The Globular Cluster Systems of Dwarf Elliptical Galaxies

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Do Globular Cluster Systems Mirror Their Host Galaxies? Not really...

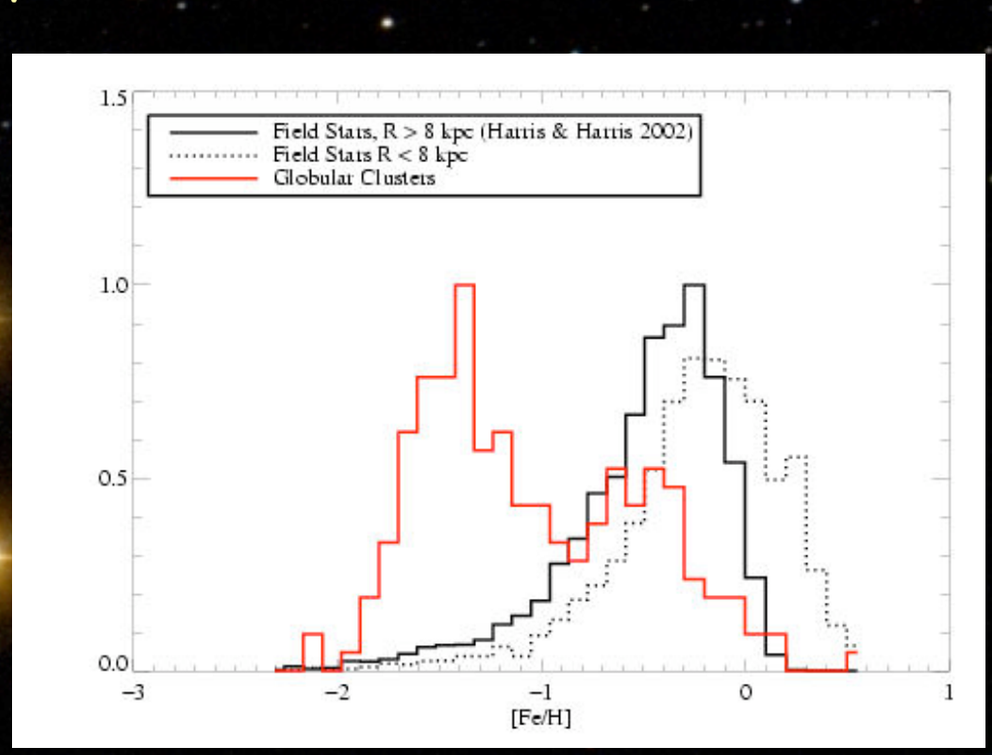
Globular cluster formation efficiencies are not constant across galaxy mass and morphology

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

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

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

[Fe/H] offset between GCs and field



Peng et al (2004); Harris & Harris (2002)

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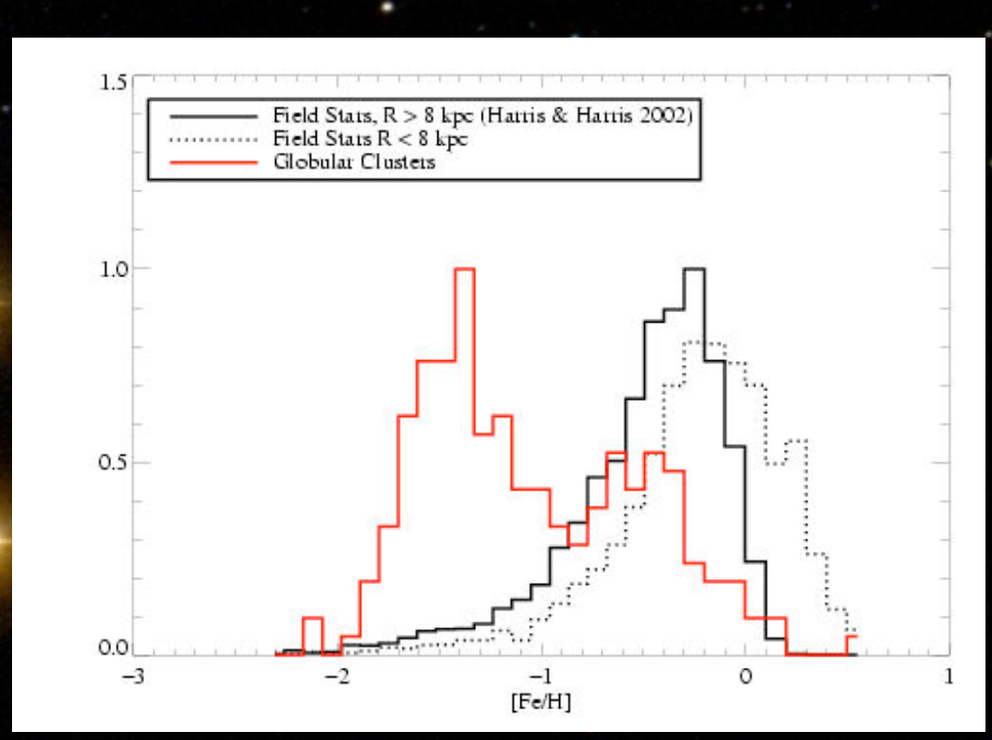
How do different S_N and metallicity distributions fit in a framework of hierarchical assembly?



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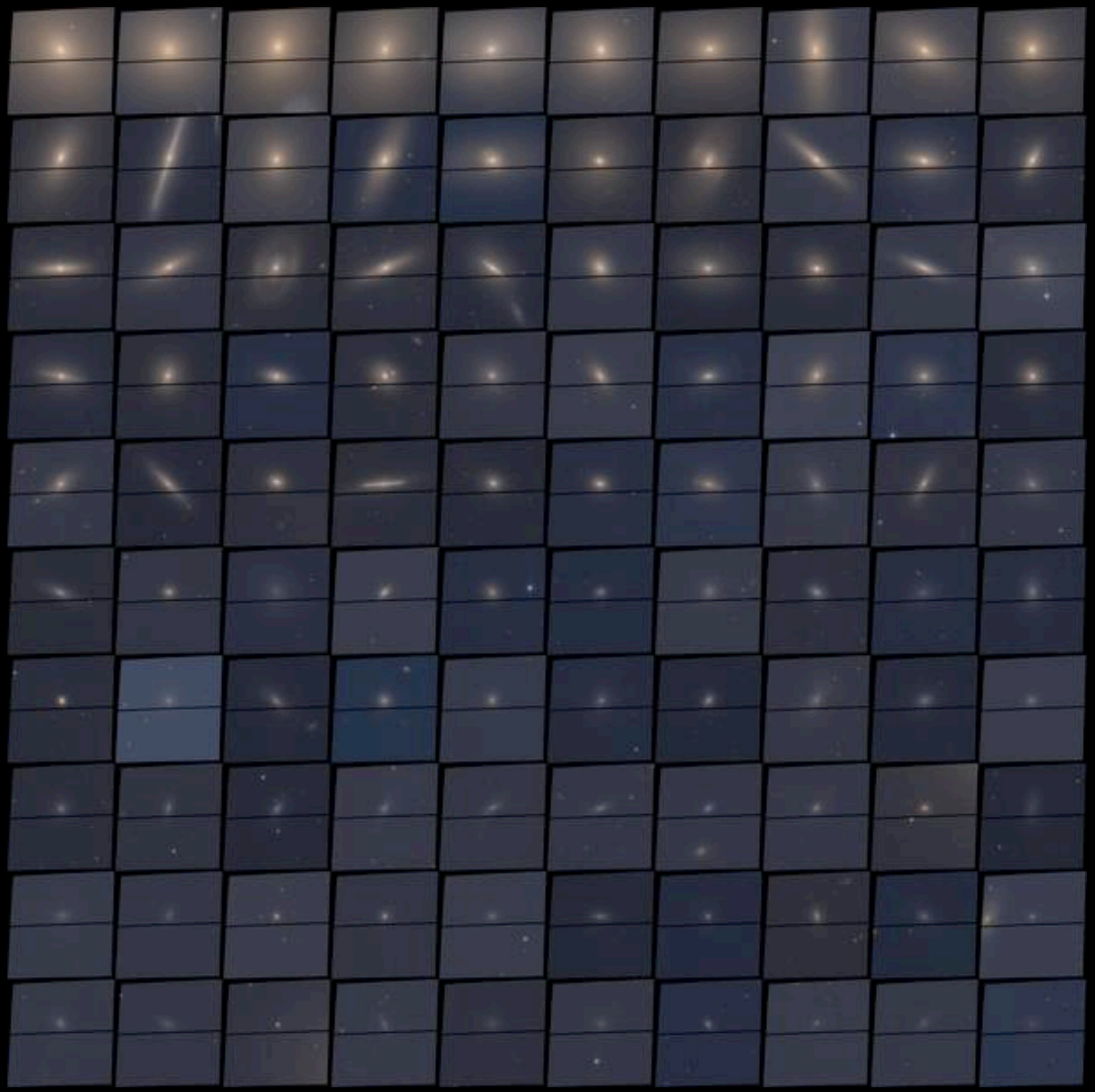
The ACS Virgo Cluster Survey



- HST/ACS imaging survey in *g* and *z*
- 100 early-type galaxies
- $-22 < M_B < -15$, giants to dwarfs
- Depth: 90% of *GC* population
- 16 control fields for *GC* identification and background subtraction

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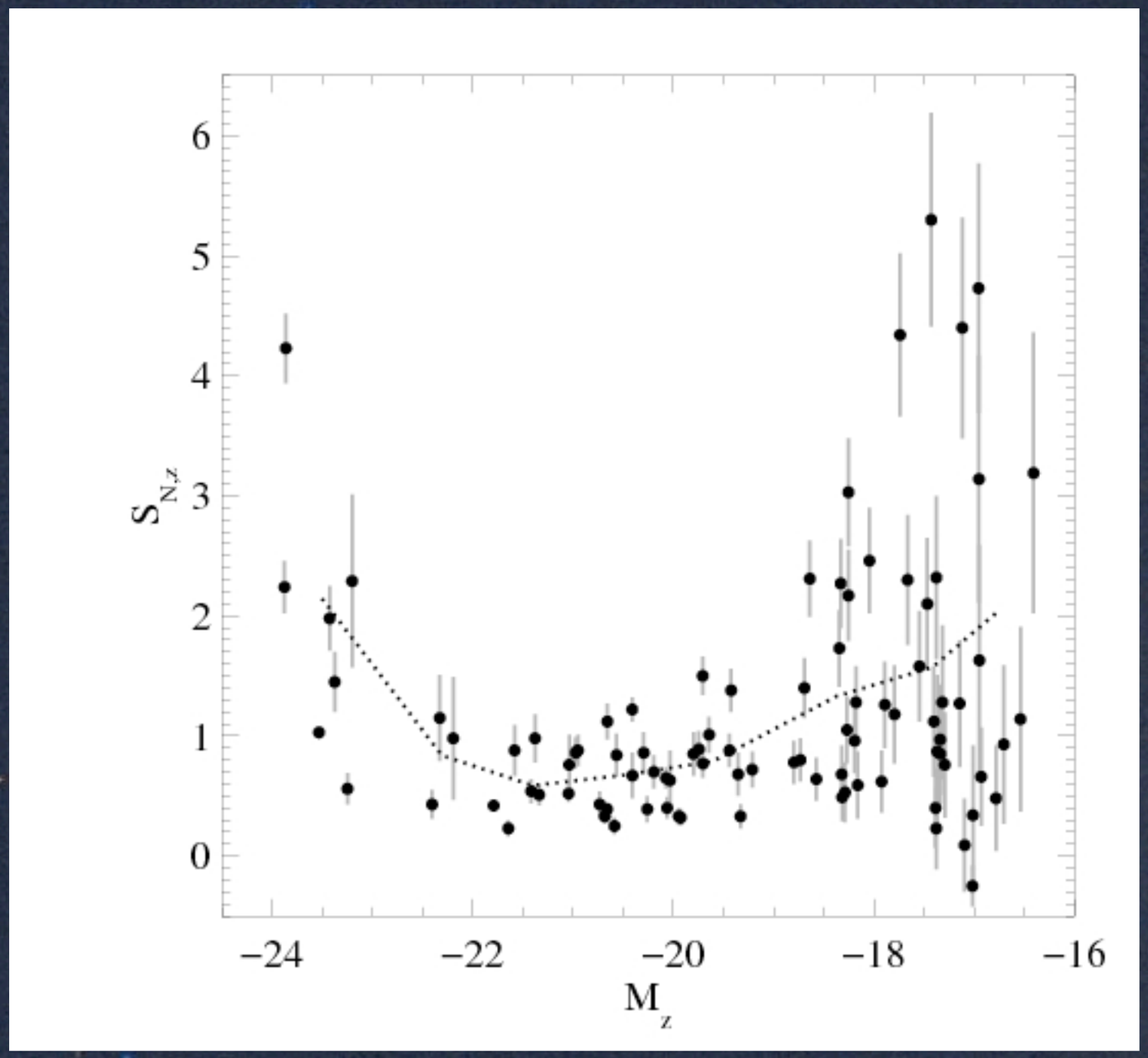
A homogeneous survey across the mass spectrum of "surviving progenitors" and "merger products"

The ACS Virgo Cluster Survey

Patrick Côté (PI: Virgo)
John Blakeslee
Laura Ferrarese
Andrés Jordán (PI: Fornax)
Simona Mei
Eric Peng
John Tonry
Michael West

Dalia Chakrabarthy
Chin-Wei Chen
Elena Dalla Bontá
Marla Geha
Monica Haşegan
Dean McLaughlin
Steffen Mieske
Chris Onken
Slawomir Piatek
Marianne Takamiya

How does GC fraction behave across galaxy mass?



