Small galaxy groupings: triggered star formation and quenching

Environmental effects in the simplest environments

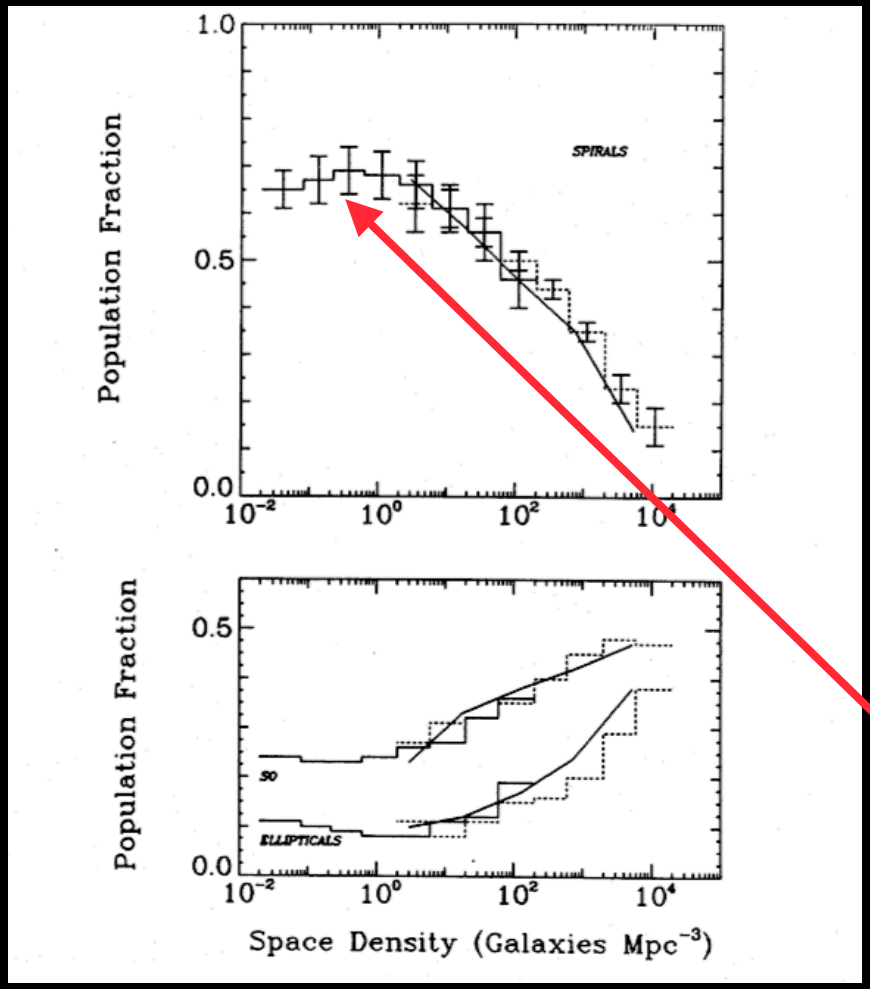
Betsy Barton

Center for Cosmology
University of California, Irvine

Outline

- What is the relationship between cluster processes and small group processes?
  - If the same effects are happening to galaxies of the same stellar mass, as van den Bosch et al. (2009) seem to suggest, should constrain the dominant processes
- Can we see evolution in the sparsest systems, with N=2 luminous members?
- Triggered star formation: what is its role?
- Will we ever see evidence for strangulation-related processes in halo absorption line studies?

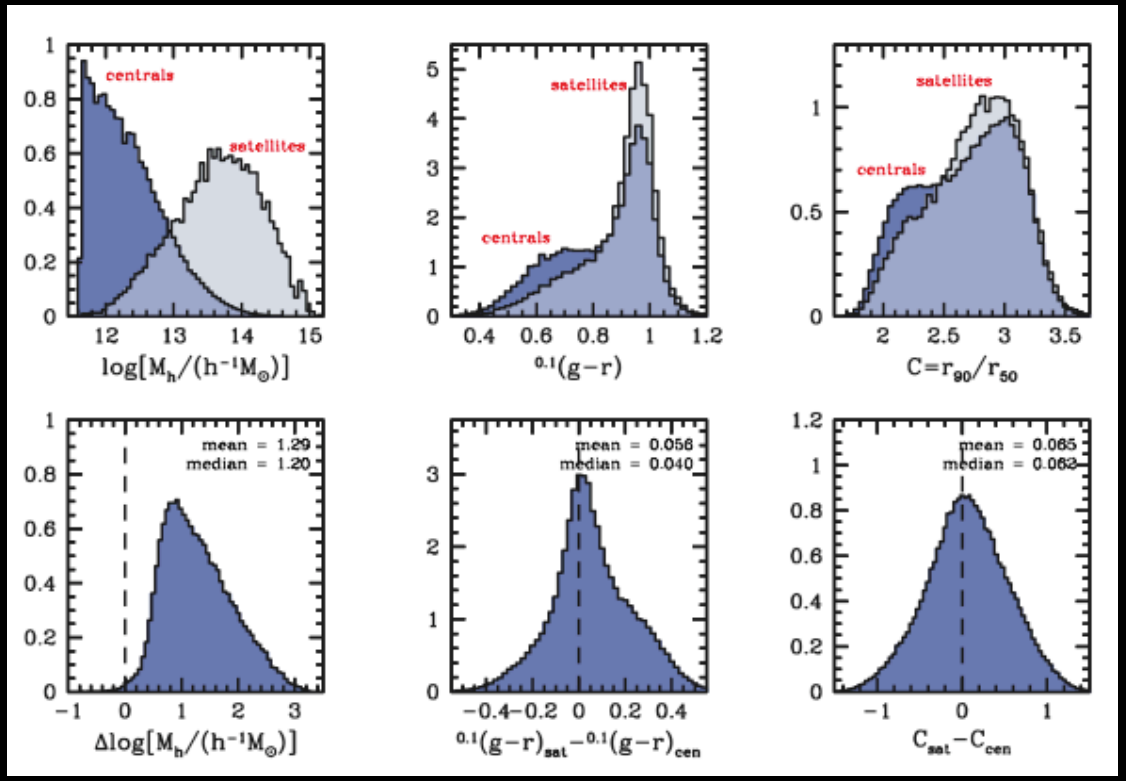
The Morphology-Density relation extends well outside clusters



- **Postman & Geller (1984):**
  - **The spiral fraction climbs as density falls, even outside clusters**
  - **Some suppression mechanism(s) operate in groups, too**

Interlopers make it hard to identify group mass in here

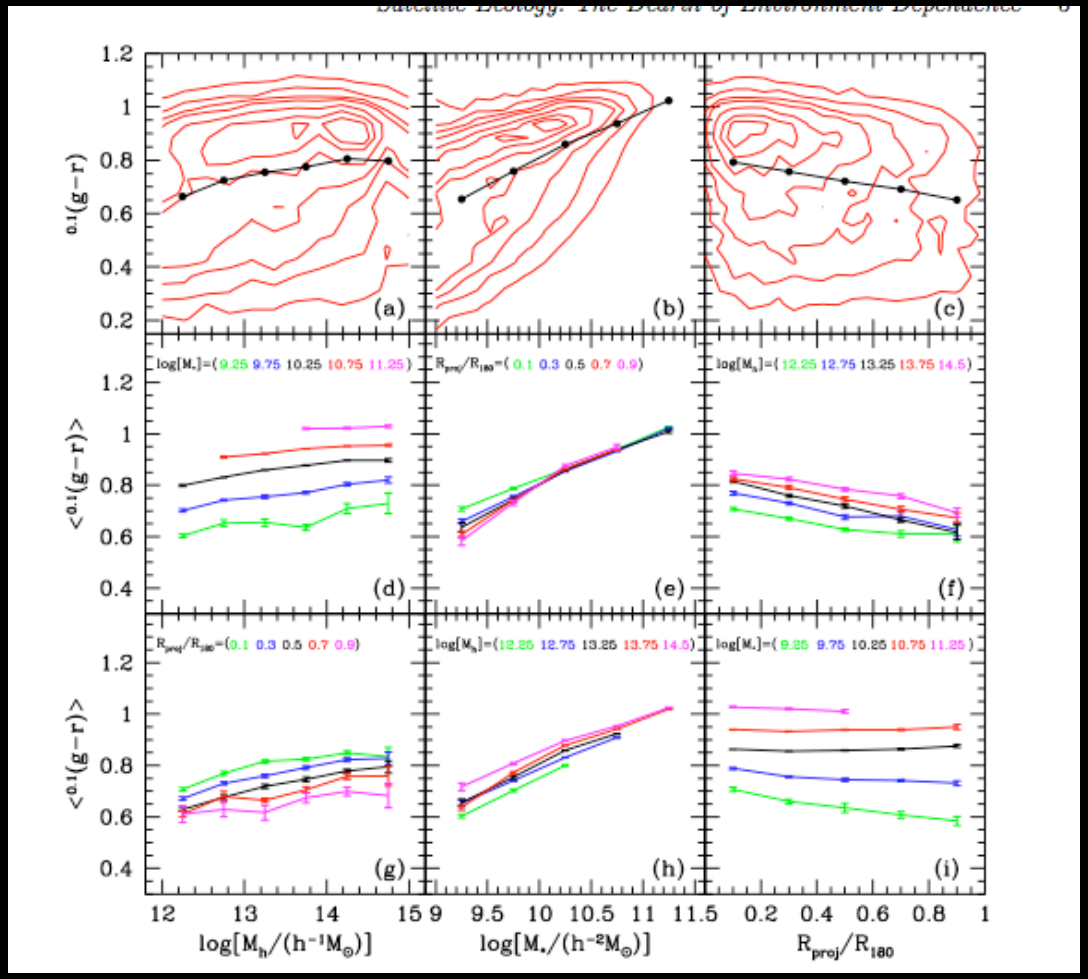
Satellite galaxies are redder (and more concentrated)



(van den Bosch et al. 2008a)

- van den Bosch et al. (2008a) group-catalog-based analysis
- Different group catalogs survey very different ranges of satellite and group mass

van den Bosch et al. result: Color depends on stellar mass more than halo mass



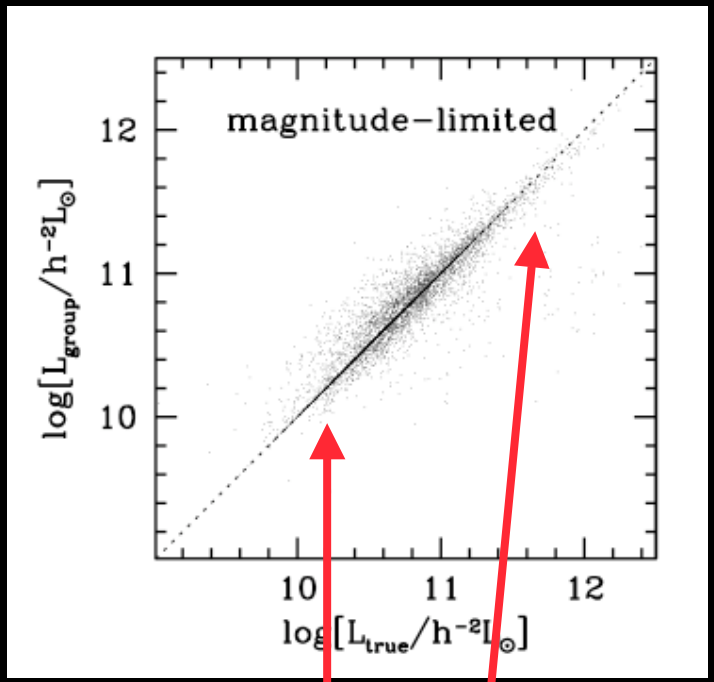
(van den Bosch et al. 2008b)

