The Roles of Environment in Galaxy Evolution

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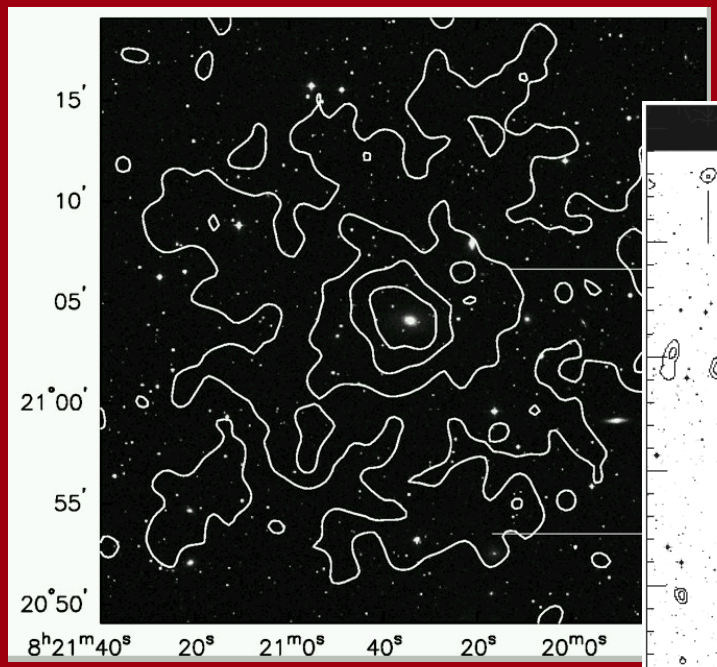
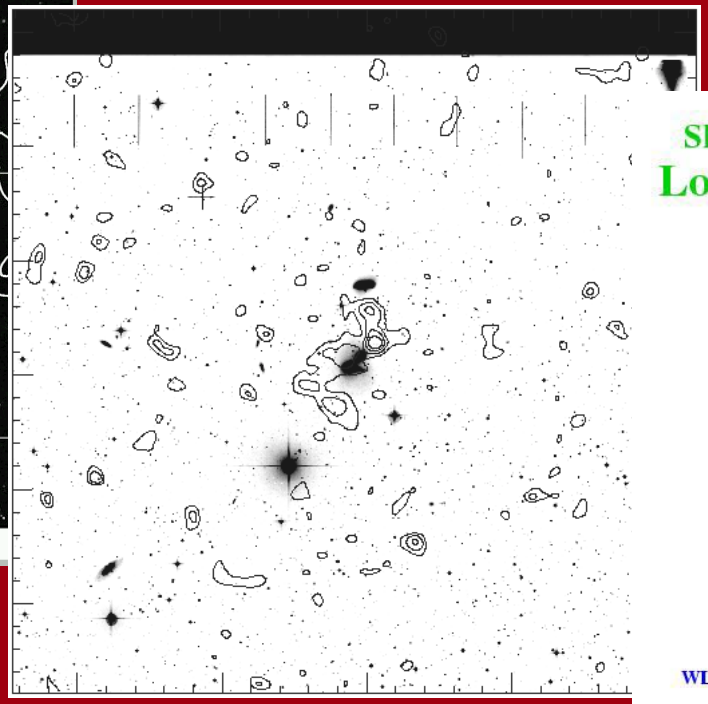
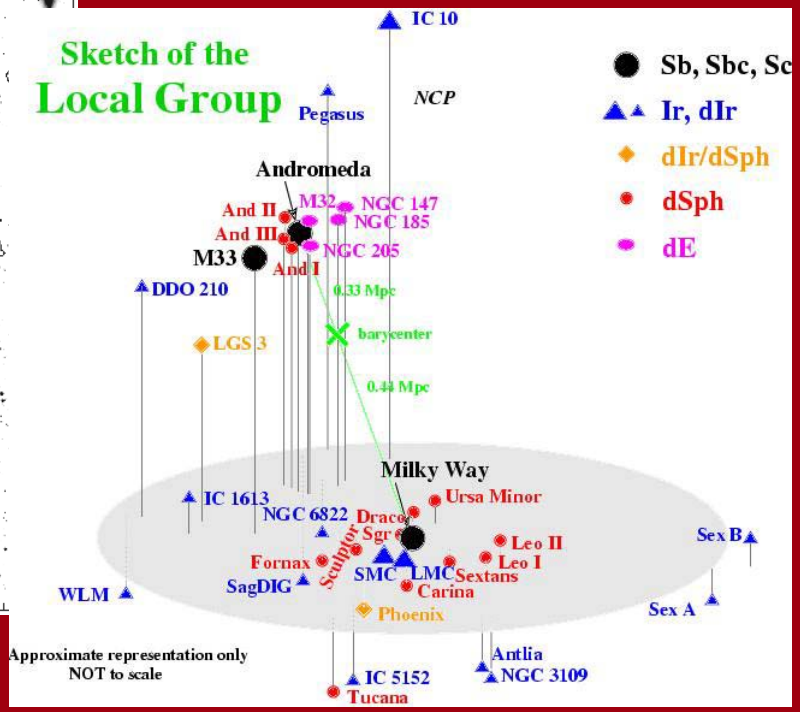






