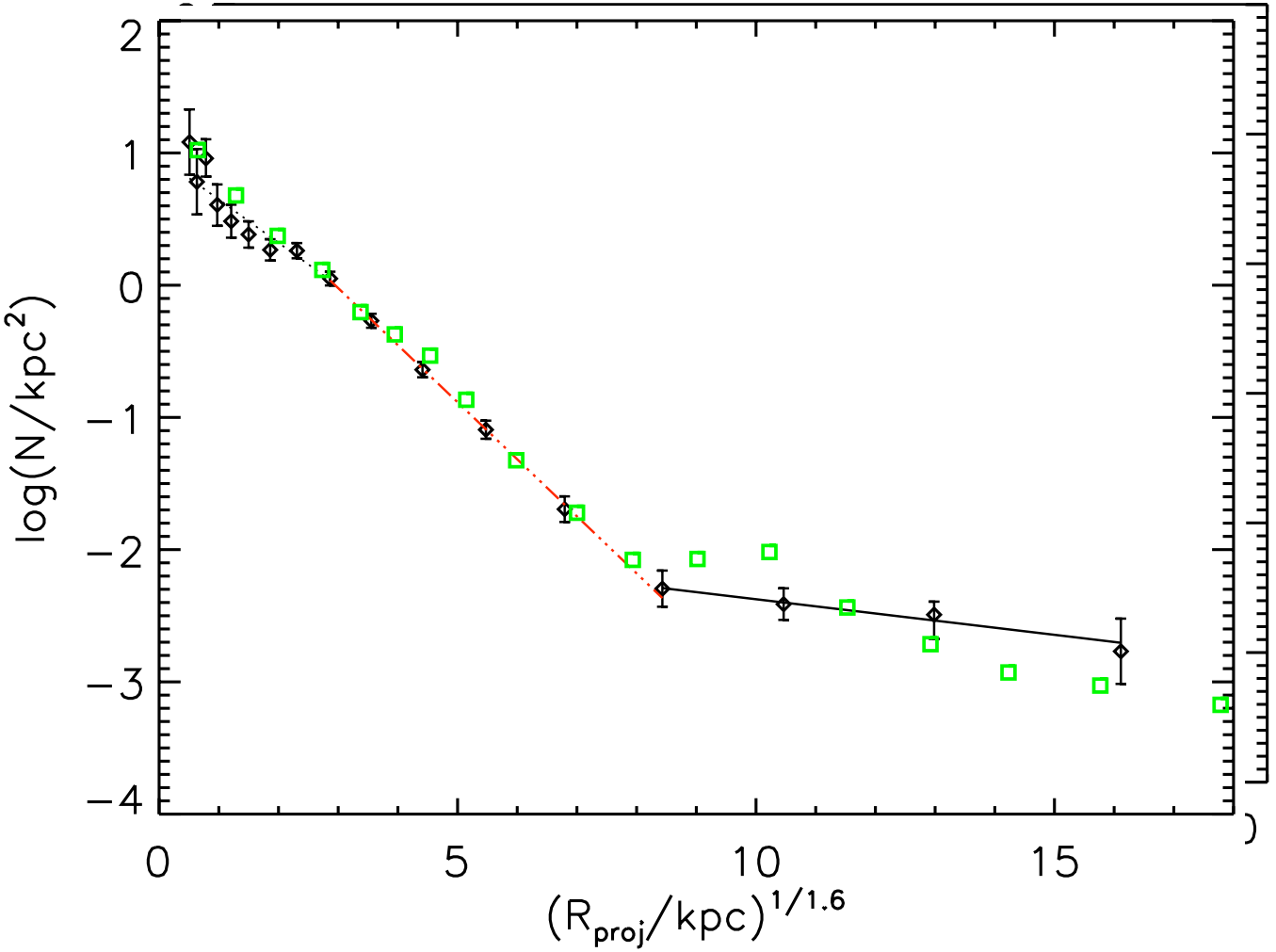
Using best empirical fit from Battistini et al. (1993), $R^{1/1.6}$ we get excellent fit, despite much amended dataset



GC surface density profile

New data consistent, with much larger number of clusters.