Peng et al.

- Narrow range of S_N at intermediate L
- High S_N values for both giants and dwarfs
- Reminiscent of M/L vs galaxy mass

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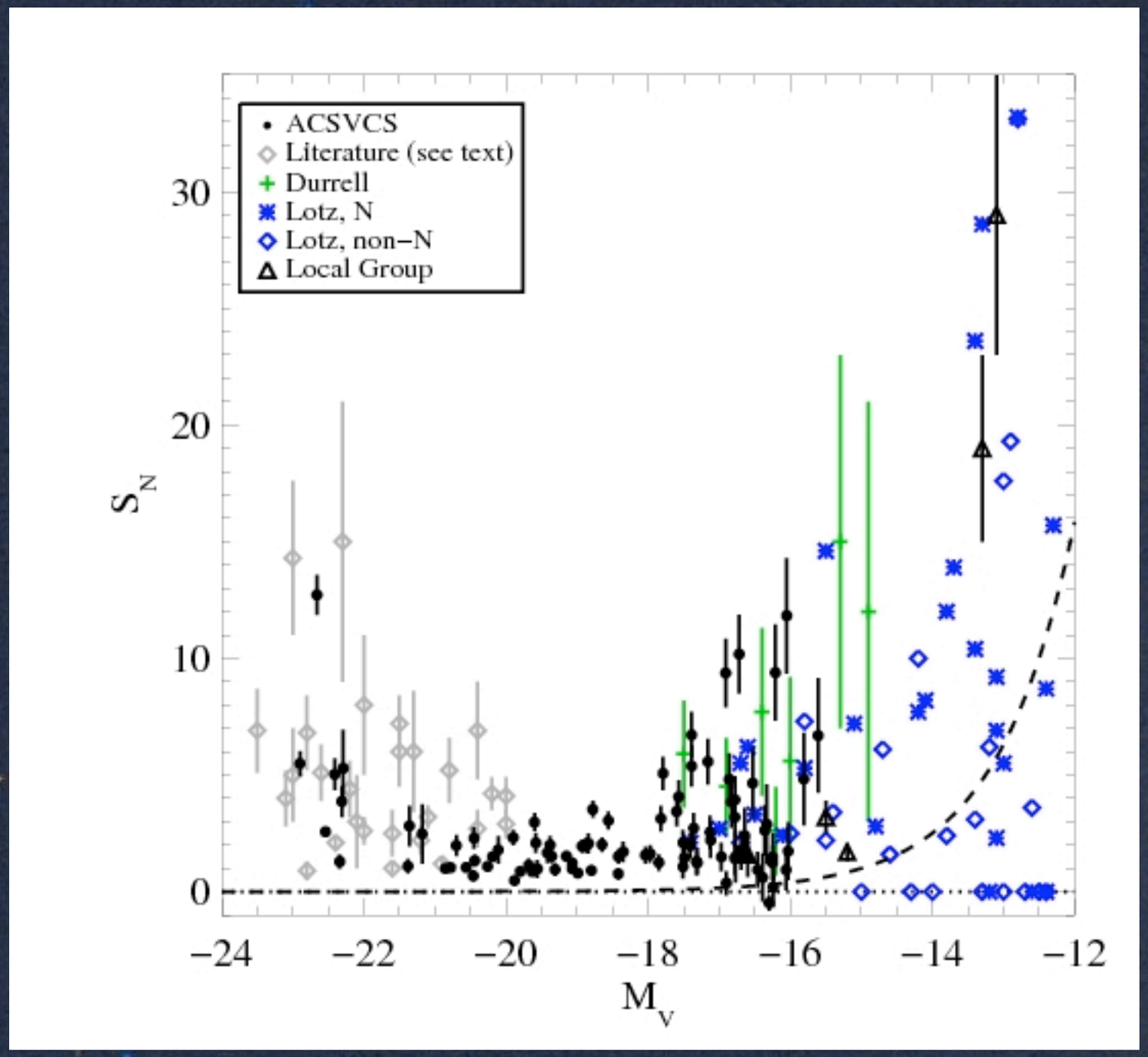

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Do Globular Clusters trace Total Mass?

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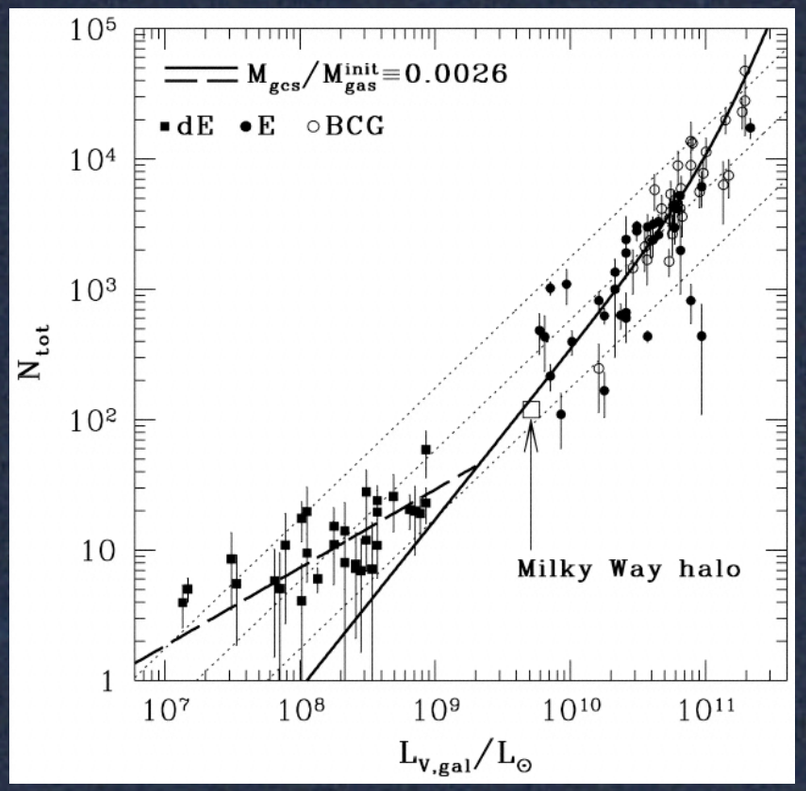
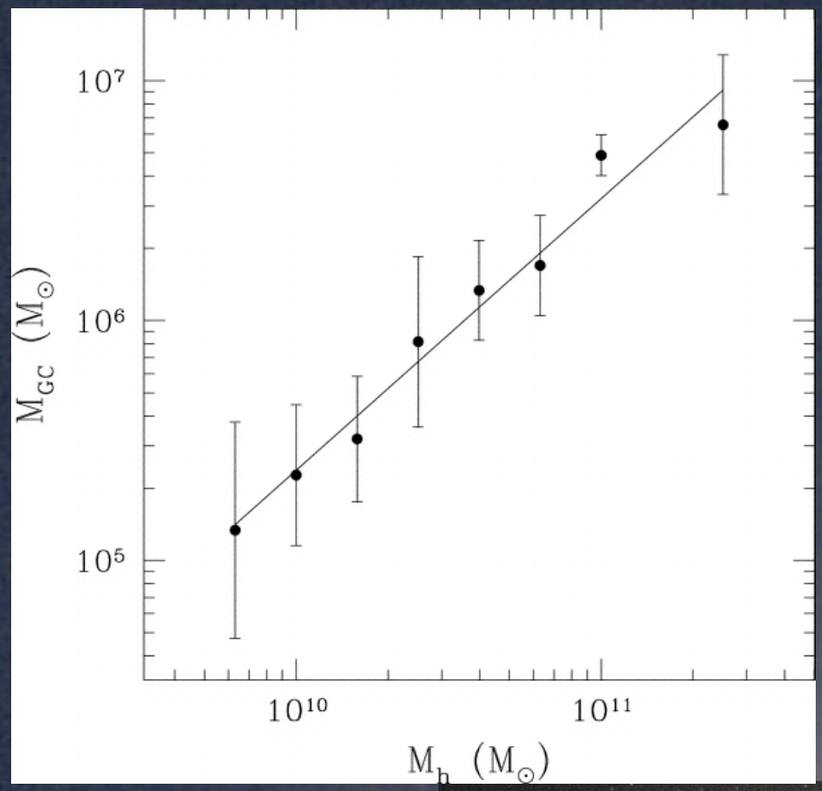
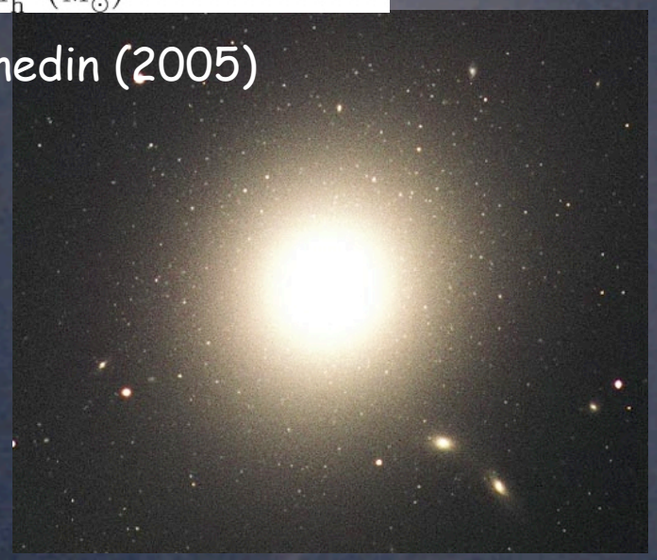
Mass in GCs may correlate with total baryonic or total dark mass



McLaughlin (1999)



Kravtsov & Gnedin (2005)



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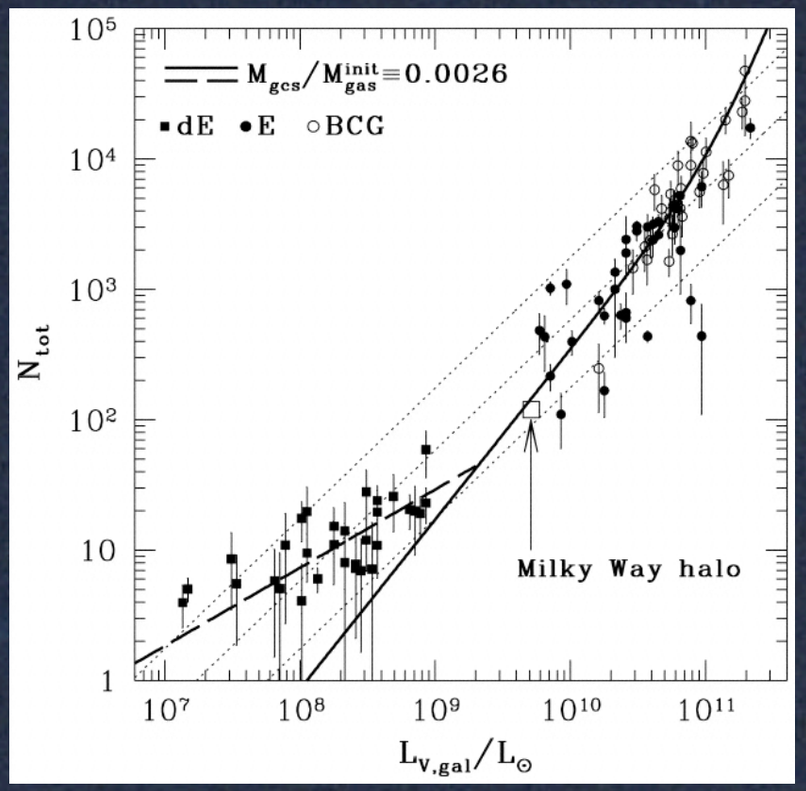