On-going Puzzles...

morphology-density relation

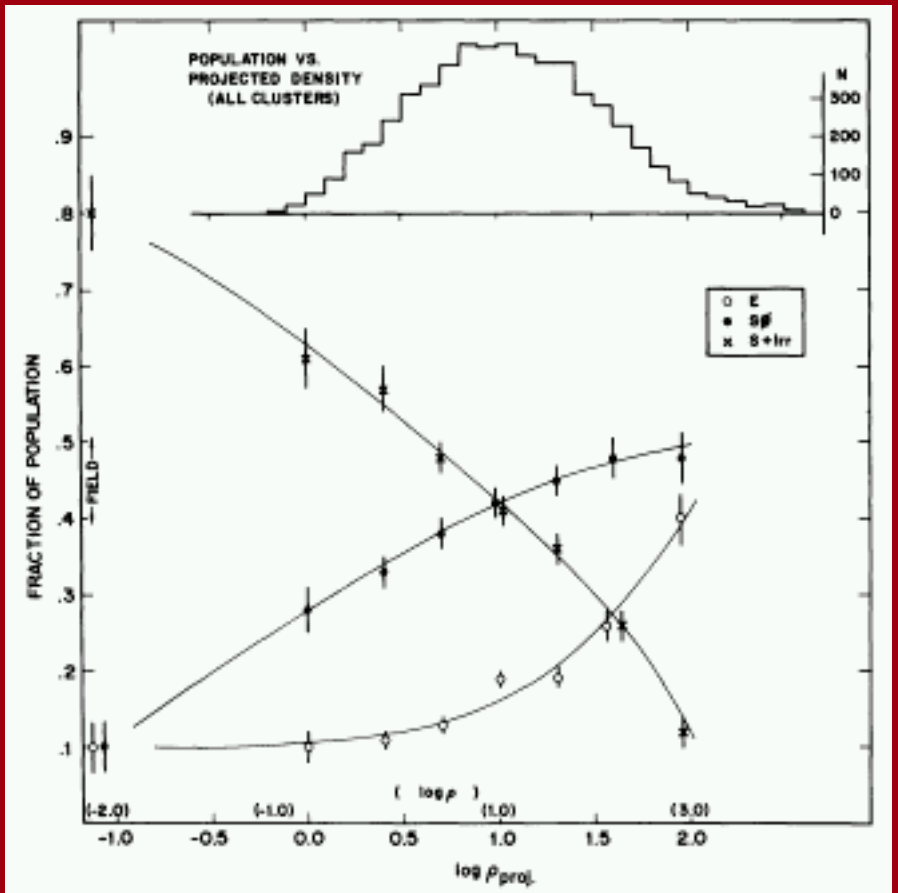


FIG. 4.—The fraction of E, S0, and S+I galaxies as a function of the log of the projected density, in galaxies Mpc^{-2}. The data shown are for all cluster galaxies in the sample and for the field. Also shown is an estimated scale of true space density in galaxies Mpc^{-3}. The upper histogram shows the number distribution of the galaxies over the bins of projected density.