- **Result is hard to understand:**
  - **substructure spends more time in clusters than field**
  - **velocities, dispersion, ICM totally different**
  - **pre-processing doesn't seem to dominate in massive groups**

Group mass misidentification may be strong, dominant

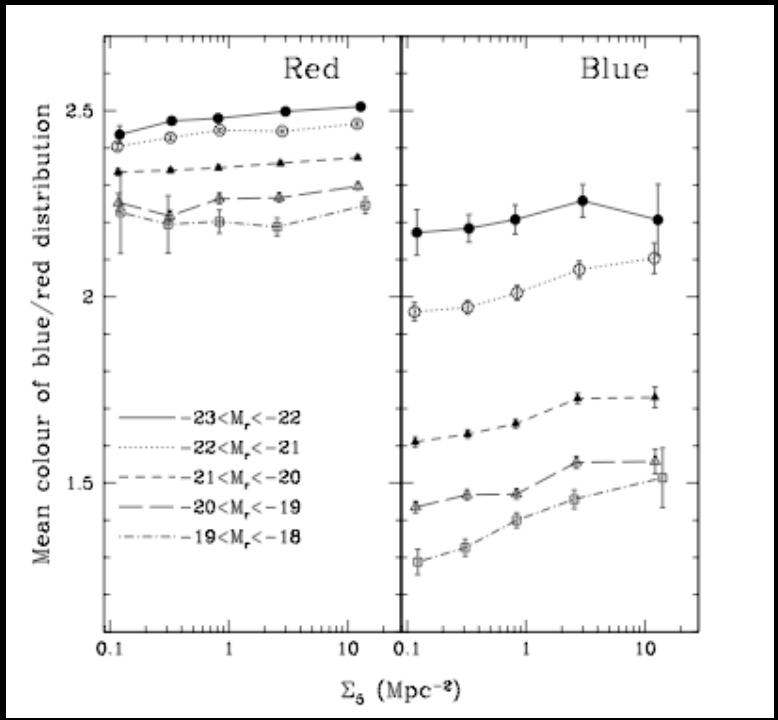
•Perhaps smearing effect from wrong halo mass is large, and dominant at low-mass end
•(But, as Simon Lilly pointed out, if effect **too** big, would not see strong relationship between halo mass and stellar mass)

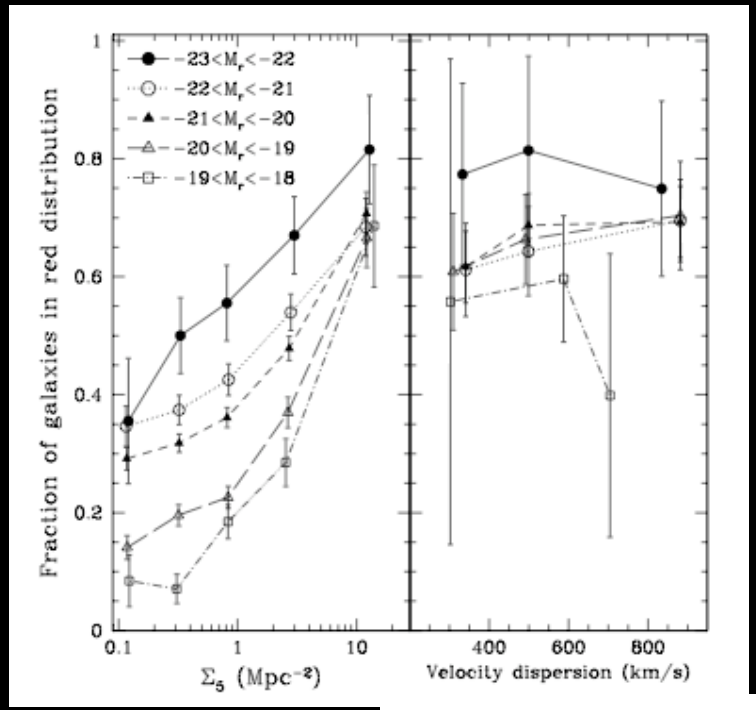
(Yang et al. 2005)



Average scatter in group luminosity differs as a function of group luminosity

A slightly different picture...

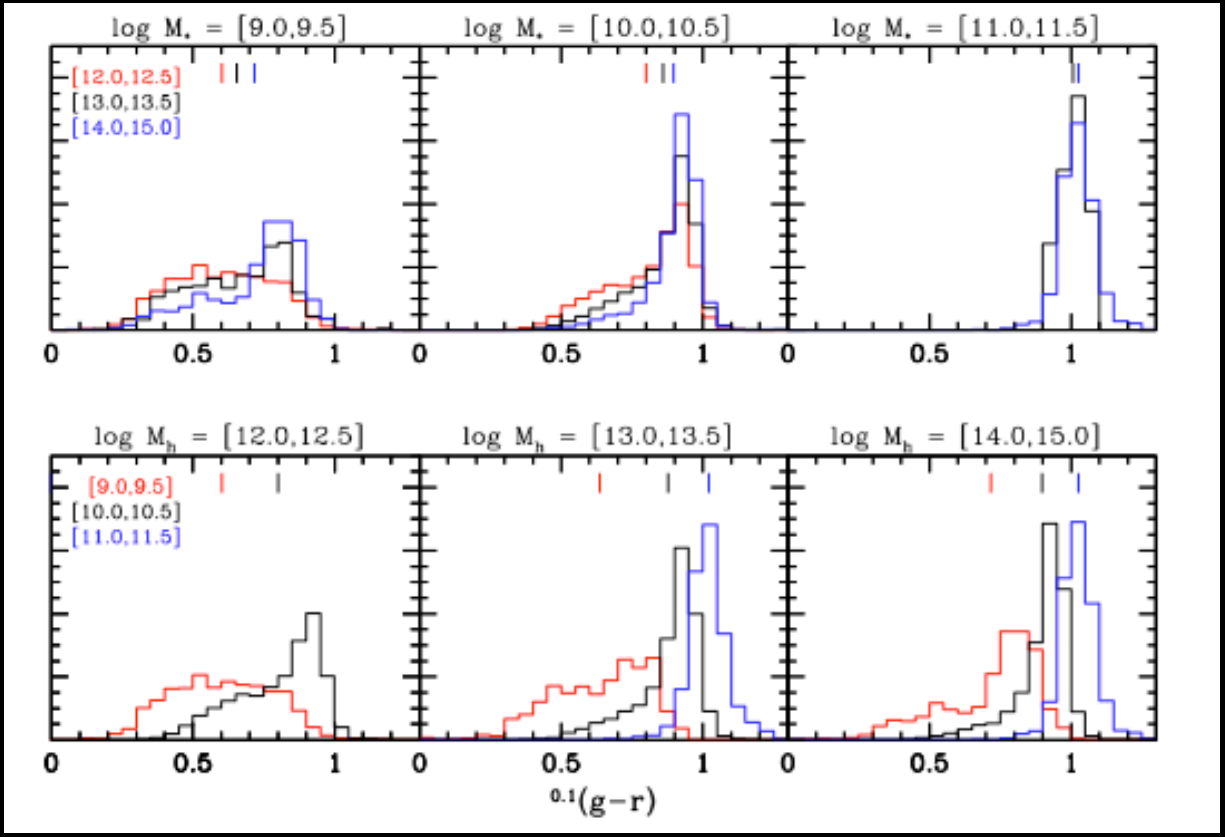




(Balogh et al. 2004)

- Within cluster, at fixed luminosity, fraction of blue galaxies depends on environment
- Mike points out: difference between average color and red fraction?

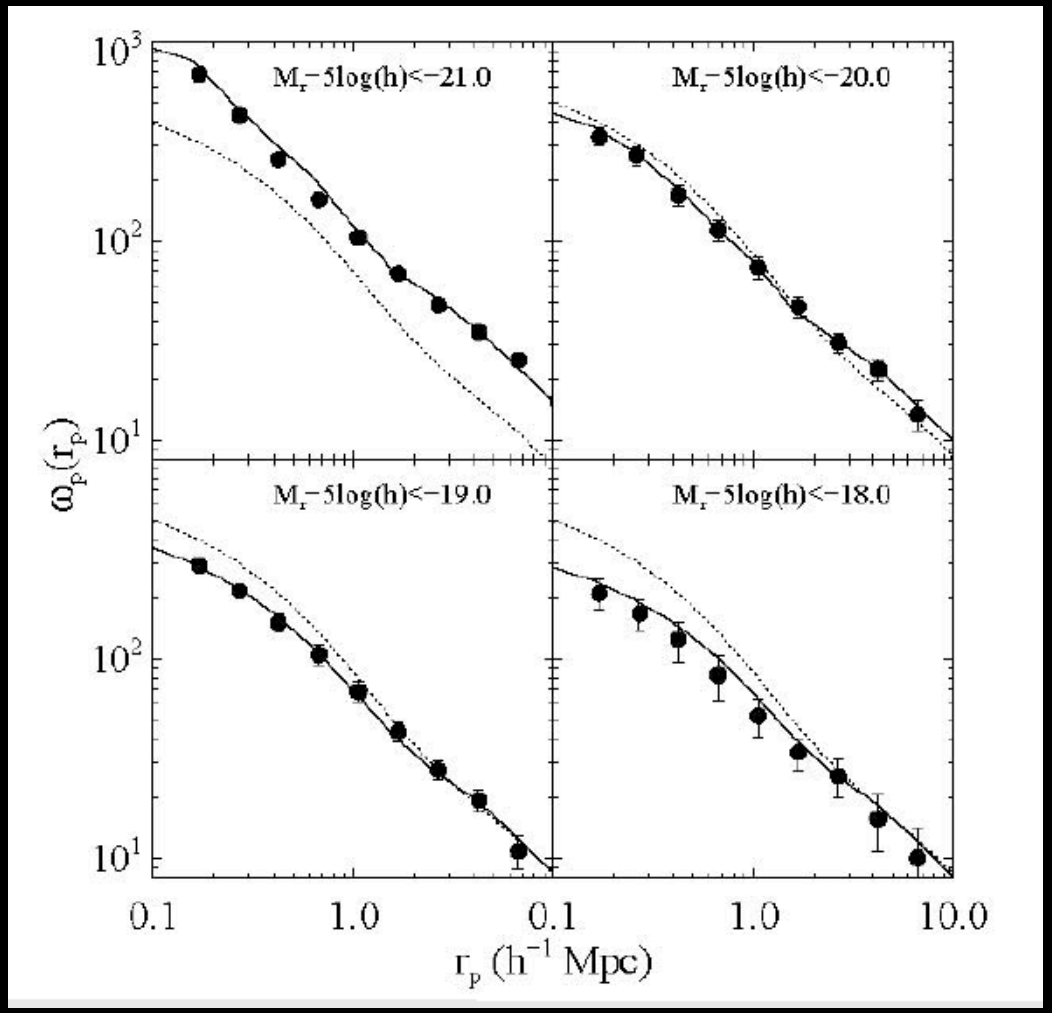
Relatively minor trends with environment persist



- **Maybe it is pre-processing: maybe everybody evolves while a satellite in a smaller group?**
- **(But I think ΛCDM says pre-processing is a modest effect in modest-sized clusters.)**

(van den Bosch et al. 2008)