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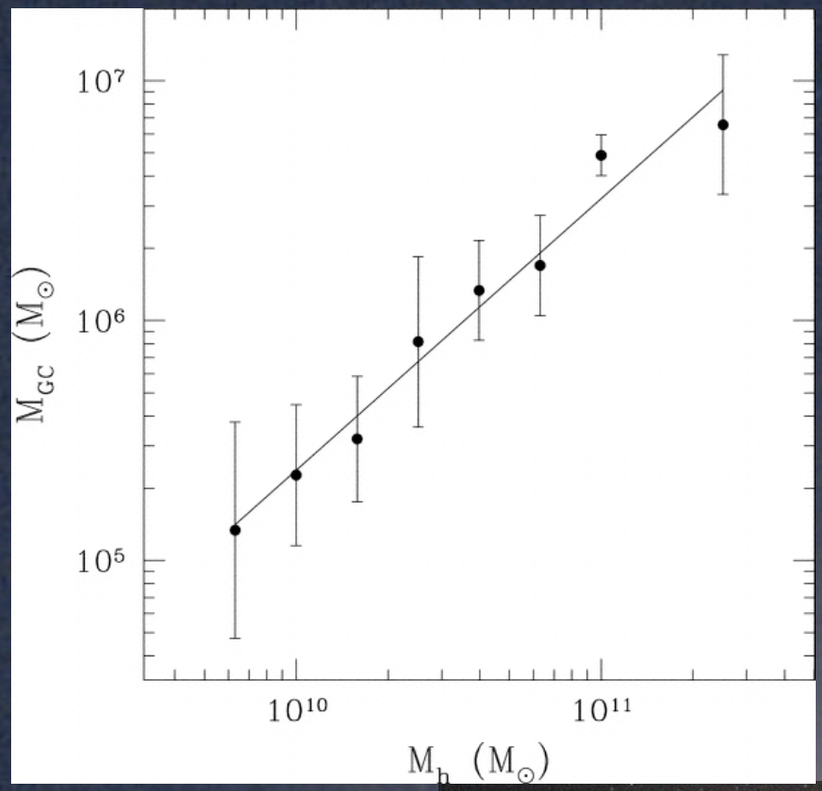

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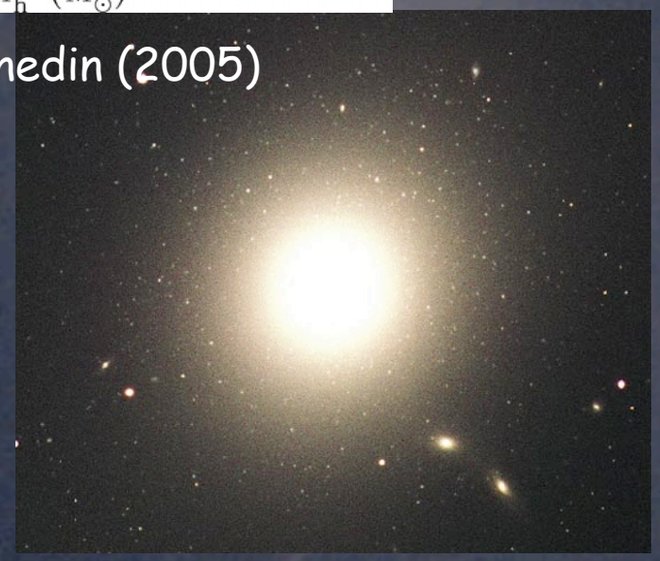
Are globular clusters better tracers of total mass than stars themselves?



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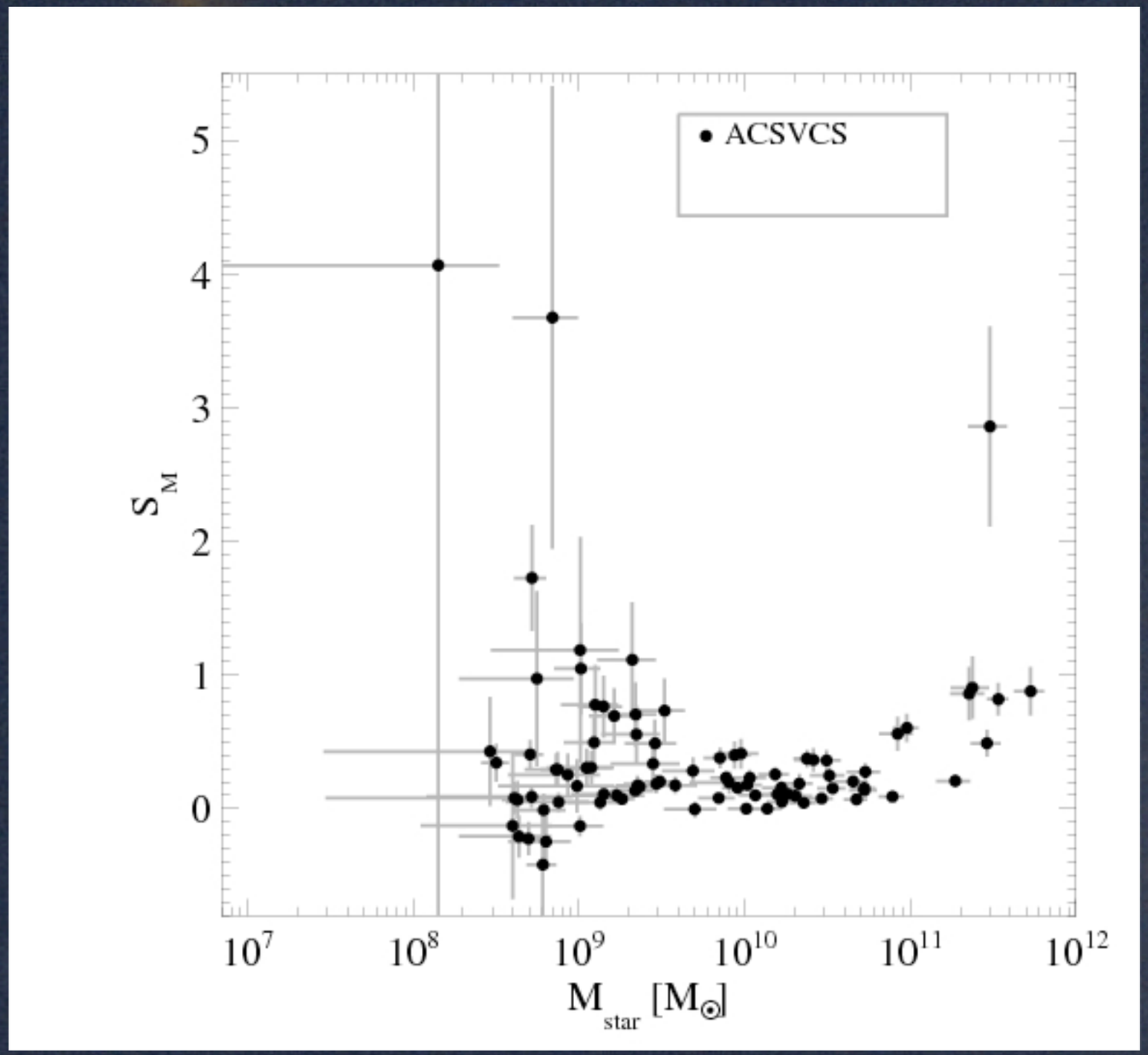

- Translate into *GC* stellar mass fraction

Peng et al.

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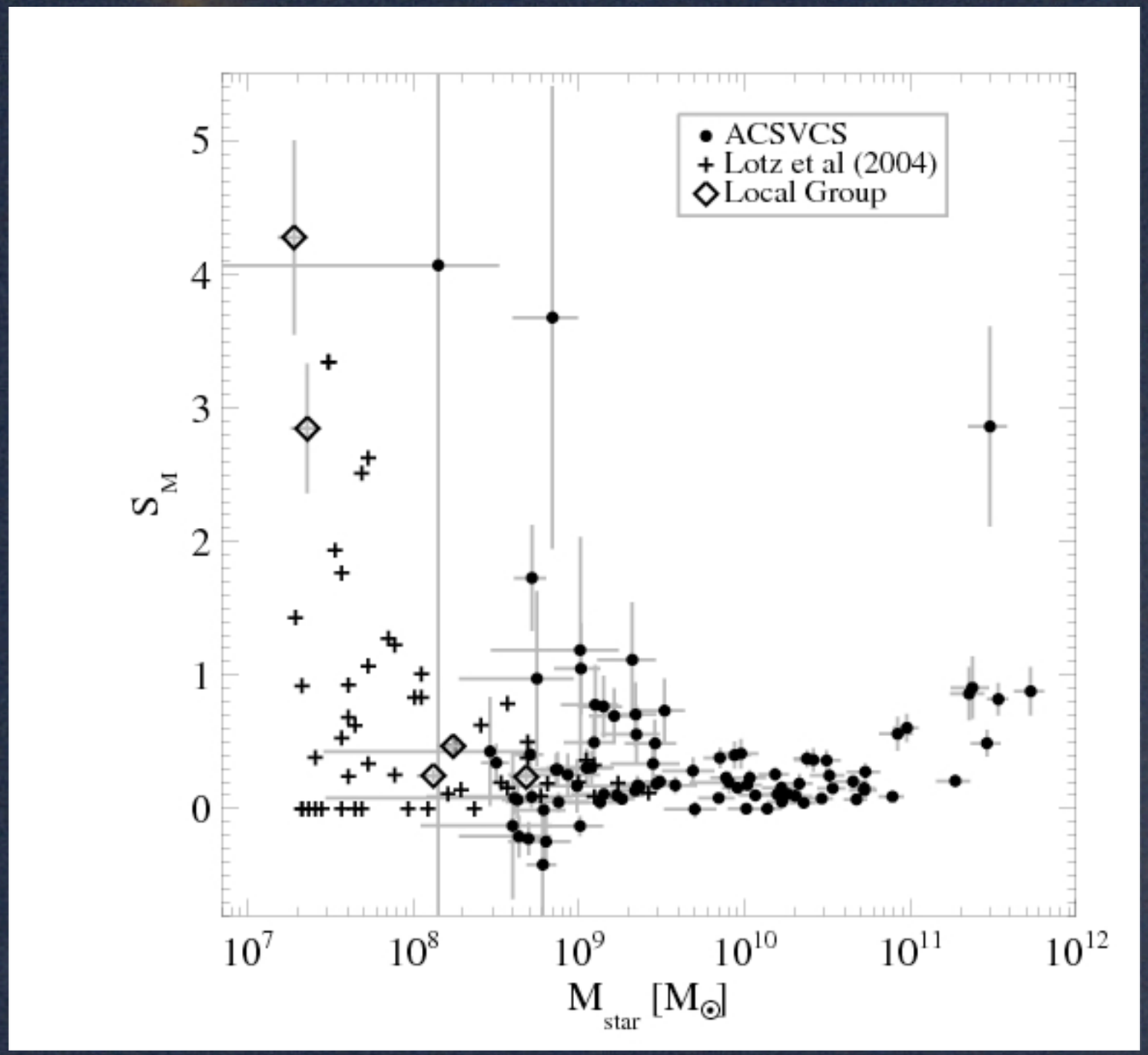