Outer region starting to show suggestions of ‘substructure’.

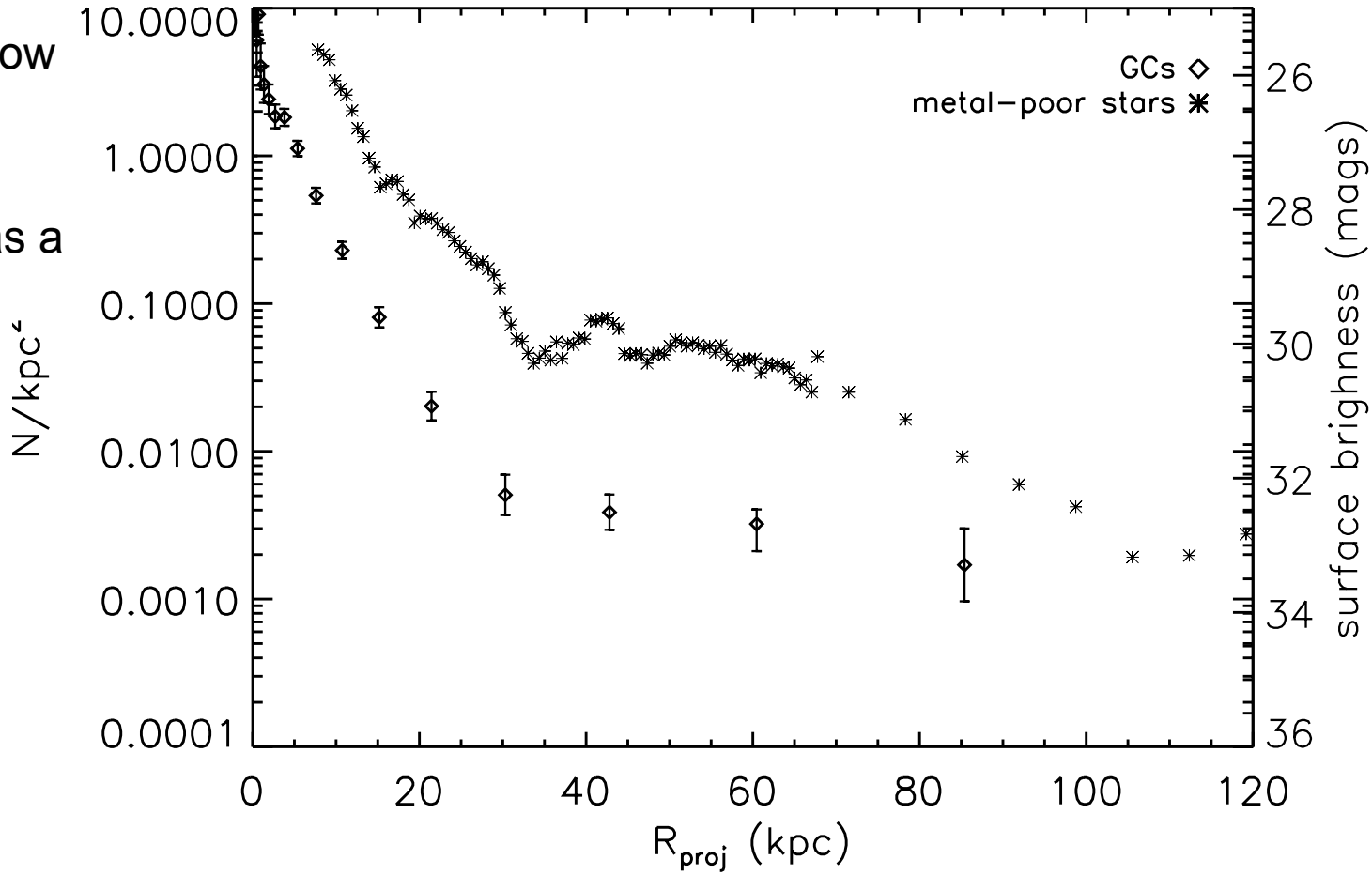


GC surface density profile

GCs and stars follow similar profile.