Simple technique: abundance matching to make mock catalog

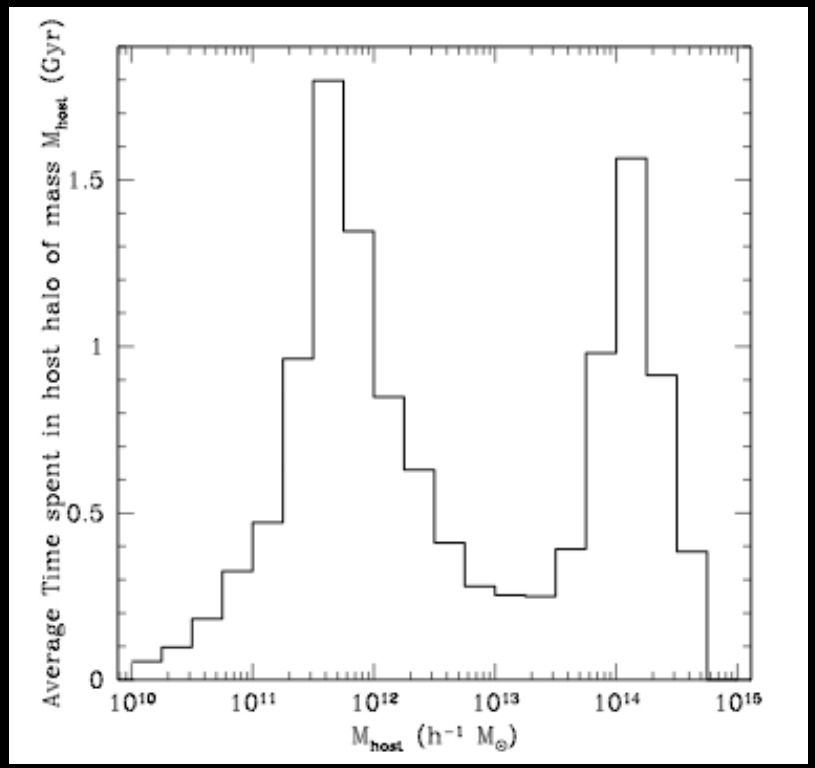


- Models are halos in DM simulations
- Data are *SDSS*

Matches are made by matching abundances

(Conroy, Wechsler, & Kravtsov 2006)

How (surviving, simulated) z=0 cluster galaxies have spent their time



- **Most time spent alone or in cluster**
- **Suggests pre-processing not a big factor in these 53 $10^{14-14.8}$ solar mass clusters**

FROM FULL N-BODY SIM

(J. Berrier et al. 2008)

Fraction of galaxies that have spent any time in host halo of give mass

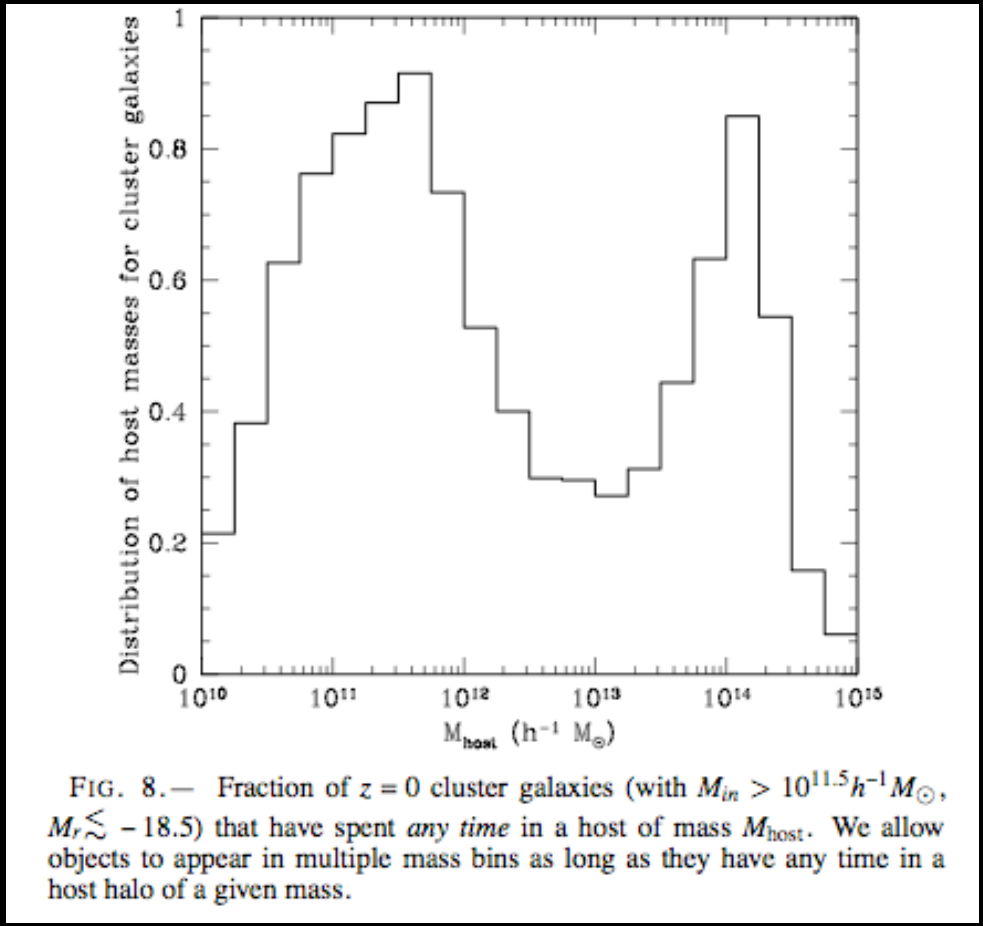


FIG. 8.— Fraction of $z = 0$ cluster galaxies (with $M_{in} > 10^{11.5} h^{-1} M_\odot$, $M_r \lesssim -18.5$) that have spent *any time* in a host of mass $M_{\rm host}$. We allow objects to appear in multiple mass bins as long as they have any time in a host halo of a given mass.

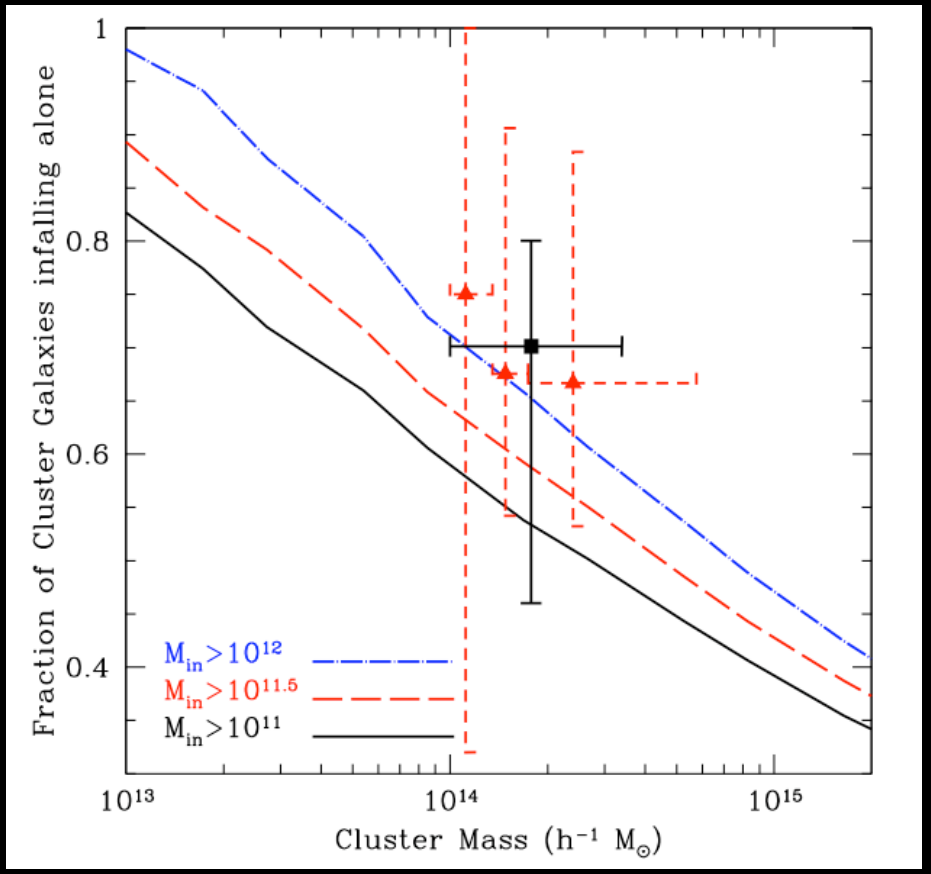
- **At least in $10^{14\text{-}14.8}$ solar mass clusters, almost no pre-processing happens in groups bigger than 1 bright galaxy**

FROM FULL N-BODY SIM

(J. Berrier et al. 2008)

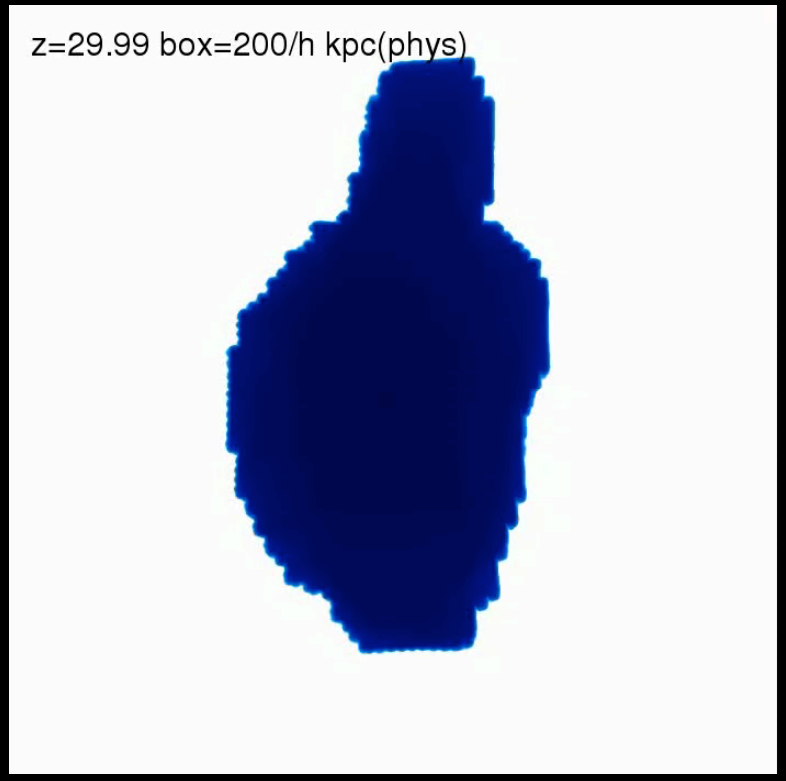
Preprocessing: ΛCDM suggests it is not dominant (in lower-mass clusters)

- **Semi-analytic models and full n-body simulations: at least in lower-mass clusters, most surviving galaxies fell in alone**



(J. Berrier et al. 2008)

"Strangulation" independent of halo mass: is it just cutting off the "feeder" filaments?