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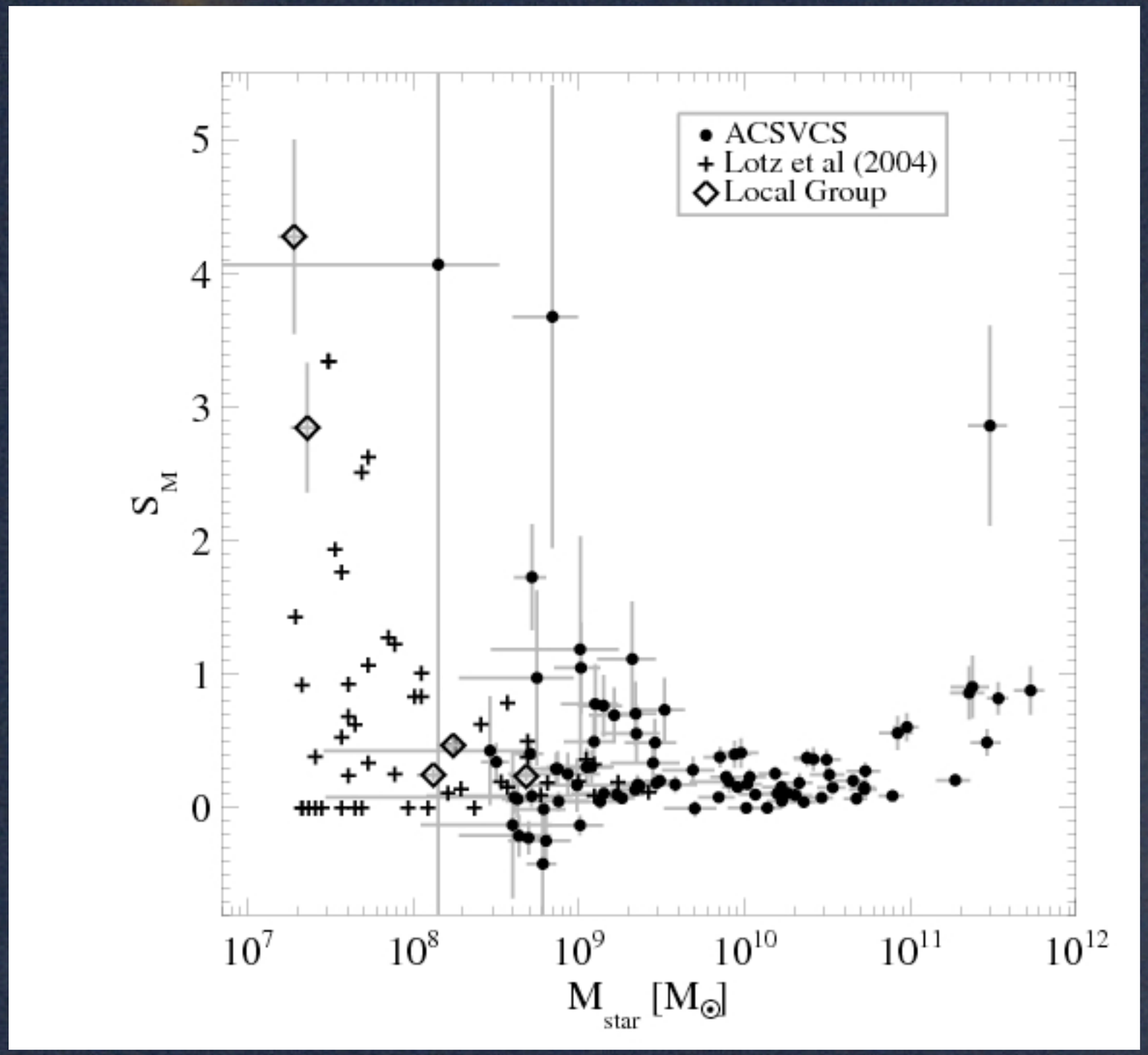

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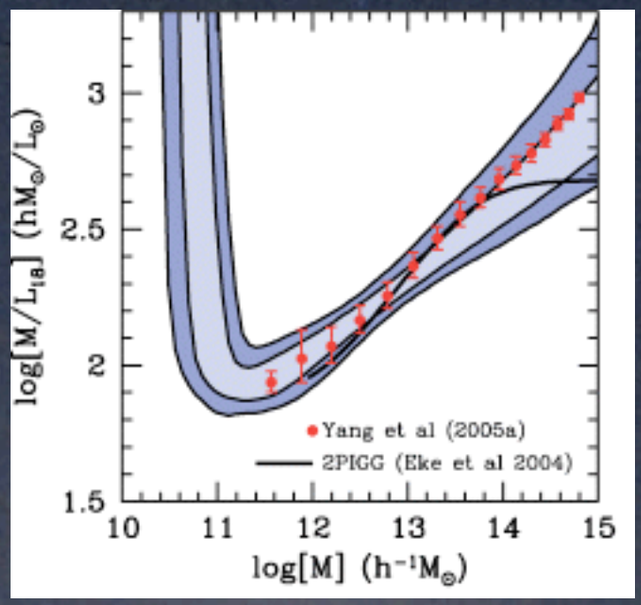
- M_h/L vs M_{gal} also has "U"-shaped relation



$S_M \propto M_h/L$?

- Use relation derived from HOD (van den Bosch 2007)

Peng et al.

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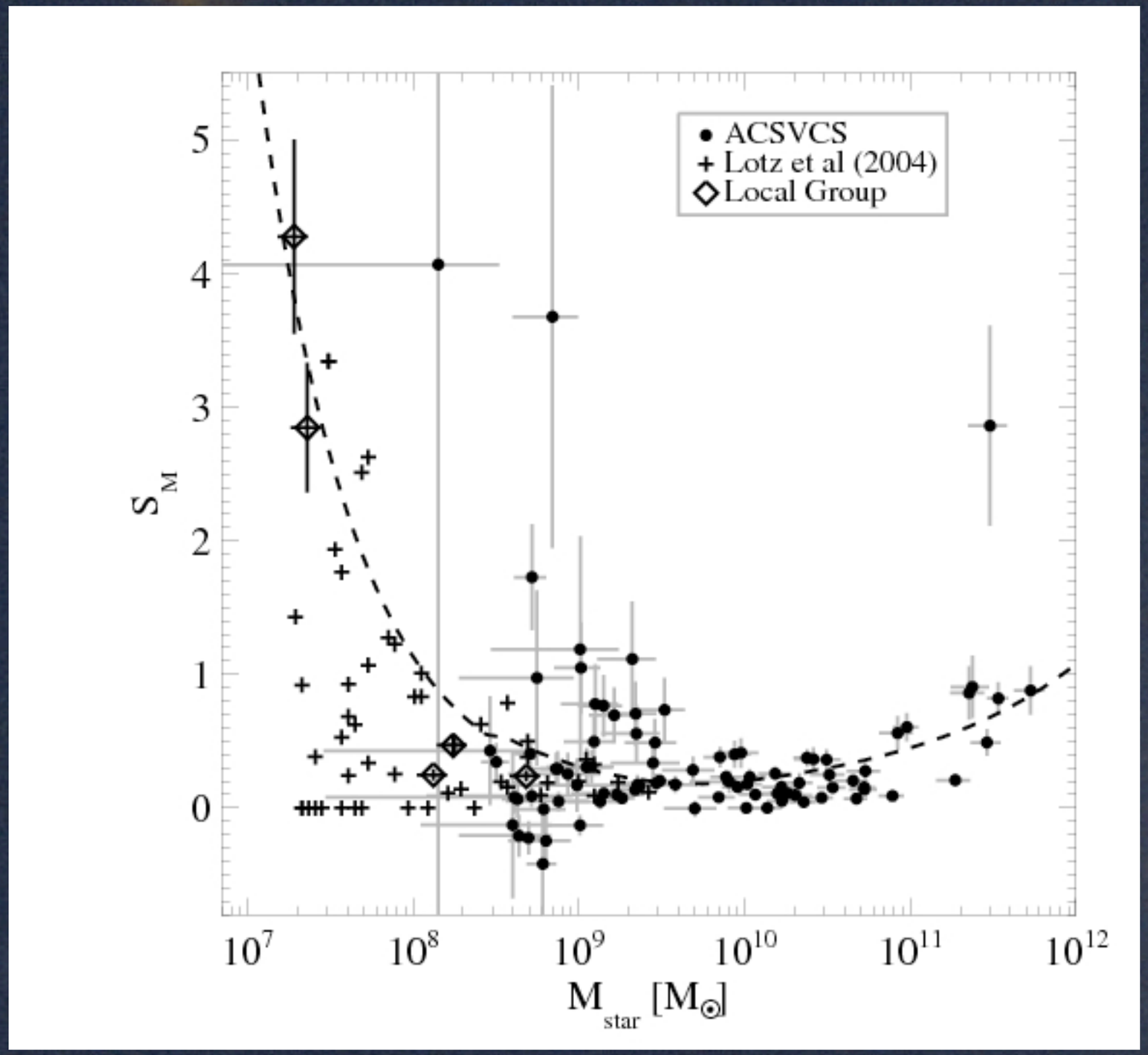

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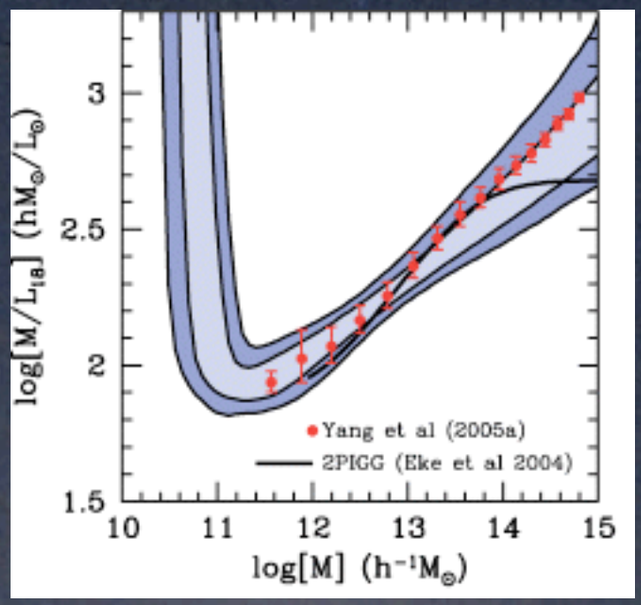

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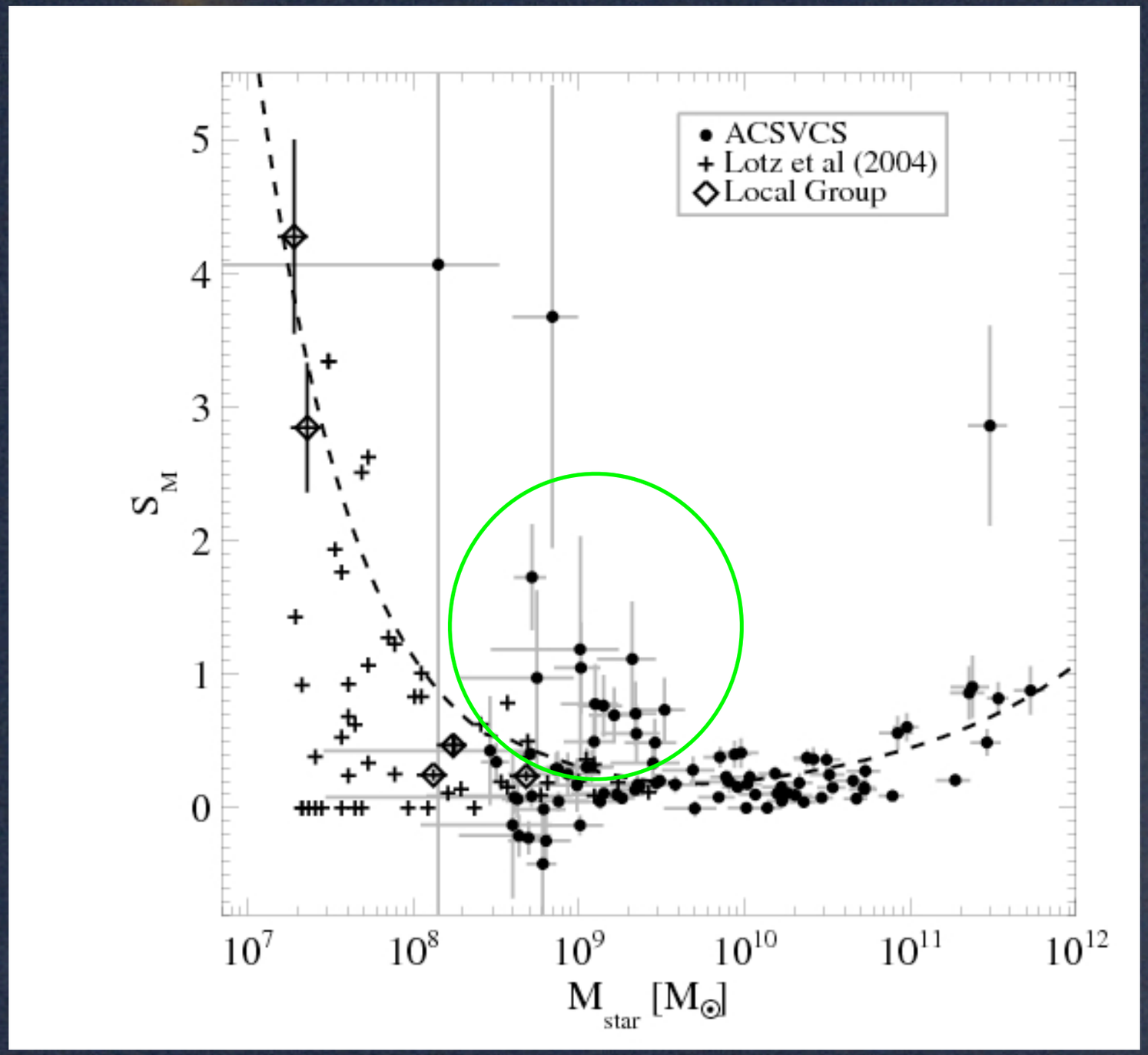