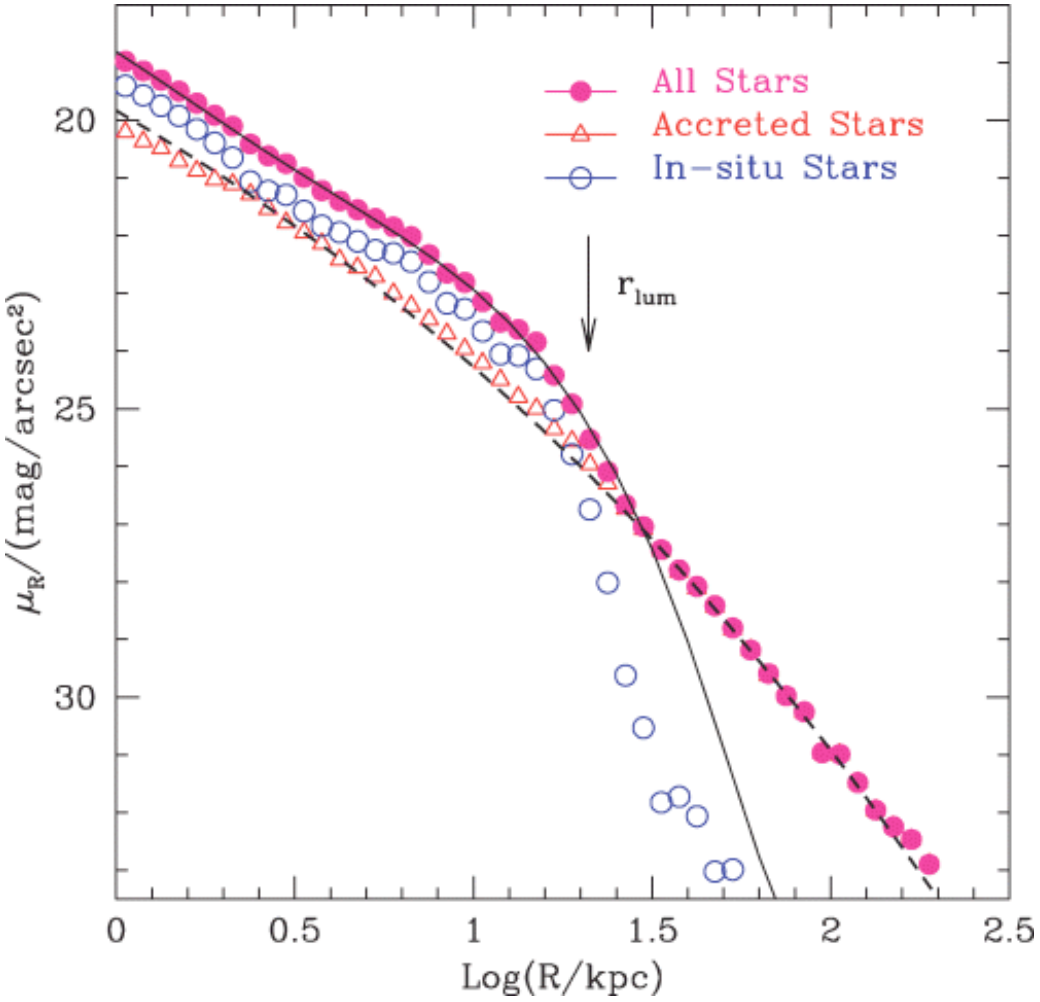
New data even has a bump at R_{proj} ~ 40 kpc.

Suggestive of a common origin?