Dressler 1980

Butcher-Oemler Effect

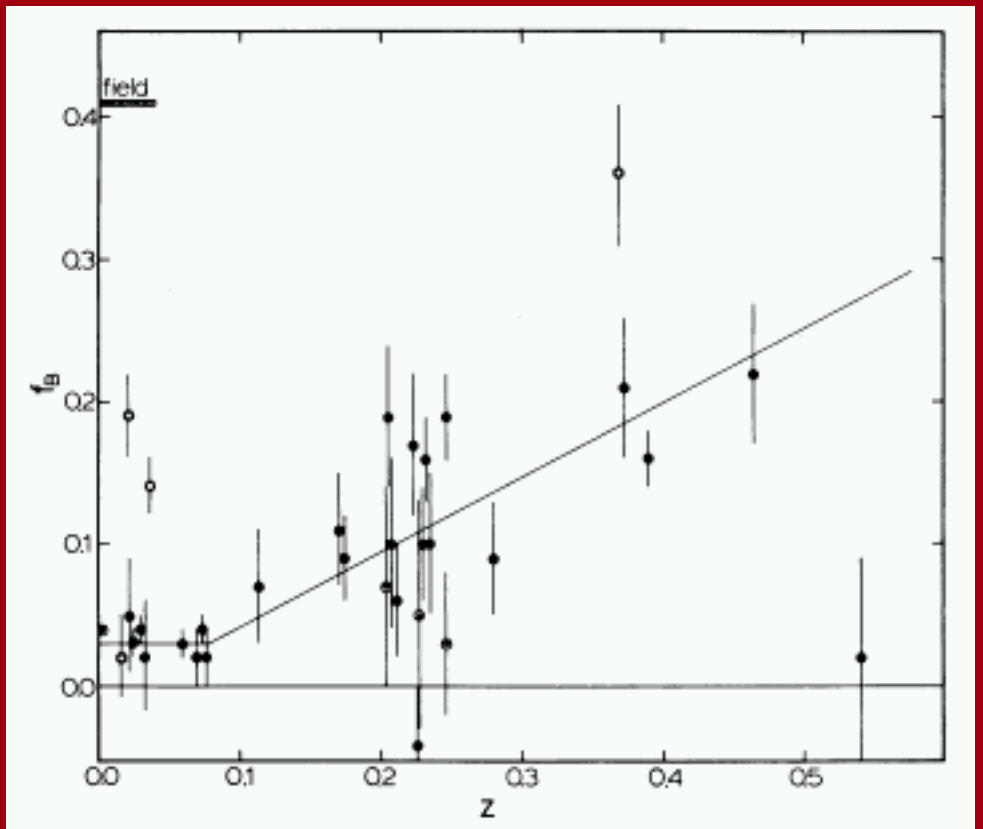
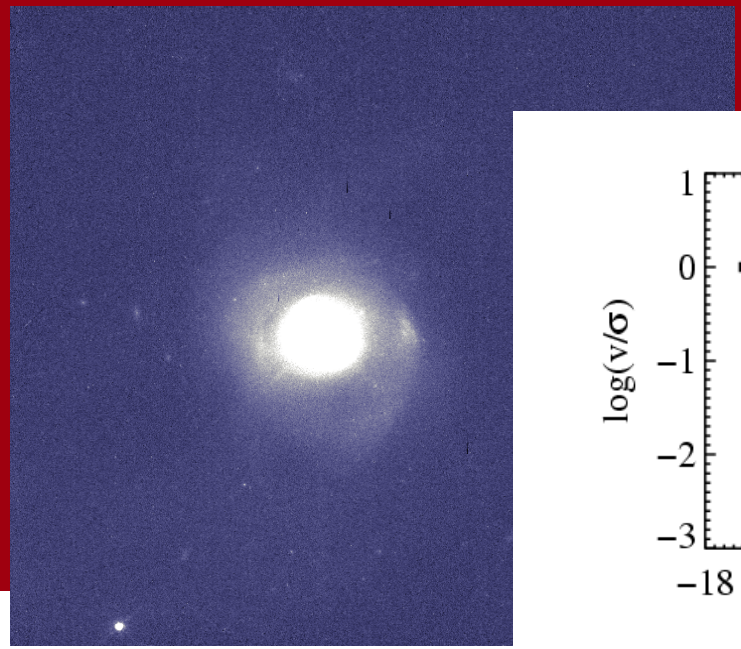


FIG. 3.—Blue galaxy fraction versus redshift. *Filled circles*, compact clusters ($C \geq 0.40$); *open circles*, irregular clusters ($C < 0.35$); *dotted circles*, intermediate clusters ($0.35 \leq C < 0.40$).