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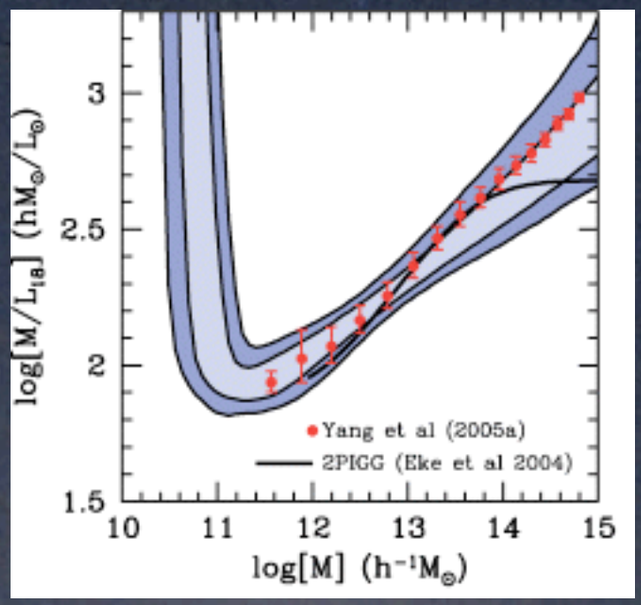

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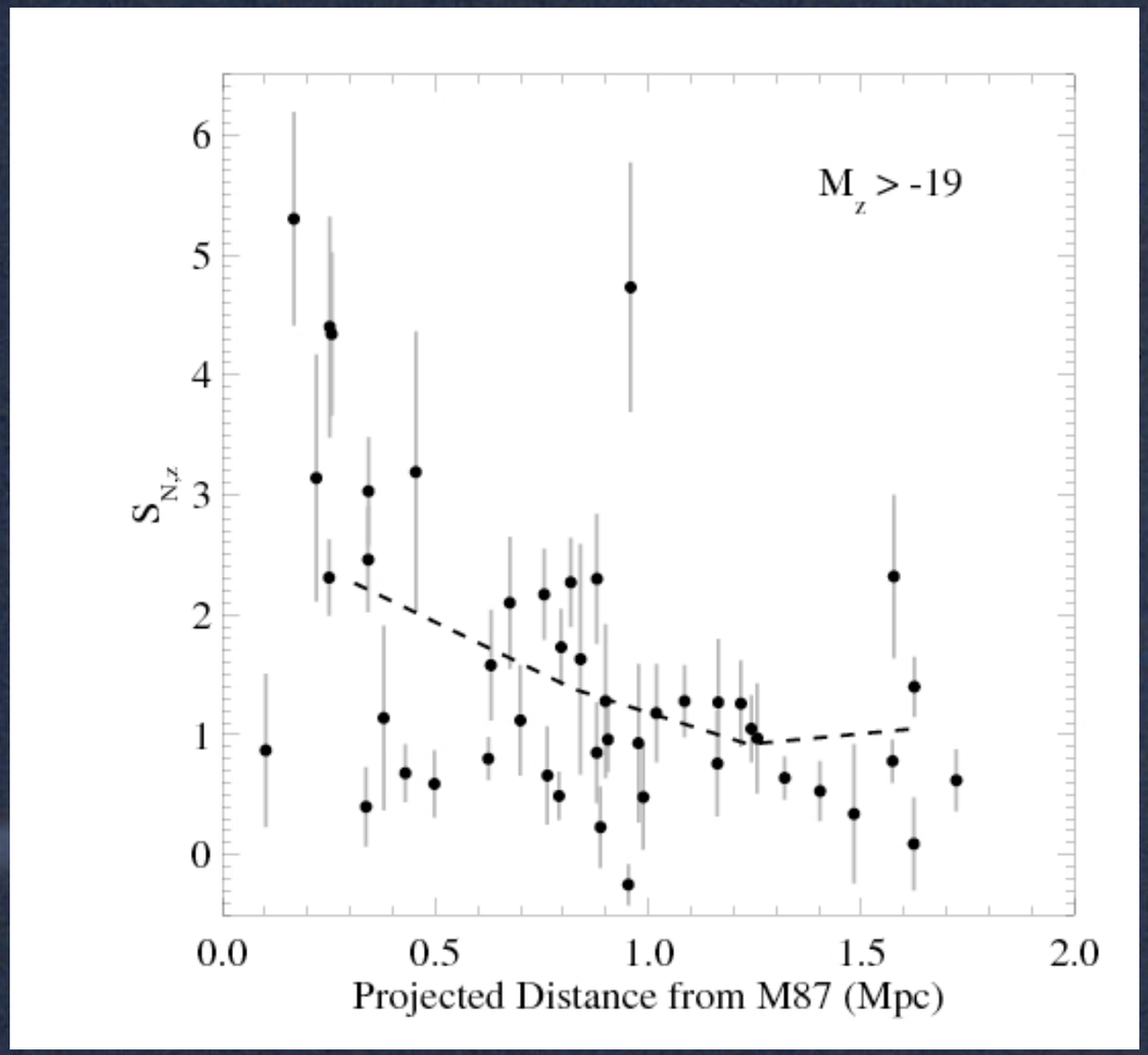
$N_{GC} \propto M_h$ can explain some, but not all trends in S_M.

Peng et al.

Globular Clusters in dEs: The Role of Environment



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

Peng et al.

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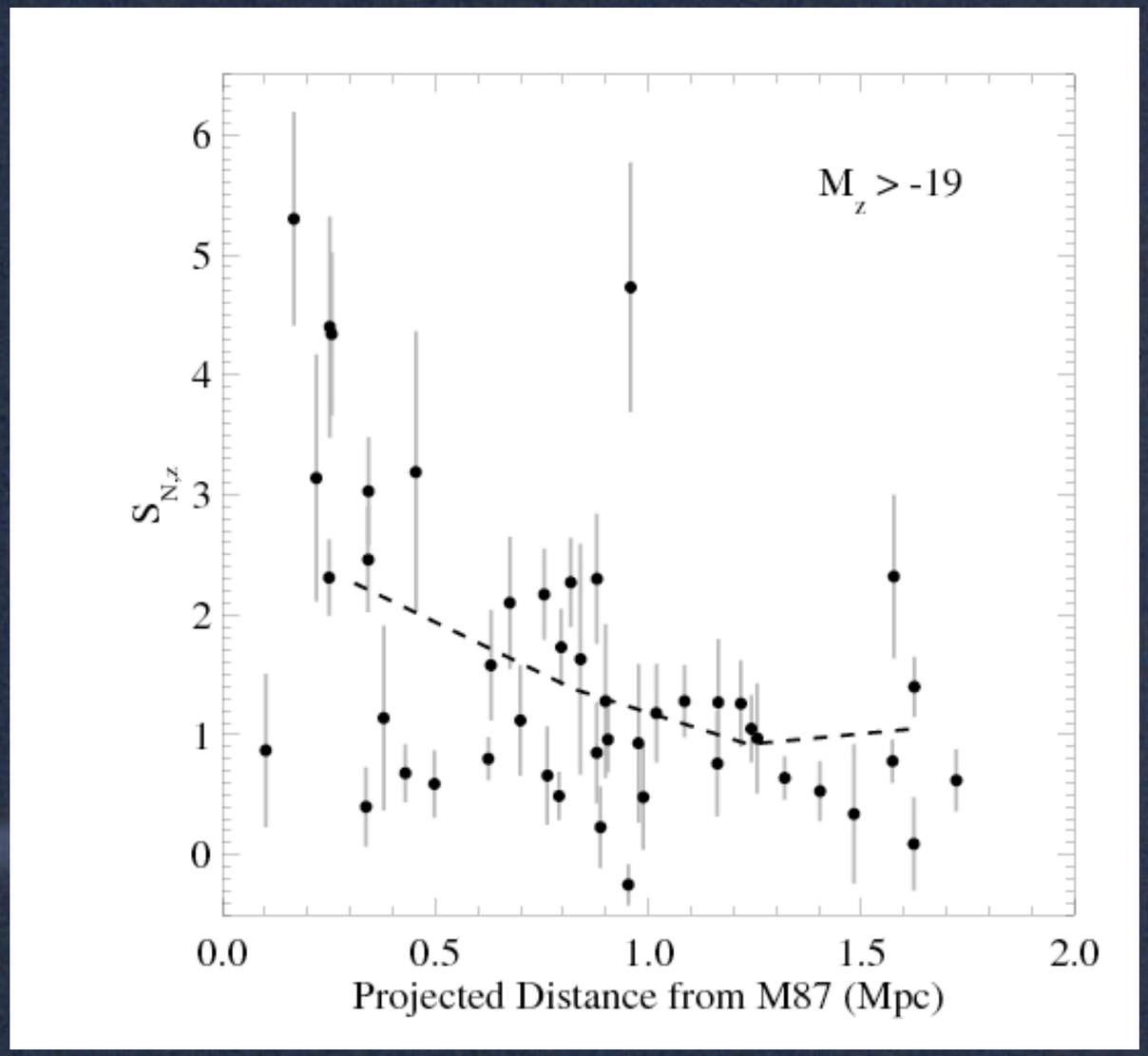