Comparison with models

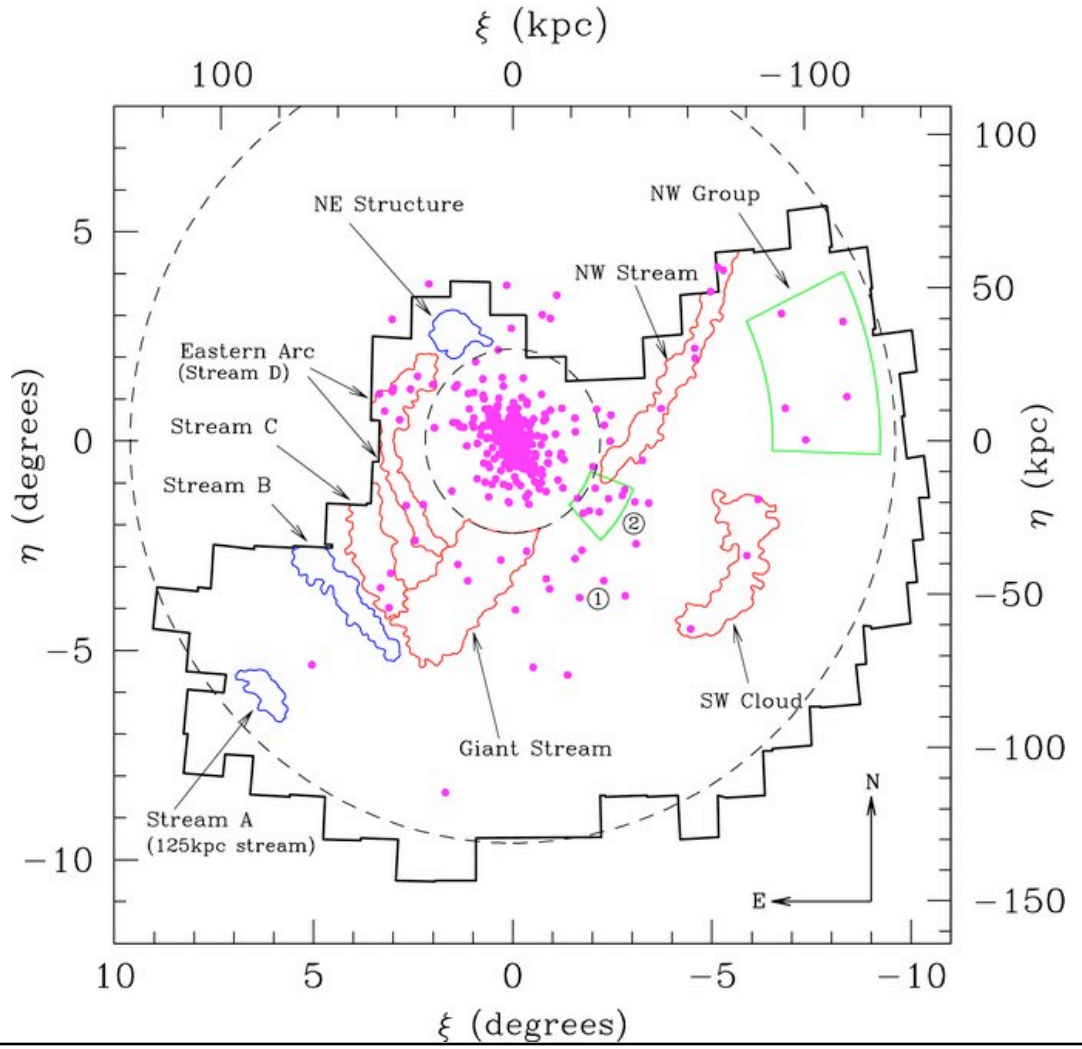
- Abadi et al. (2005)
- Numerical simulations of mergers produce a ‘luminous radius’ r_{lum}, beyond which stars mostly accreted.
- We have different slopes in our data, but qualitative similarity with break in M31 profiles.



GCs and substructure

GCs lay on stellar substructure.

Mackey et al (2010) applied a Monte Carlo technique and found a < 1% chance that clusters would lie on the stellar over-densities (> 3.5 σ over local background).