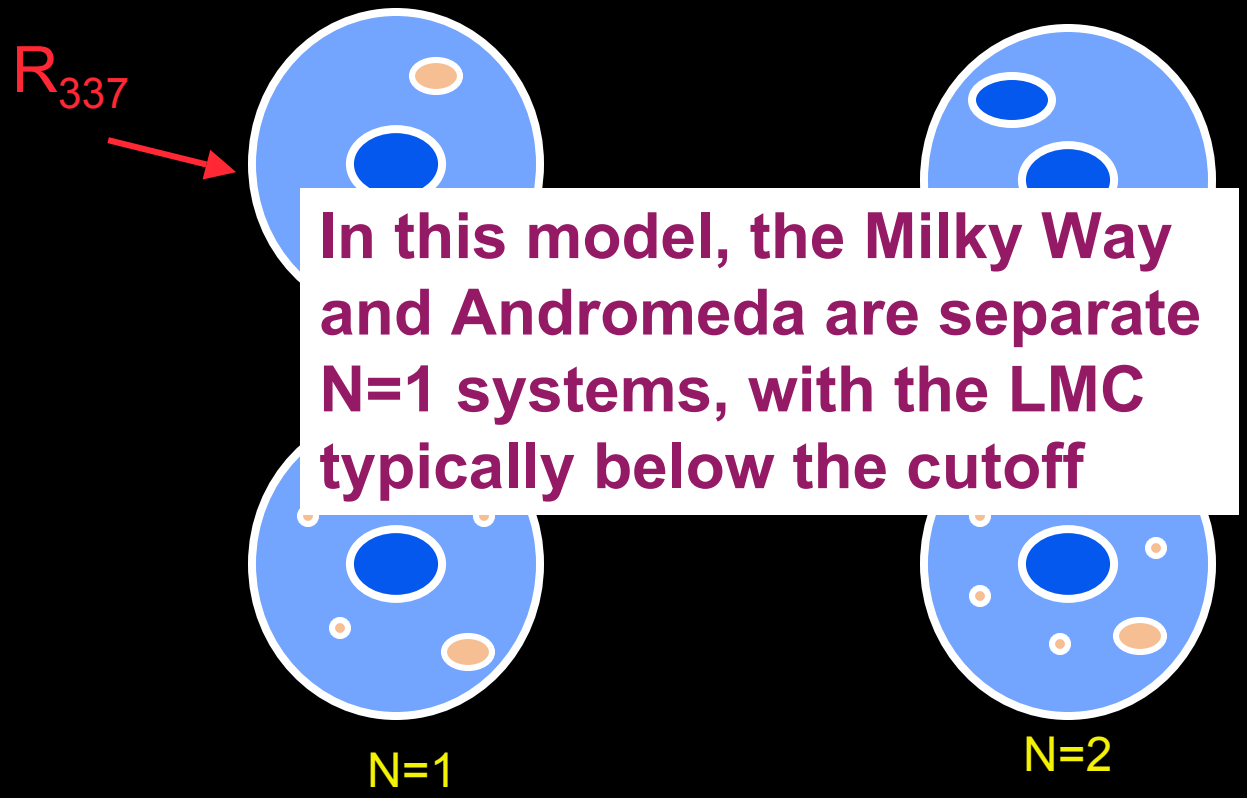
cold gas

hot gas

(Keres, Davé, Katz, Weinberg simulation)

filaments of satellites are cut off: "natural" strangulation? (Katz et al. 2003)

Identifying the sparsest systems (based on halo occupation above some cutoff)



In this model, the Milky Way and Andromeda are separate N=1 systems, with the LMC typically below the cutoff

above V_c cut

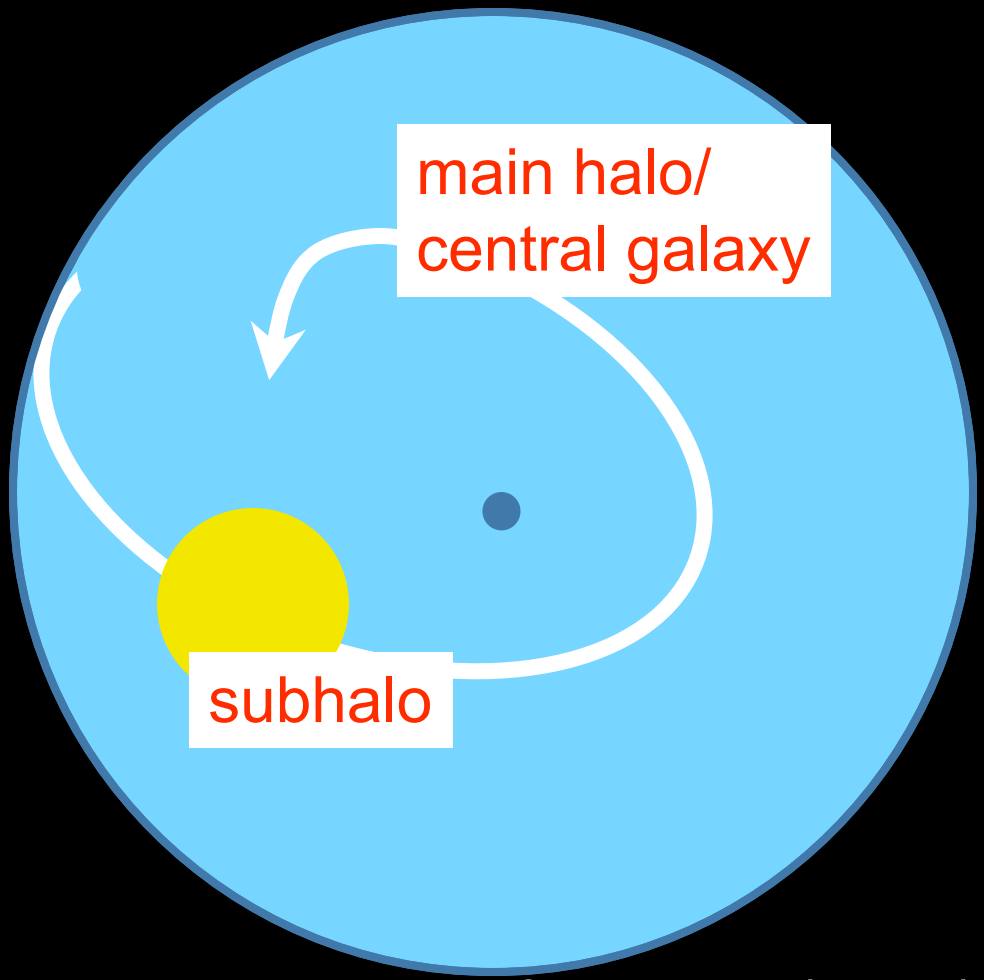
below V_c cut

Account for diversity of other properties like substructure below cutoff by examining full distributions

Can identify these (nearly) unambigously with isolation criteria

Can find samples rich in these and subtract contamination from N=1 contaminants

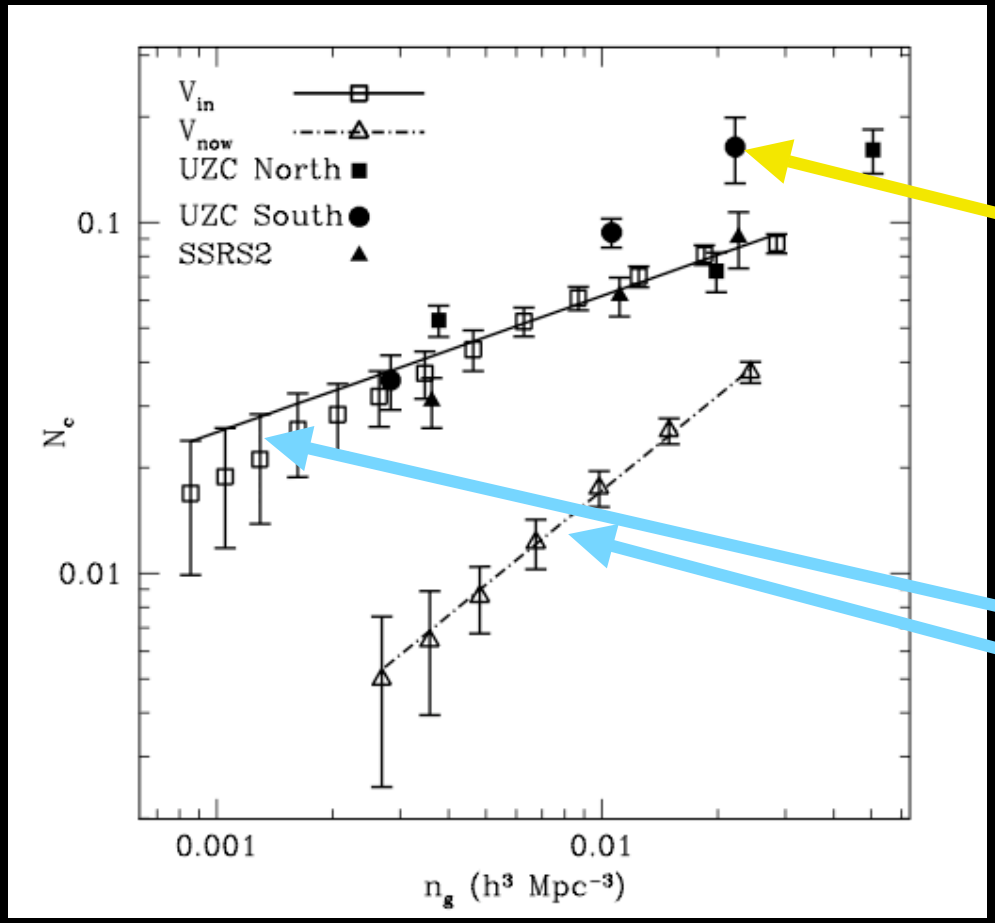
Mock catalog technique: a hybrid n-body and semi-analytic model



- Track detailed close-pair orbits in cosmological context
- Substructure orbits analytically calculated (Zentner et al. 2005); perigalactic passages recorded (Barton et al. 2007)
- Substructure from EPS
- Overcomes numerical "overmerging"; can resolve very close pairs
- Abundance matching to assign galaxies to halos

Zentner & Bullock (2003); Zentner et al. (2005)

The model explains close-pair counts in the nearby universe

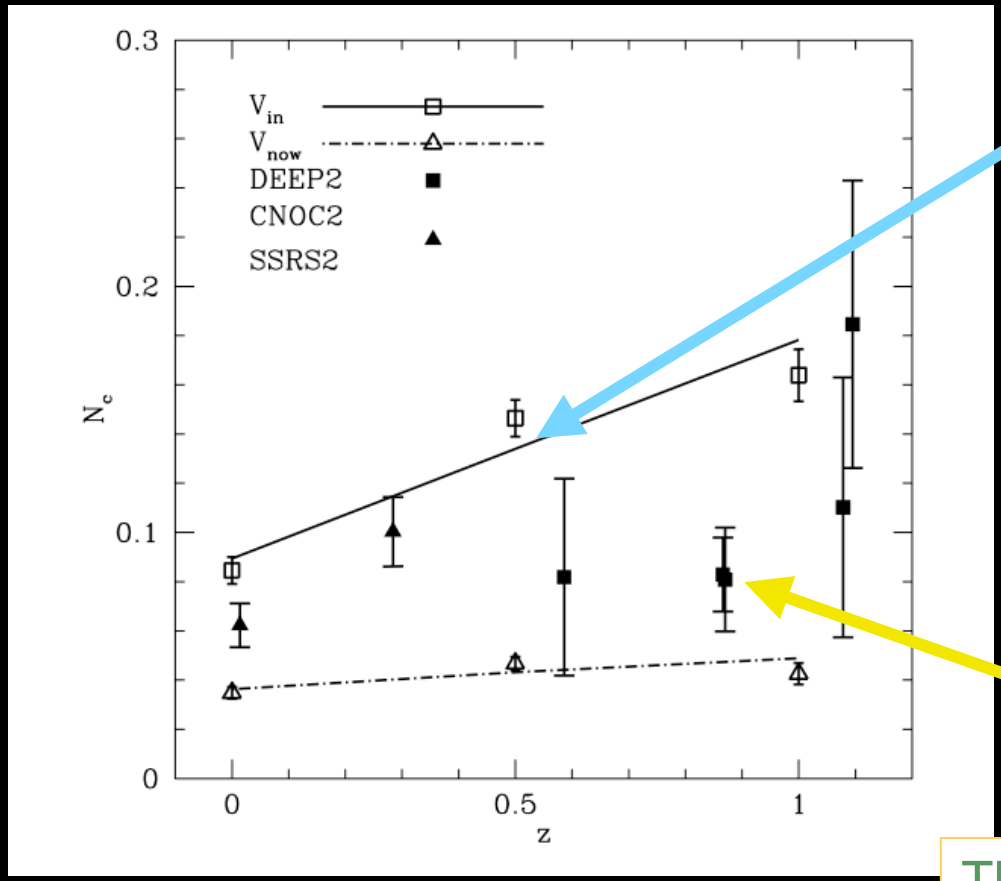


(J. Berrier et al. 2006)