Butcher & Oemler 1984

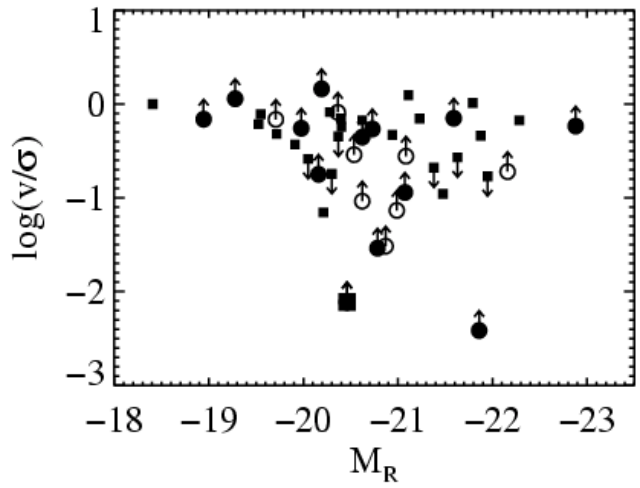
Observed Galaxy Evolution in Poor Groups

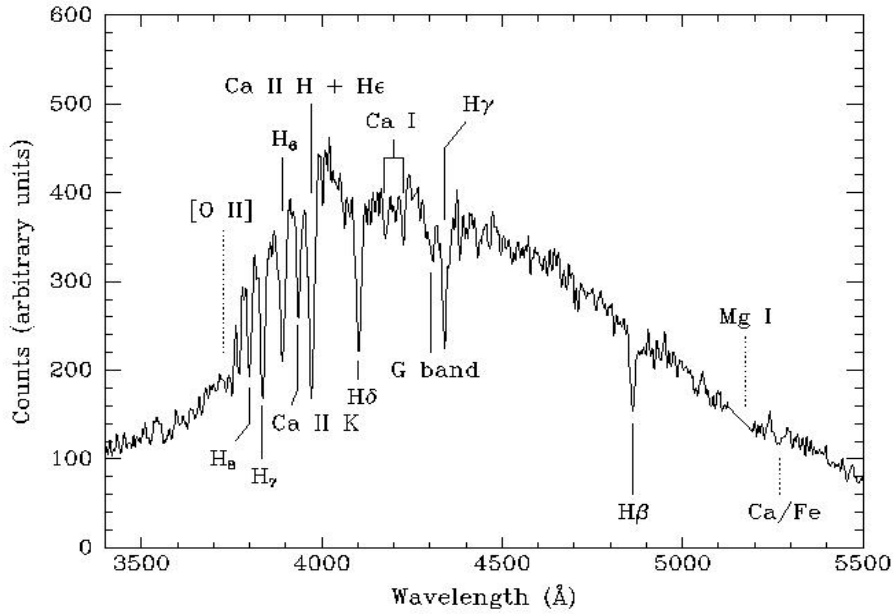
J. Dubinski

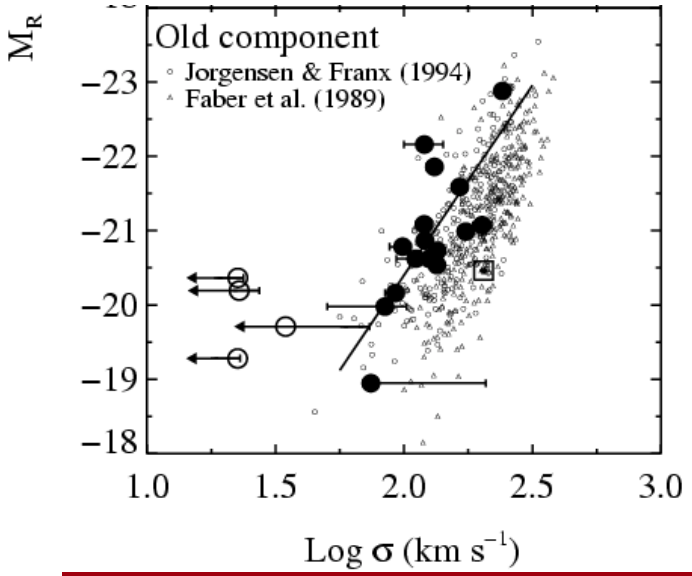


Yujin Yang et al. 2004

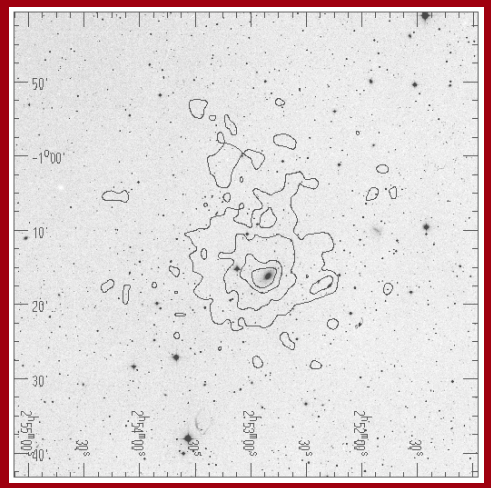
Norton et al. 2001