Velocities

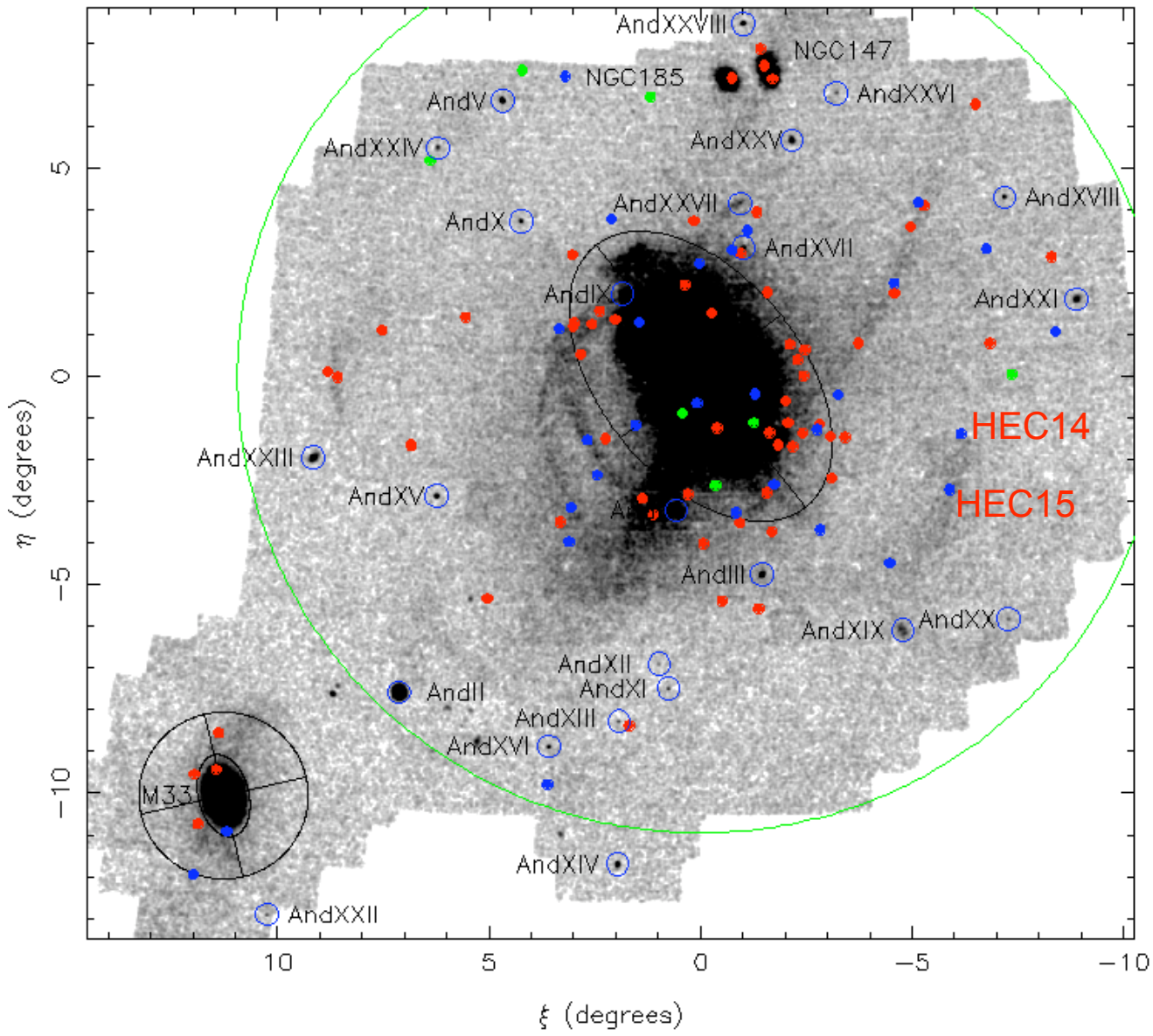
Most R_Vs to date are in the inner halo, where substructure more confusing