Data from nearby redshift surveys, UCZ (CfA) and SRSS2

Counts from hybrid N-body/substructure model

Lack of strong pair-count evolution with redshift is natural in ΛCDM



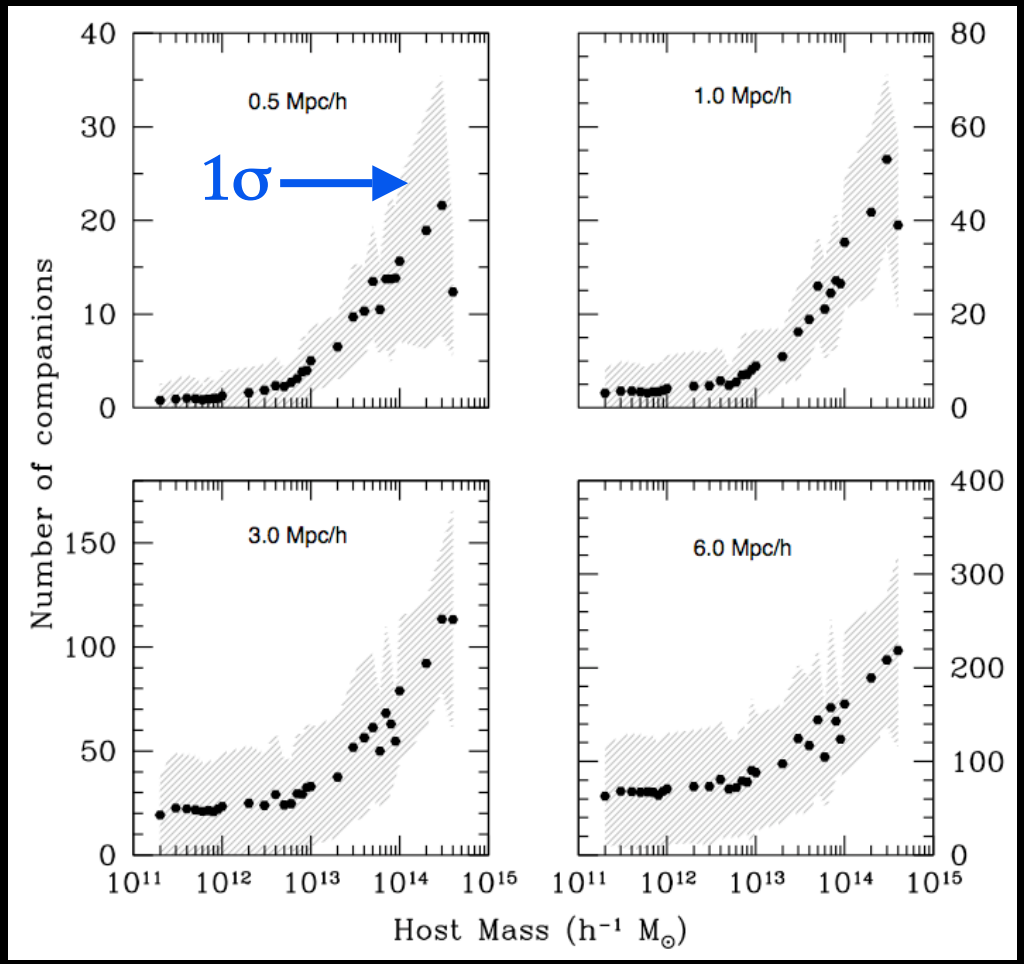
(J. Berrier et al. 2006)

Counts from hybrid N-body/substructure model

Data from intermediate-z redshift surveys, CNOC2 and DEEP2 (Lin et al. 2004)

The merging of galaxies doesn't track the merging of halos

Aside: Counts-in-cylinders from cosmo simulations noisy

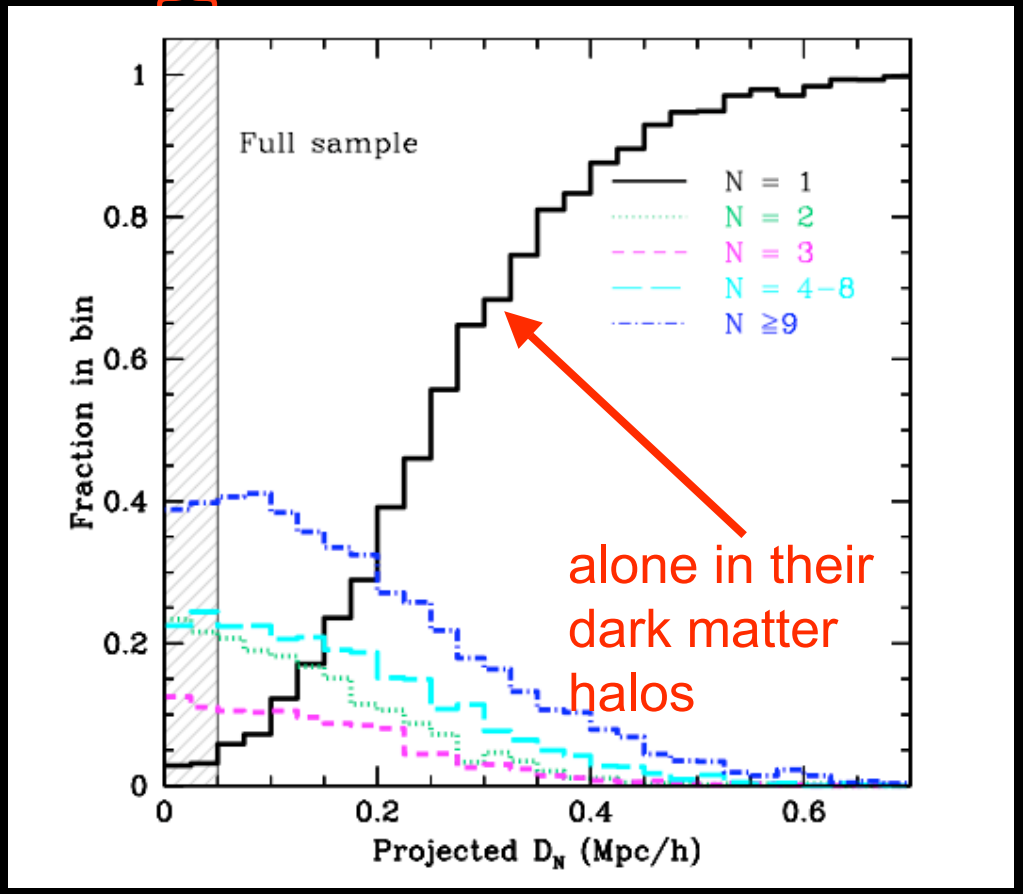


- Counts of number of neighbors within X Mpc/h, 1000 km/s
- Similar to many "local density" environment methods used

(H. Berrier et al. 2009, in prep.)

Model raises flag of caution: pairs are preferentially in populated, massive halos

50 kpc/h "pair zone"



Fraction

$N_{halo} = 1$
$N_{halo} = 2$
$N_{halo} = 3$
$N_{halo} = 4-8$
$N_{halo} \geq 9$

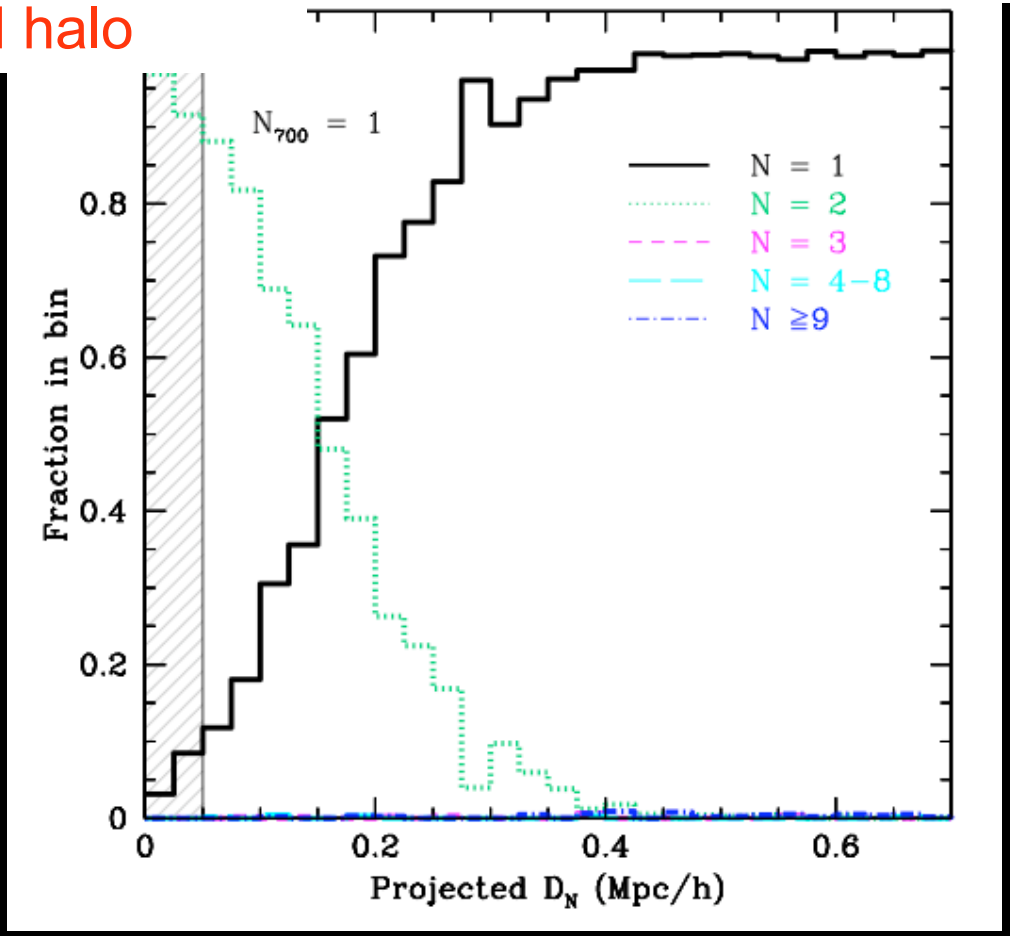
Distance to nearest neighbor

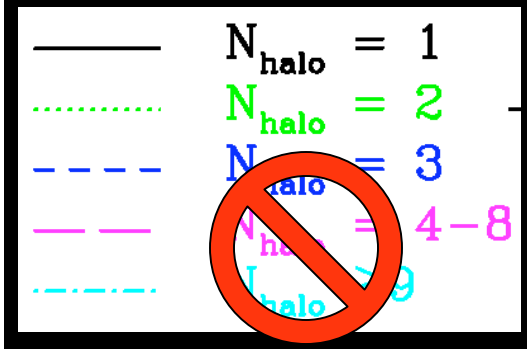
(Barton et al. 2007)