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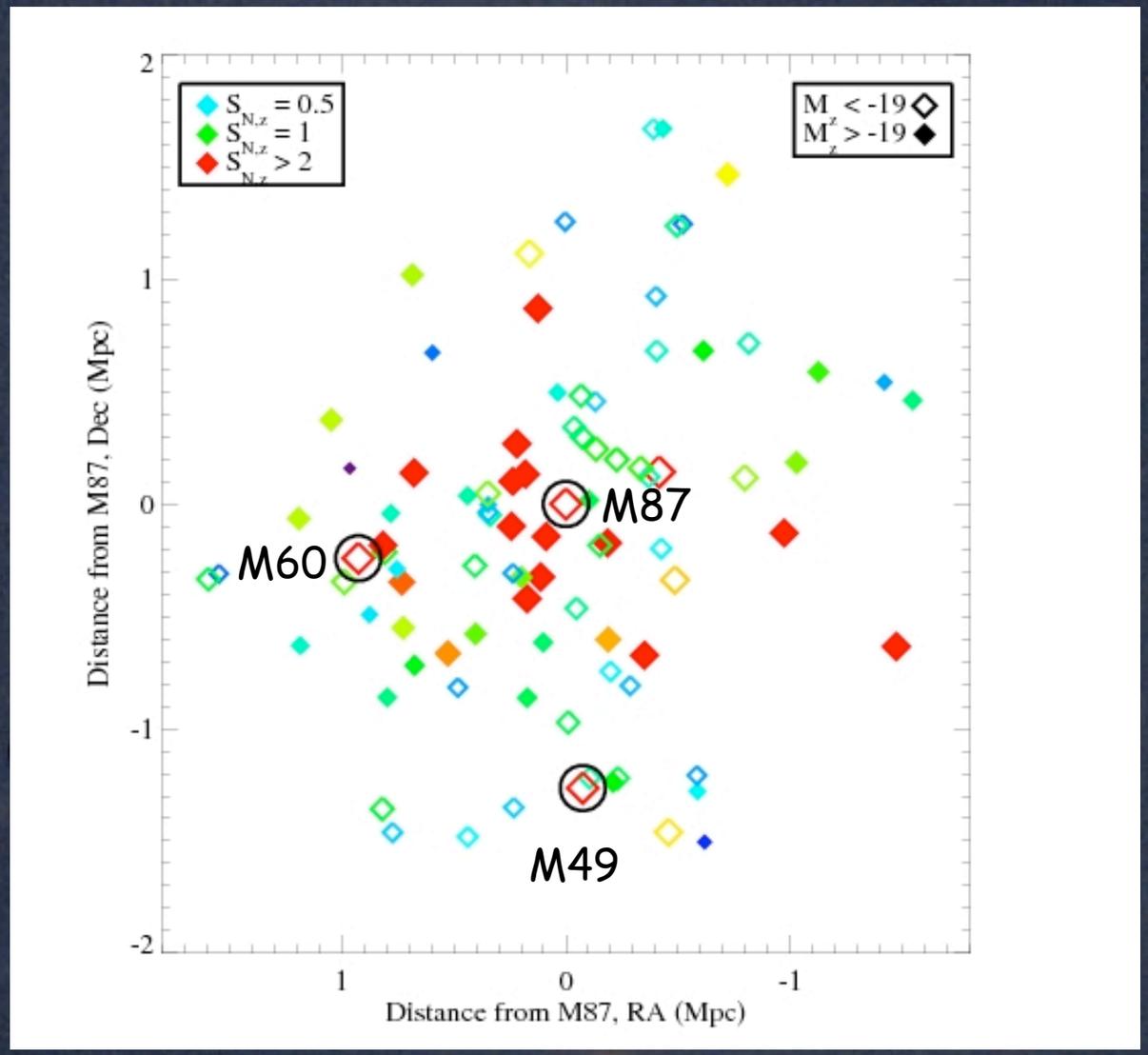
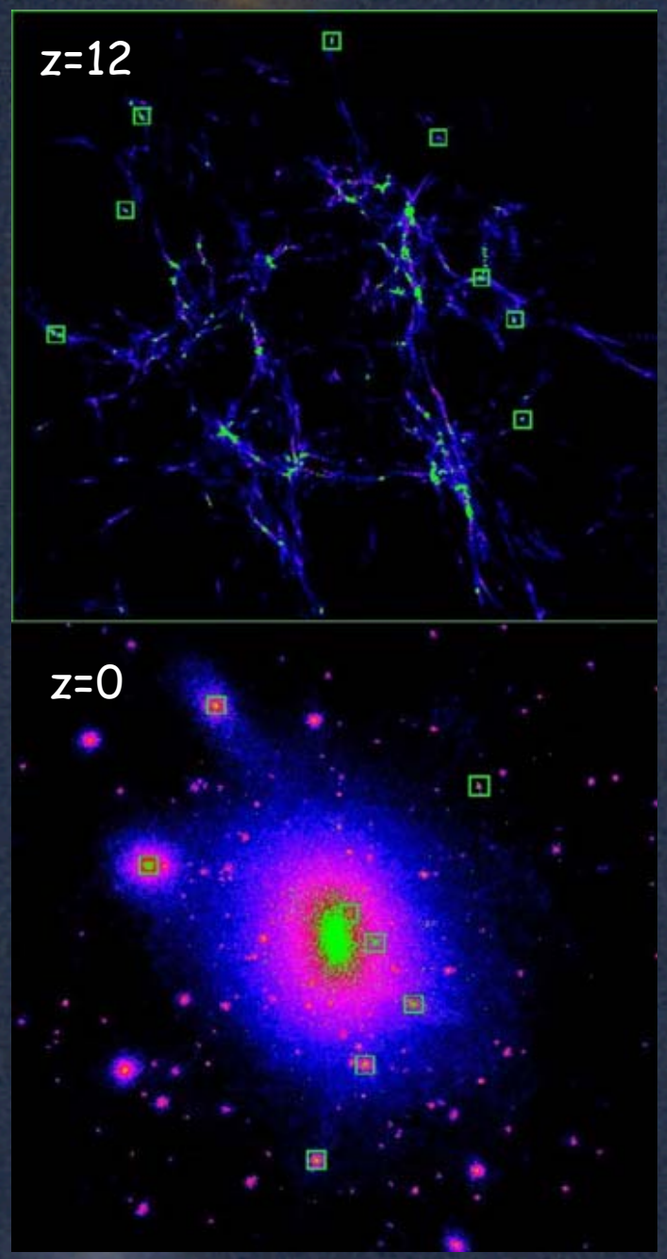


dEs with high GC fractions are within $D_p < 1$ Mpc

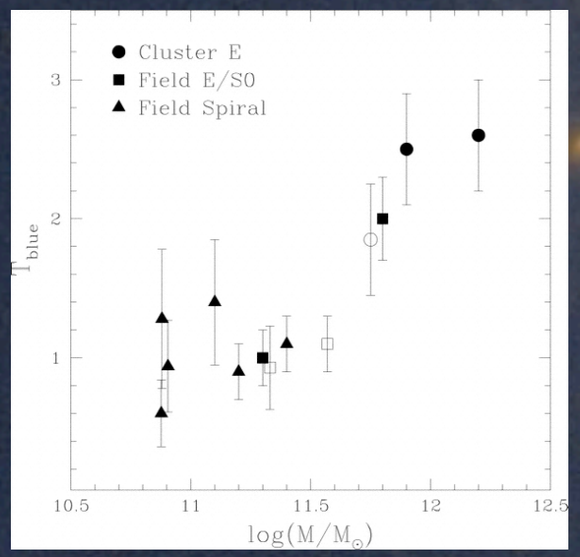
Peng et al.

Implications



Moore et al (2006)

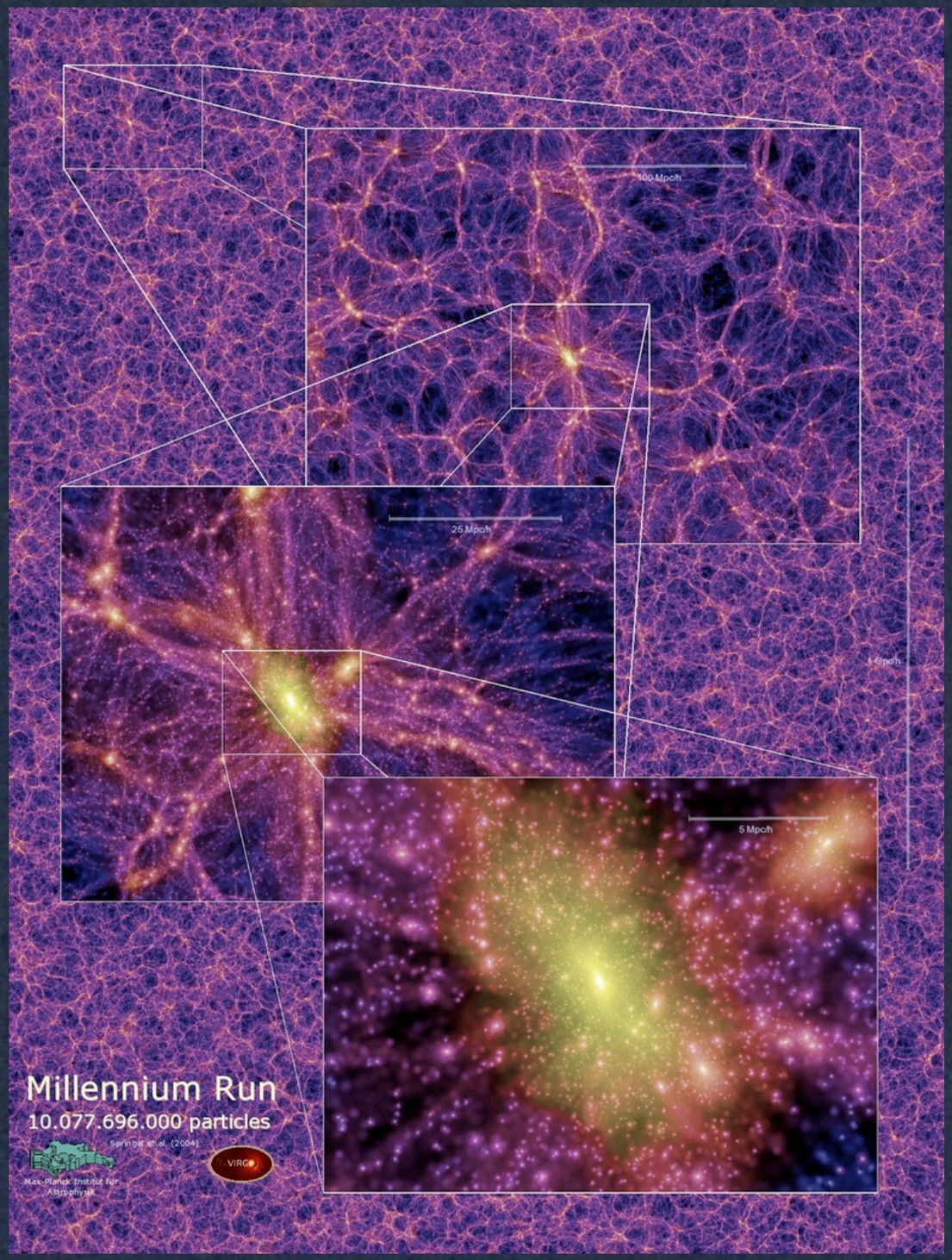
- GC formation in dEs is biased toward dense regions
- Low mass halos in dense regions collapse earlier, and are perhaps more efficient at producing GCs (reionization cutoff? e.g., Beasley et eal 2002, Moore et al 2006)
- Earliest collapsing low mass halos in densest regions could build metal-poor GC populations in giants



Rhode, Zepf & Santos 2005
also West (1993)

The Millennium Simulation

(Springel et al 2005, De Lucia et al 2006)