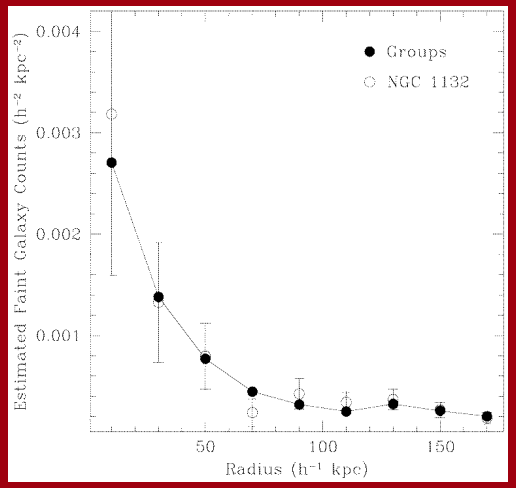






Observed Galaxy Evolution in Groups (cont.)

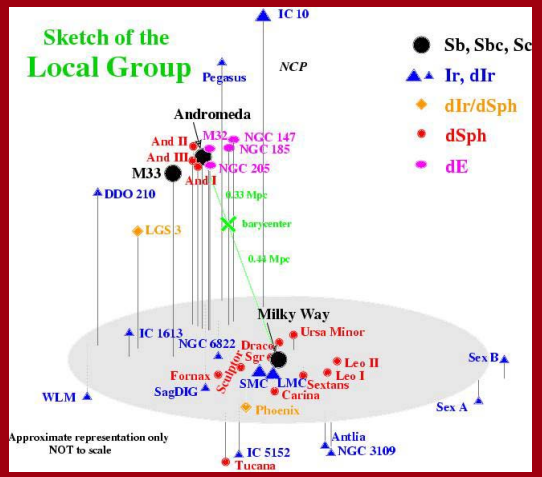


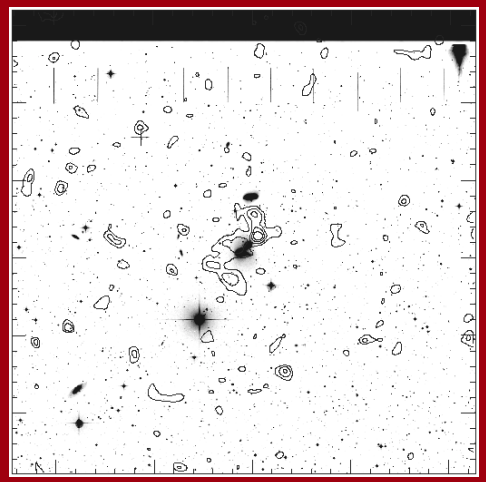


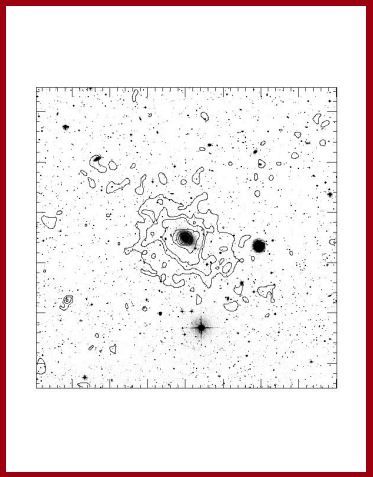
isolated ellipticals: X-ray extent, L, T, metallicity, gas mass, total mass, and dwarfs like groups