Restricting to <= 1 neighbor within 700 kpc/h yields clean N=2 sample and N=1 control

Pairs alone in DM halo

Single galaxies alone in DM halo



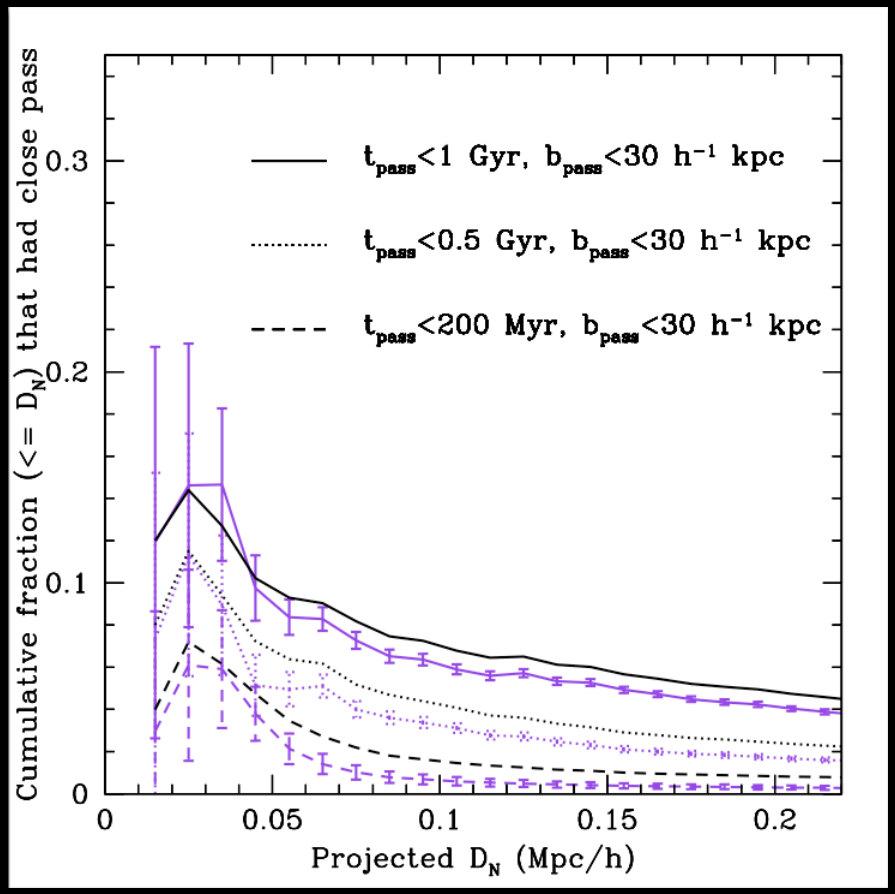


Fraction

Distance to nearest neighbor

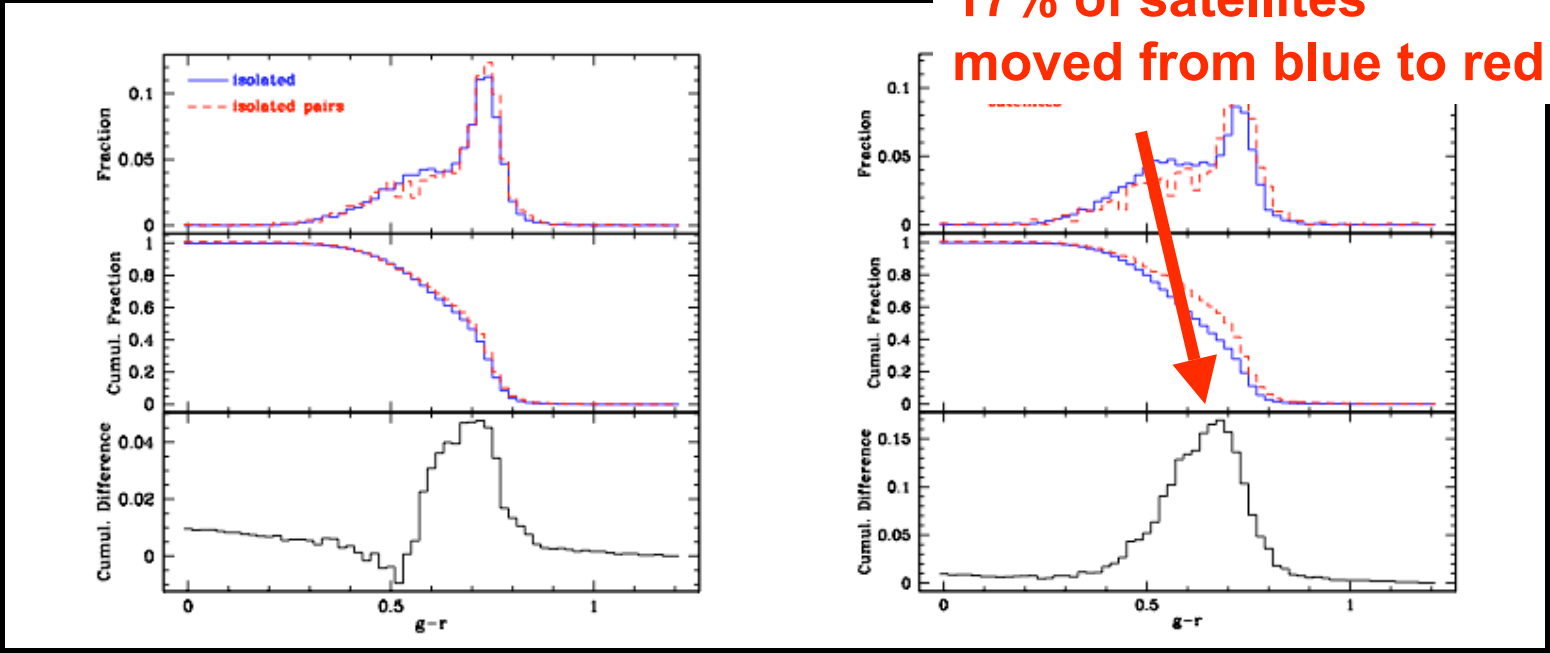
(Barton et al. 2007)

Stranglation/quenching/stripping: a sample to study star formation suppression



- As pair selection radius becomes wider, recent close passes are rarer
- Many objects have been substructure for a long time

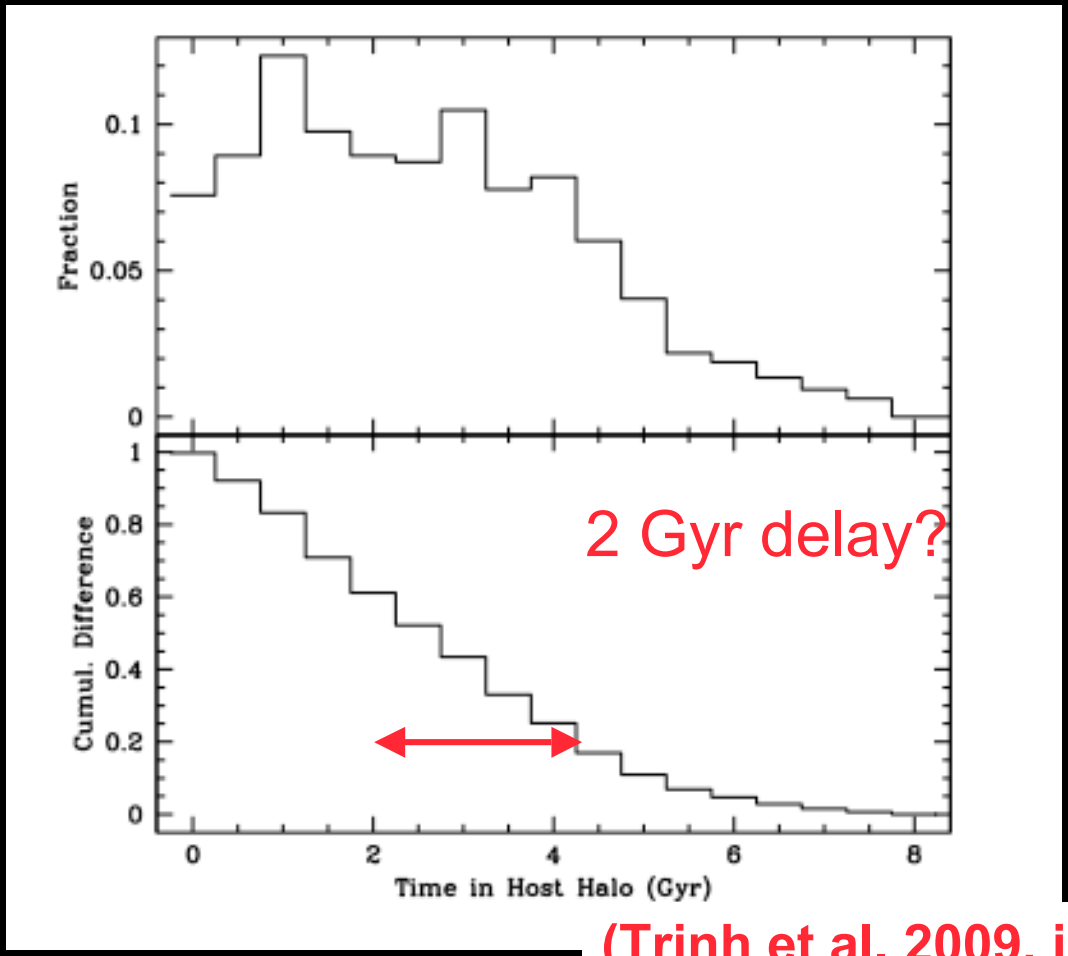
The Differences between isolated and satellite galaxies: red excess



- Volume-limited to -20 (left) or -19 (right) (H_0=100 km/s/Mpc) in SDSS NYU-VAGC (Blanton et al. 2005)
- satellites have neighbors to to 200 kpc/h with isolated contaminants subtracted
- N=1 distributions resampled to have the same stellar mass as N=2 distribution

(Trinh, EB et al. in prep)