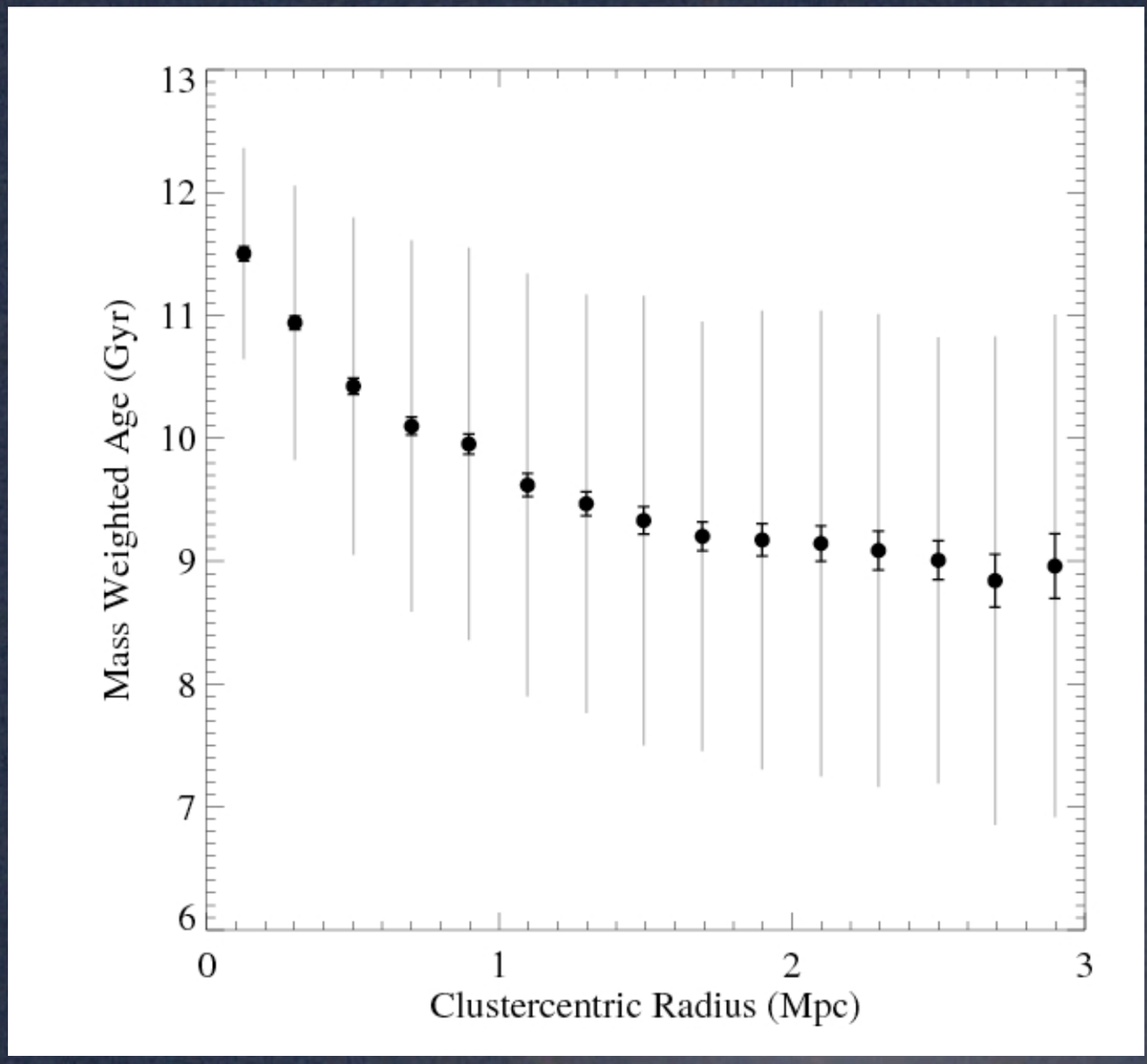
- 2160^3 dark matter particles
- 500^3 h^{-1} Mpc volume
- z=127 to present
- Galaxies with stellar mass > $3x10^8$

- 126 massive galaxy clusters
- Select 15,506 simulated early-type dwarfs (M_z>-19 at z=0) and their progenitors
- 63 snapshots from z=12

What are the properties and star formation histories of simulated early-type cluster dwarfs?

The Millennium Simulation:
Early-type cluster dwarfs

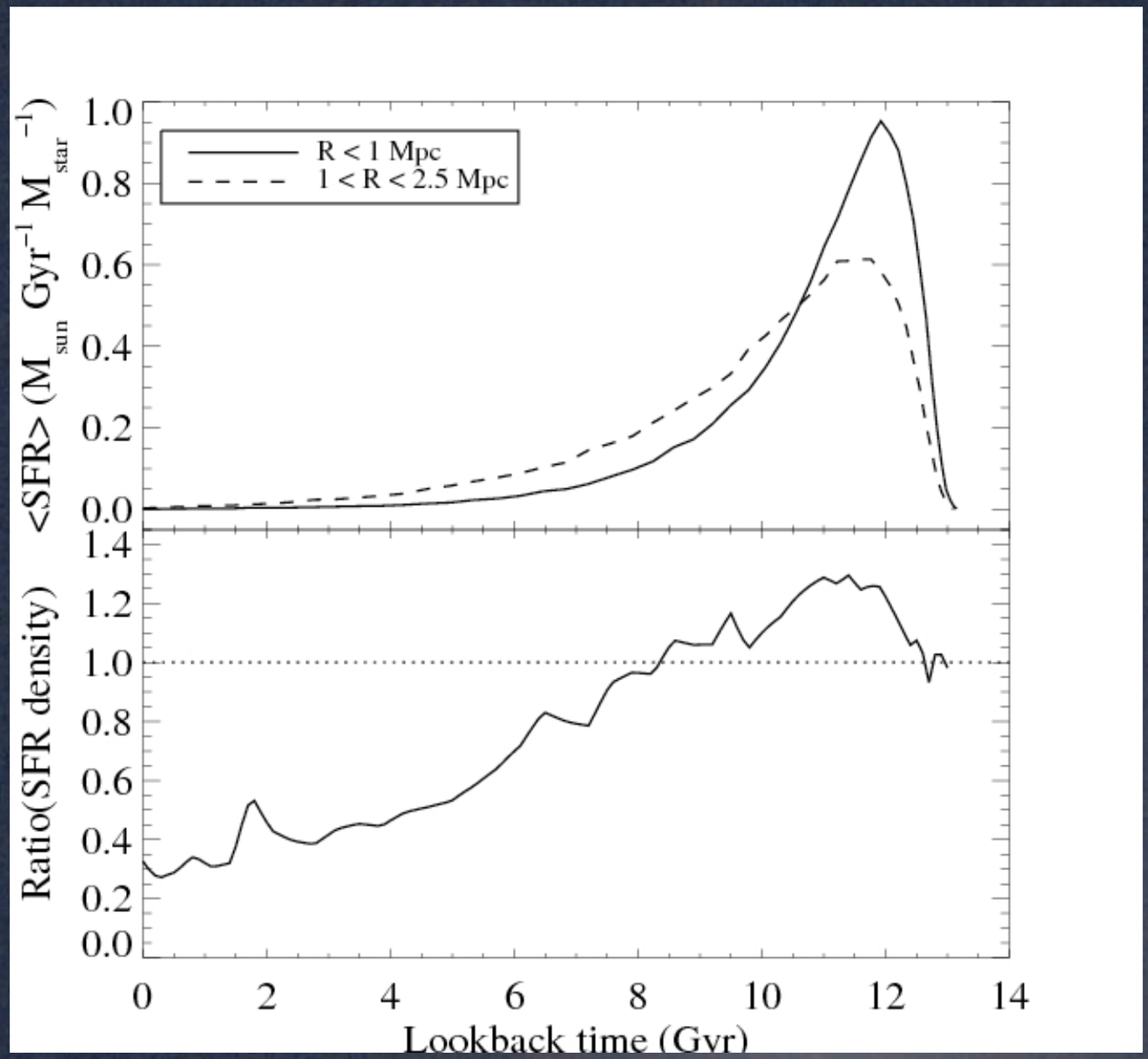
Mass-weighted age of central dEs is older



The Millennium Simulation:
Early-type cluster dwarfs

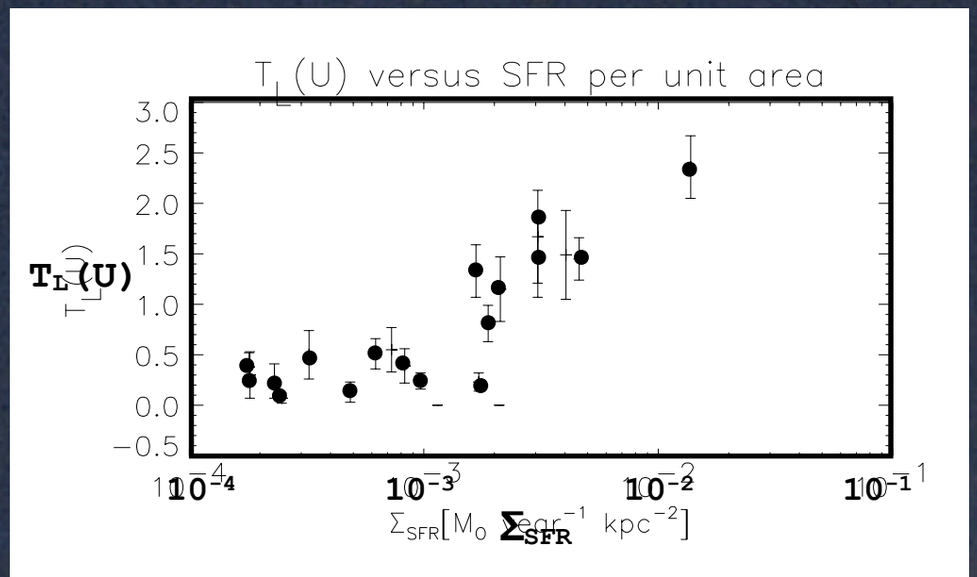
Average star formation rate of central dwarfs more peaked with rapid falloff

Star formation in central dwarfs occurs at higher star formation rate **density**



The Millennium Simulation:
Early-type cluster dwarfs

In local star forming galaxies, higher SFR surface density means a larger fraction of stellar luminosity/ mass in massive star clusters



Larsen & Richtler (2000)

We can scale the SFR and SFR densities in Millennium semi-analytic models to predict star cluster formation rates