New data taken in outer halo, and being reduced

As a taster, 2 R_Vs in the SW cloud from GMOS

HEC-14 -426 ±12 km/s

HEC-15 -405 ± 5 km/s



Concluding remarks

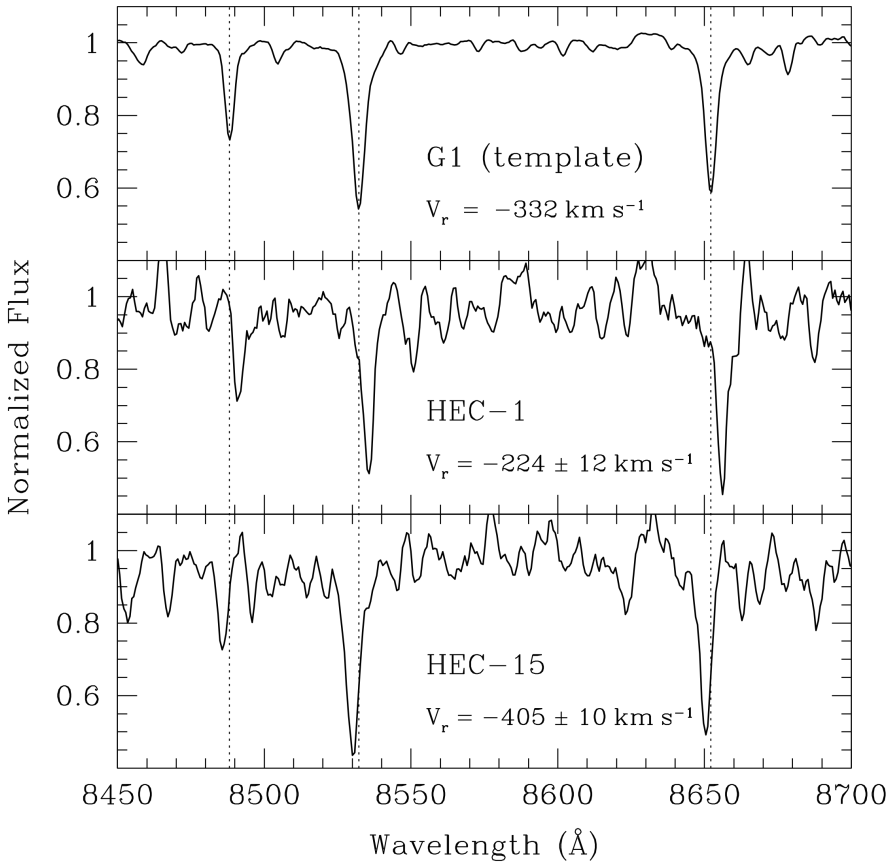
- M31 has an extensive GC system, to the edge of our survey
- Will the bimodal GCLF service close reanalysis?

- Evidence suggest that most (if not all) the outer halo clusters are accreted along with their original host dwarf galaxies
  - Spatial correlation with stellar substructure
  - The break in the GC profile appears to be a signature of this (but hard to see at large distances?)
  - Extended clusters preferentially found in dwarfs (e.g. NGC 6822, Scl-dE1)?

- The differences in the halo cluster population of M31 w.r.t the MW: the compact halo clusters, the luminous halo clusters, the extended clusters, must be telling us something about:
  - The number of merger/accretion events
  - The type/mass of satellites

GMOS

GMOS observations of ECs, for R_Vs



WHT/ISIS spectroscopy, 2009B: 3 nights, 15 targets, PI Huxor

KPNO-4m spectroscopy, 2009B: 5 nights, 18 targets, PI Ferguson

WHT/ISIS spectroscopy, 2010B: 3 nights, 17 targets, PI Huxor

Gemini/GMOS spectroscopy, 2010B: 6 hours, 4 targets, PI Mackey

HST/ACS imaging, Cycle 19: Two proposals pending (13, 15 targets).

Gemini/GMOS spectroscopy, 2011B: Proposal pending (13 targets)

Extended Clusters