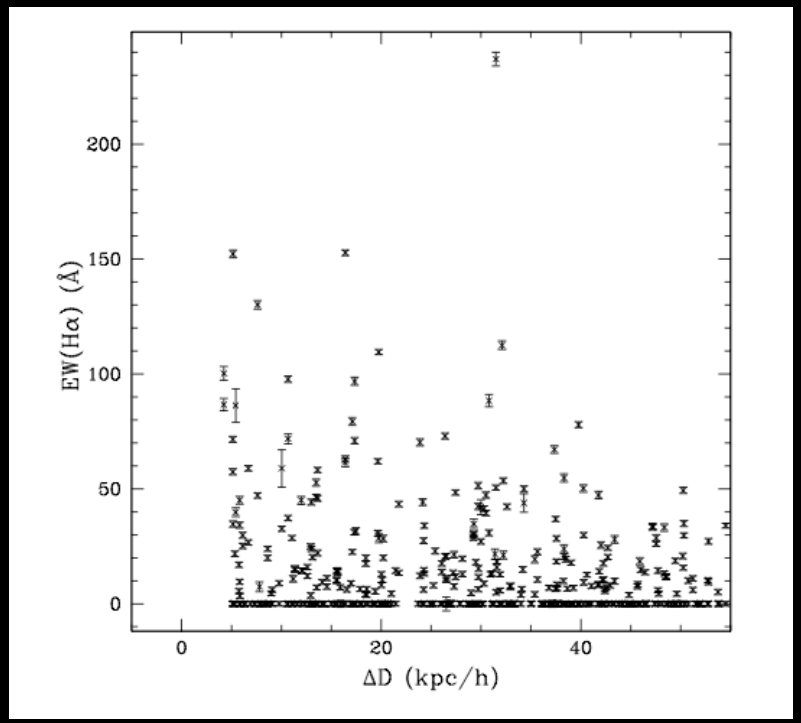
Models tell about evolution of these satellites



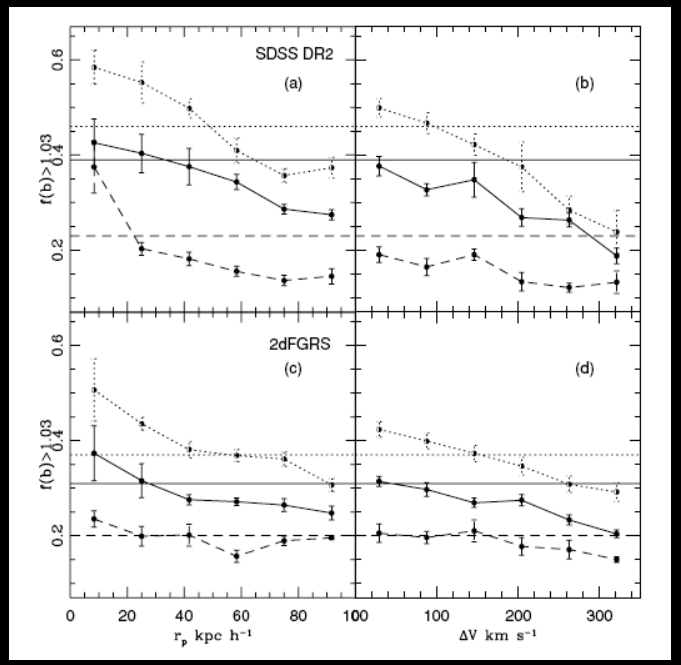
- 38% of satellites have been inside host more than 2 Gyr
- (DATA: only 17% moved blue to red)
- if quenching immediate, 2 Gyr enough time to move from blue to red
- THUS, suppression delayed
- (strangulation? that feeder filament thing?)

(Trinh et al. 2009, in prep.)

On to triggered star formation...



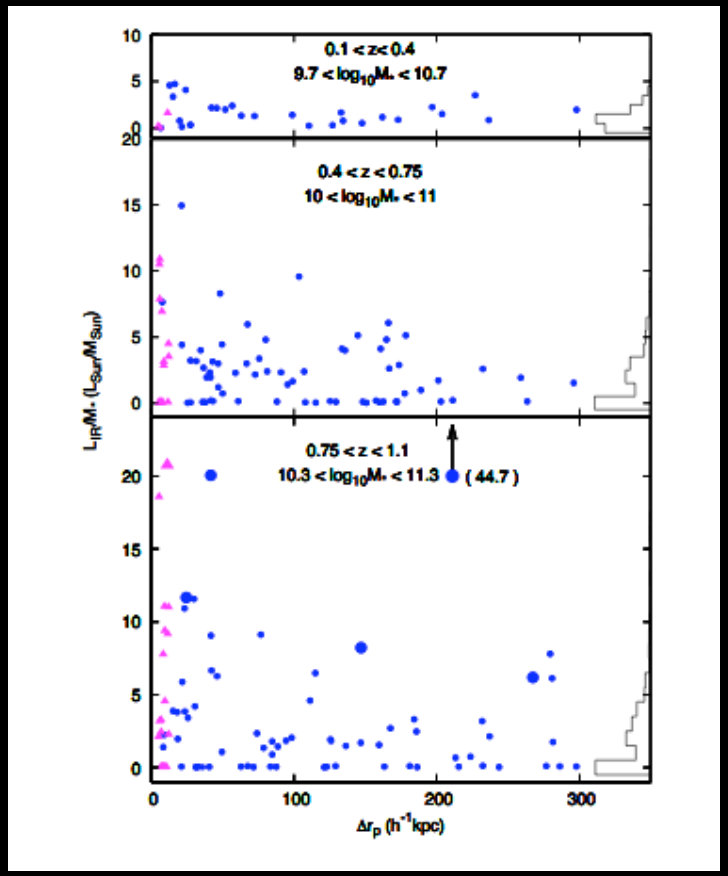
(Barton, Geller, & Kenyon 2000)



(Sol Alonso et al. 2004)

(Lambas et al. 2003; Nikolic et al. 2004; etc.)

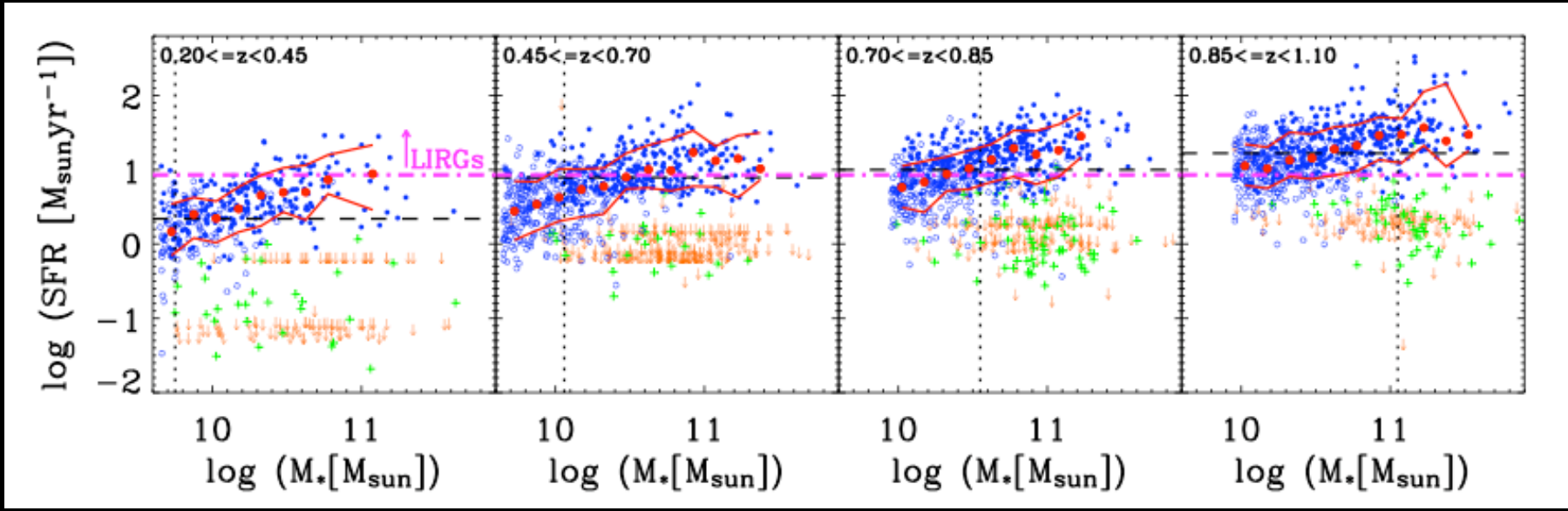
Triggered star formation: also happens in DEEP2



(Lihwai Lin et al. 2006)

- Triggered star formation as traced by FIR luminosity
- See poster by Lihwai Lin on pair environments in DEEP2
- See upcoming talk by Aday Robaina: triggered star formation not dominant effect

Tightness of SFR vs. M_* relation suggests little burstiness

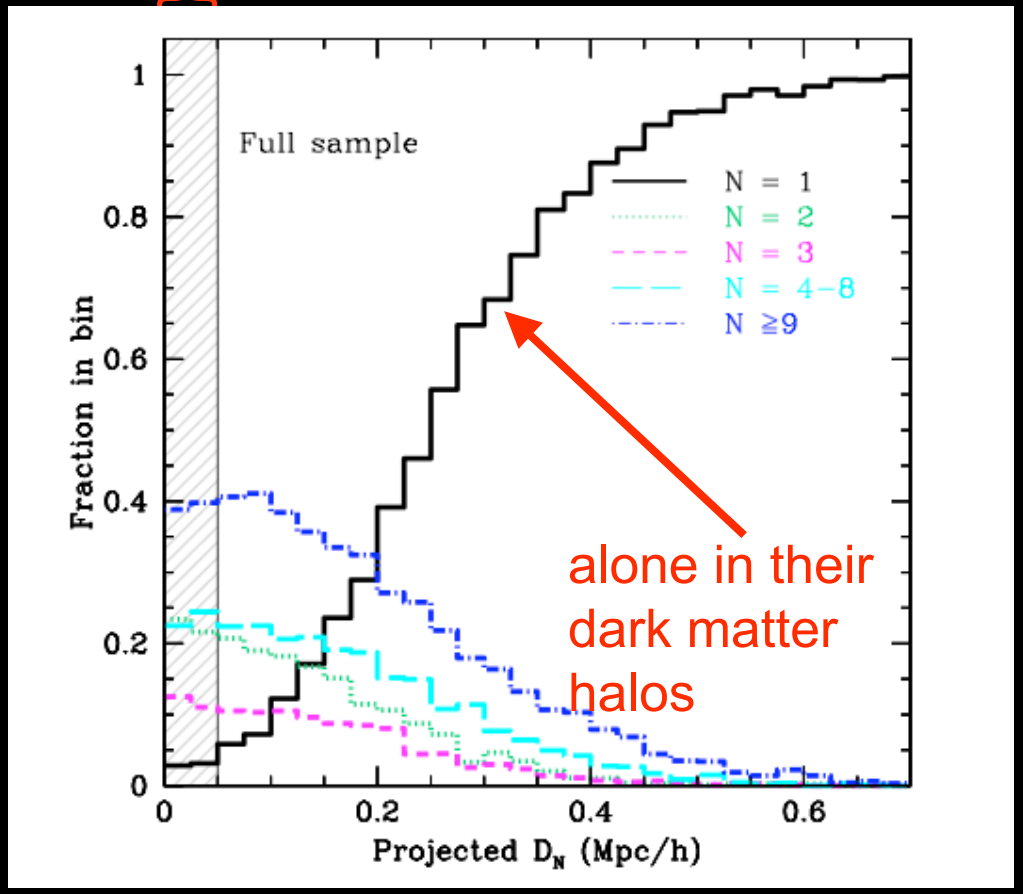


DEEP2 result

(Noeske et al. 2007)

Model explains some pair star formation results: Pairs are preferentially in populated, massive halos

50 kpc/h "pair zone"



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$N_{halo} \geq 9$

- True even if you restrict local density of parent sample
- If parent sample has any range of environments at all, pairs always reside in the densest environments