The Millennium Simulation:
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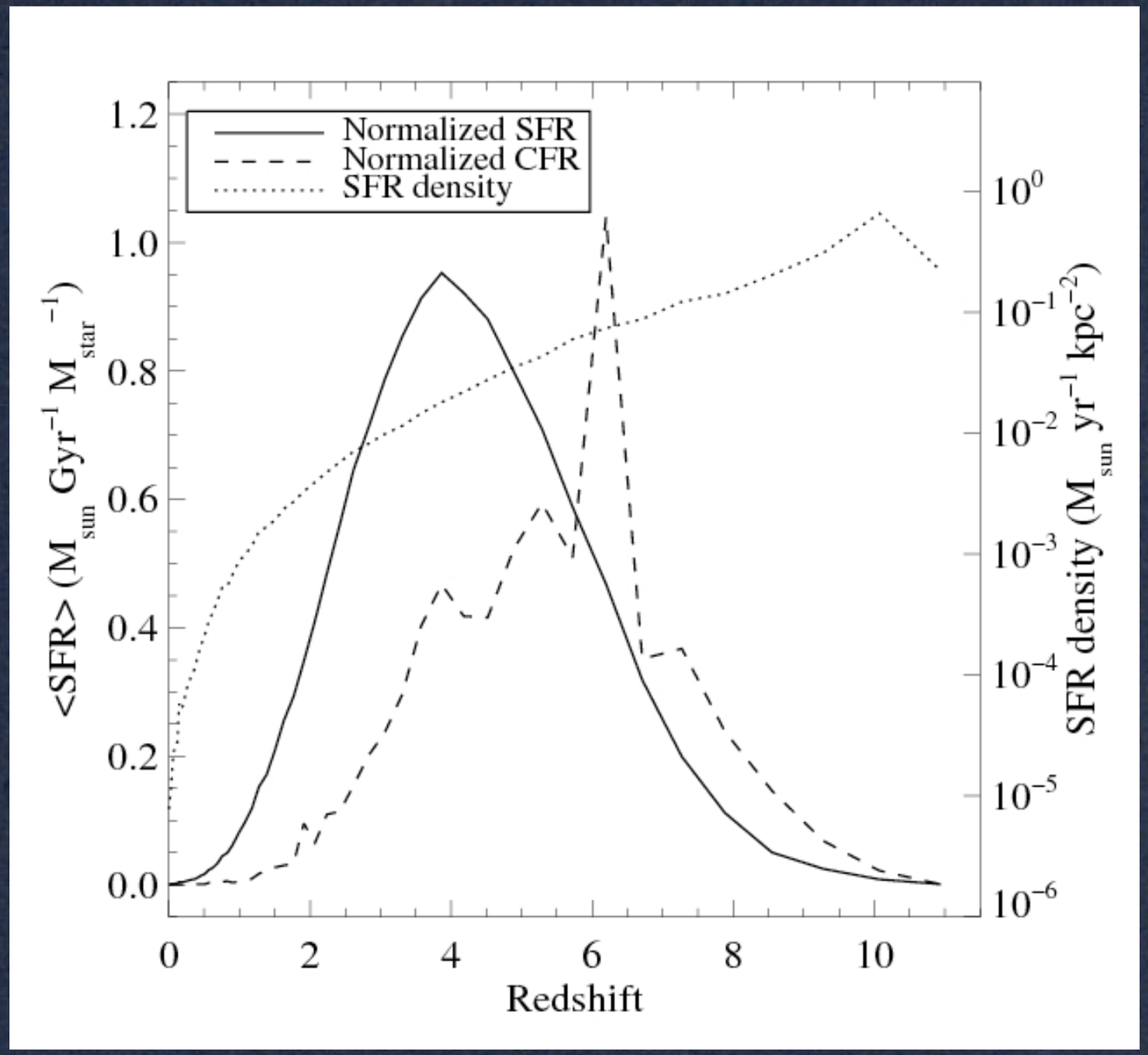
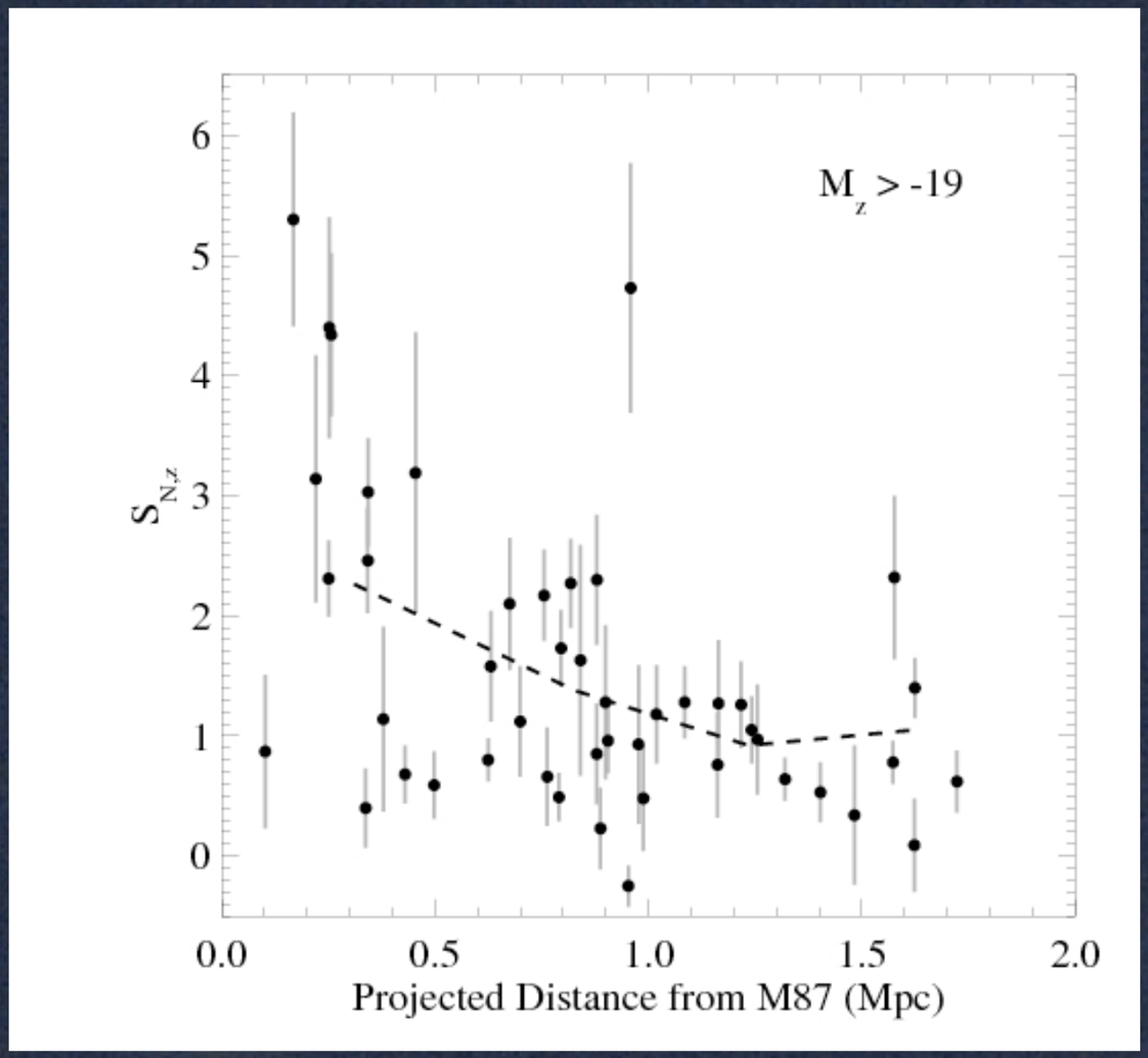


Peak formation of massive star clusters is naturally earlier than peak SFR

The Millennium Simulation:
Early-type cluster dwarfs



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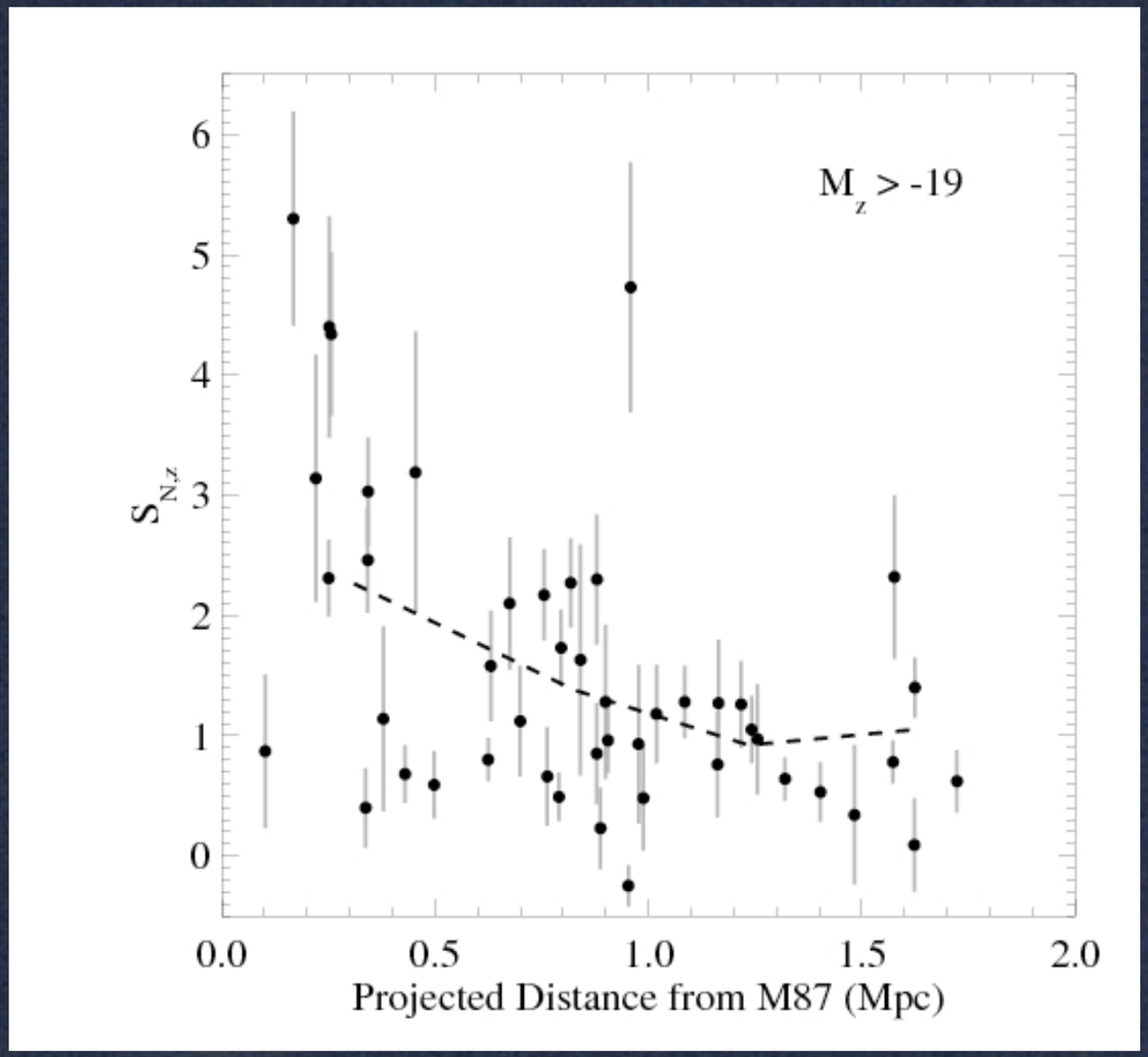

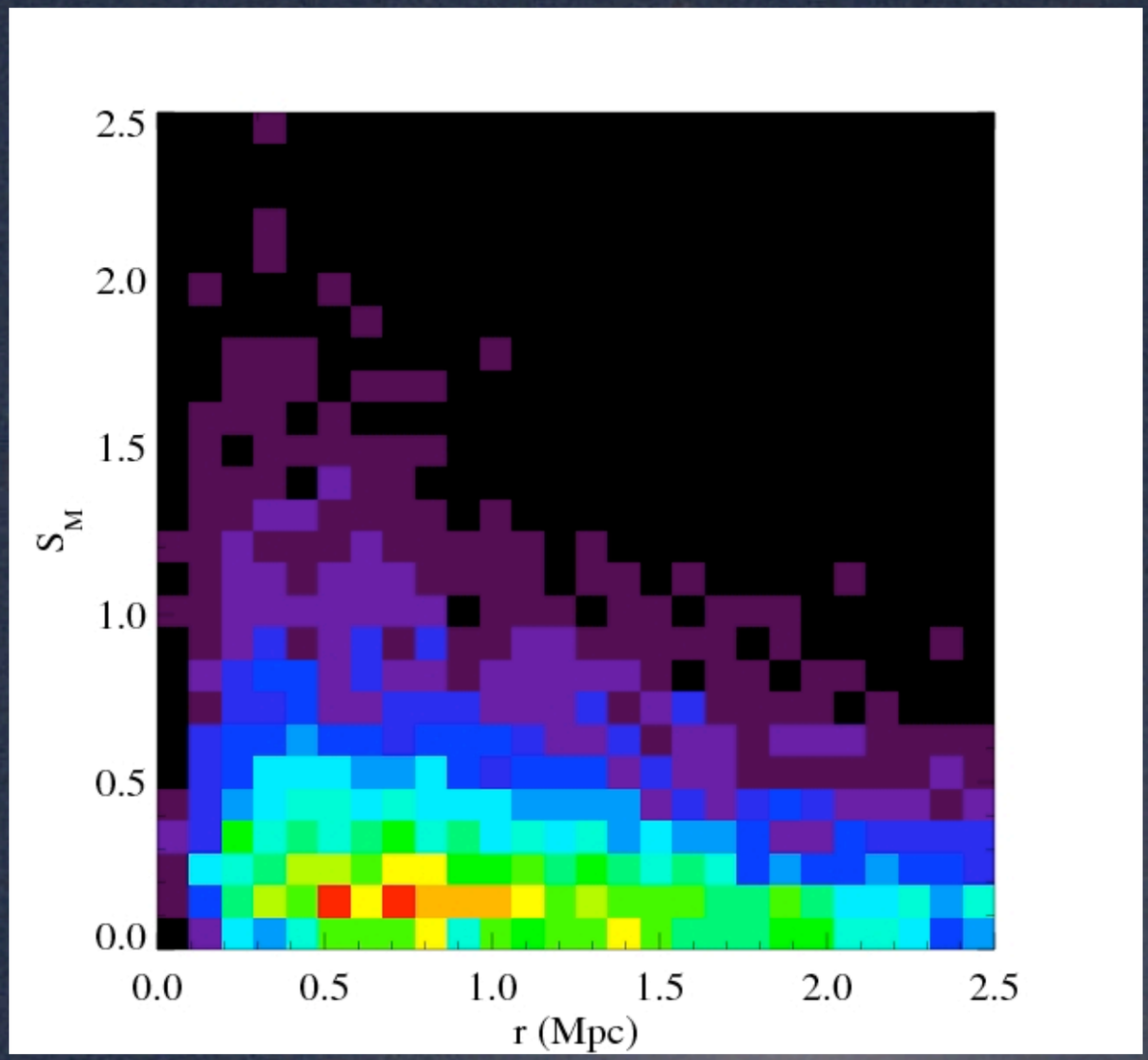

Conclusions

- 100 early-type galaxies in the ACS Virgo Cluster Survey
- GC production in dEs is biased toward cluster center (surviving progenitors of M87 GC system?)
- Comparison to Millennium Simulation assuming GC mass fraction proportional to SFR surface density
  - Central dEs have higher GC mass fraction
  - SFR density peaks at higher z then SFR, naturally leading to GC populations that are older and more metal-poor than the field stars