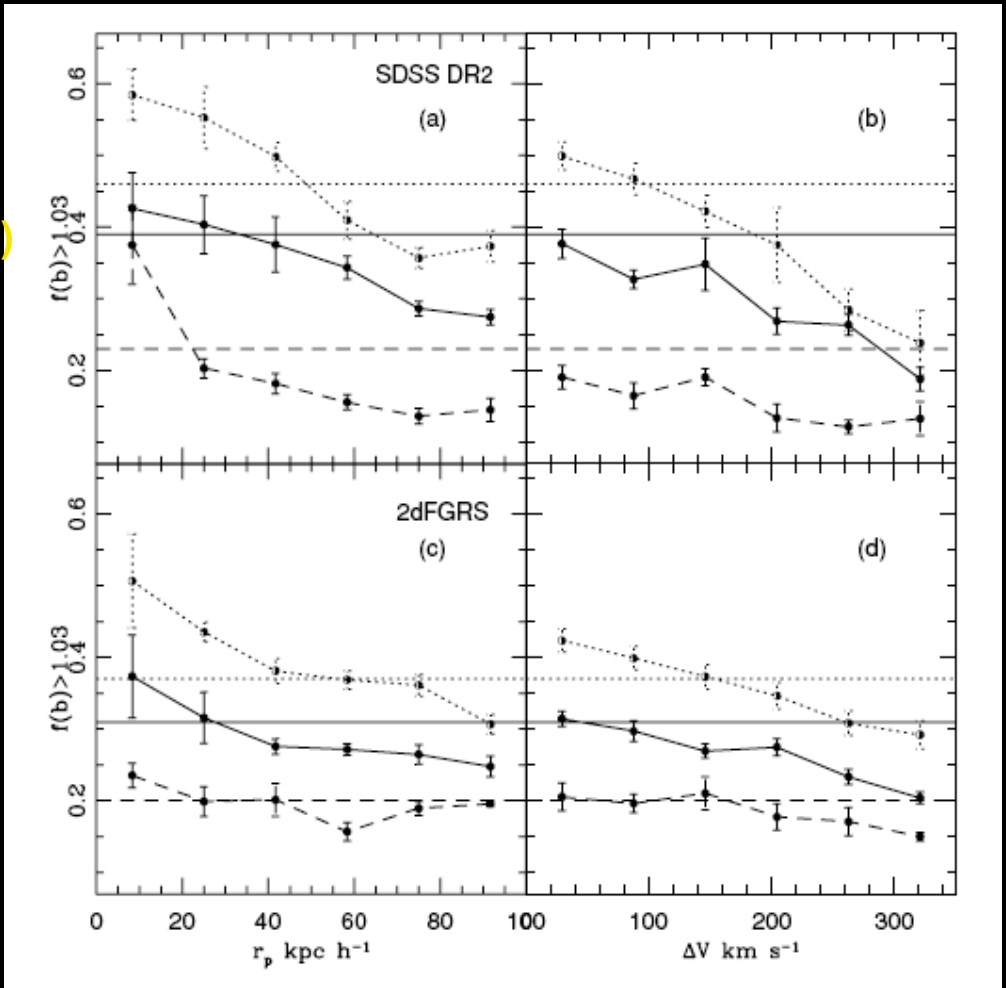
(Barton et al. 2007)

Explains how pairs can have less star formation than the field

(low density)

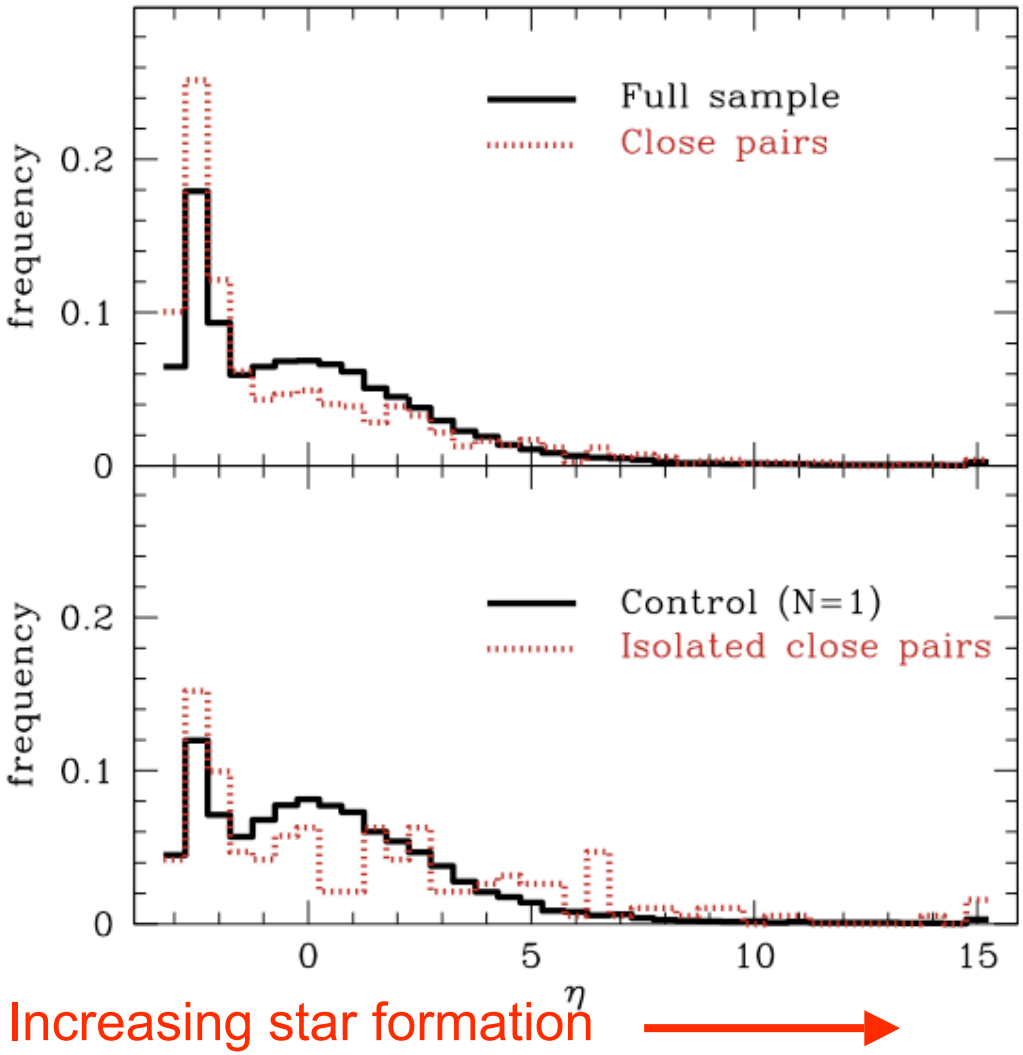
(medium density)

(high density)



(Alonso et al. 2006)

2dF Pairs

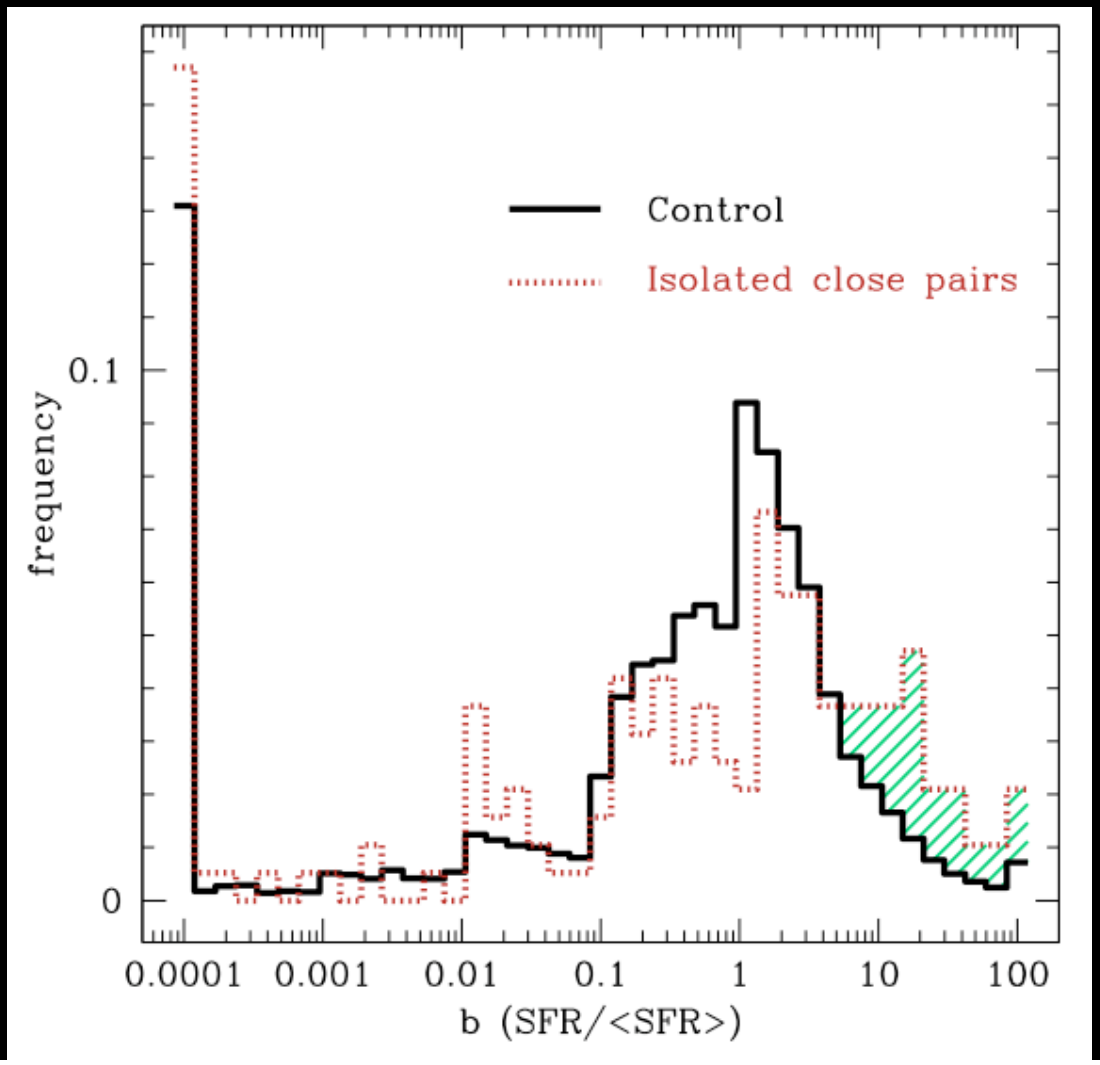


Increasing star formation →

- 2dF survey, volume-limited sample to $m_{\_bJ}$=-19
- 22601 targets
- 8564 in control
- 191 in isolated close pairs

(Barton et al. 2007)

Technique yields accurate measure of triggered star formation



Conversion from Madgwick et al. (2003)

- 10% of isolated control sample bursting,
- 25% of close pair galaxies bursting, boosted by average factor of ~30
- Depends on sf measure, galaxy luminosity cut, separation cut

(Barton et al. 2007)

Summary

- We may have to accept that satellite reddening mechanisms are not a strong function of parent halo mass (van den Bosch et al. 2008)
  - What does this imply about cluster processes? (If there is little pre-processing, then there is an important way in which cluster and group processes are the same)
- Even among luminous galaxies, detectable quenching processes extend to the sparsest (N=2) systems
- Triggered star formation is not dominant, but it happens almost whenever there is a close pass, and must be accounted for in environment analyses