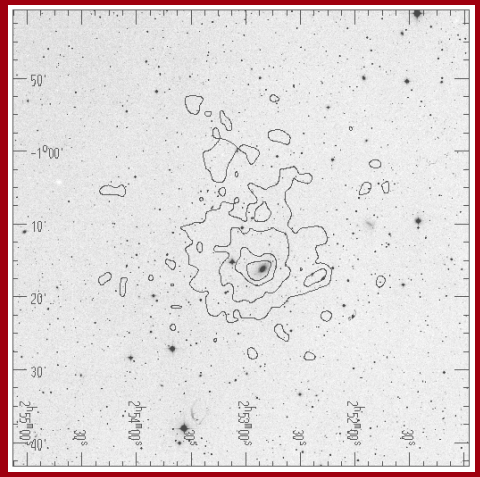
evidence for evolution of dwarf-to-giant ratio

one possible scenario ...

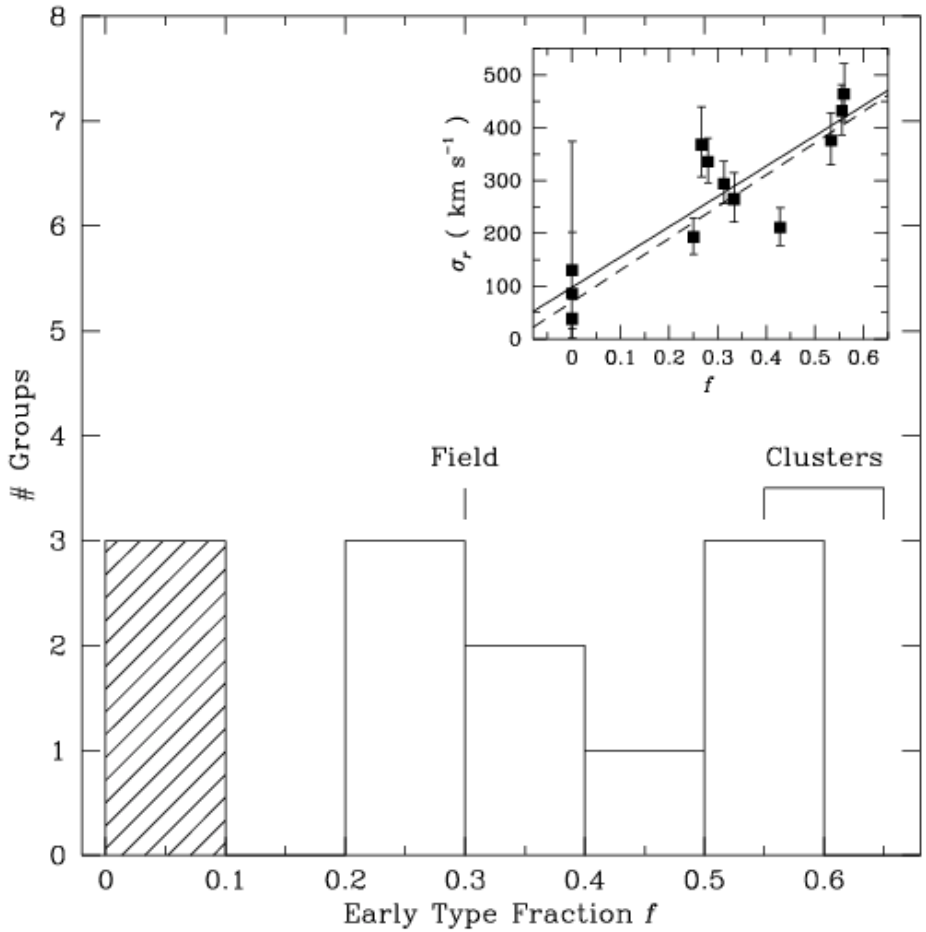








Some Groups Look Like Clusters



Zabludoff & Mulchaey 1998

at 1000 km/s, early-type fraction = 120%!

saturation point ==> *driver in groups, not clusters*

upturn at ~400-500 km/s (value for L* merger)

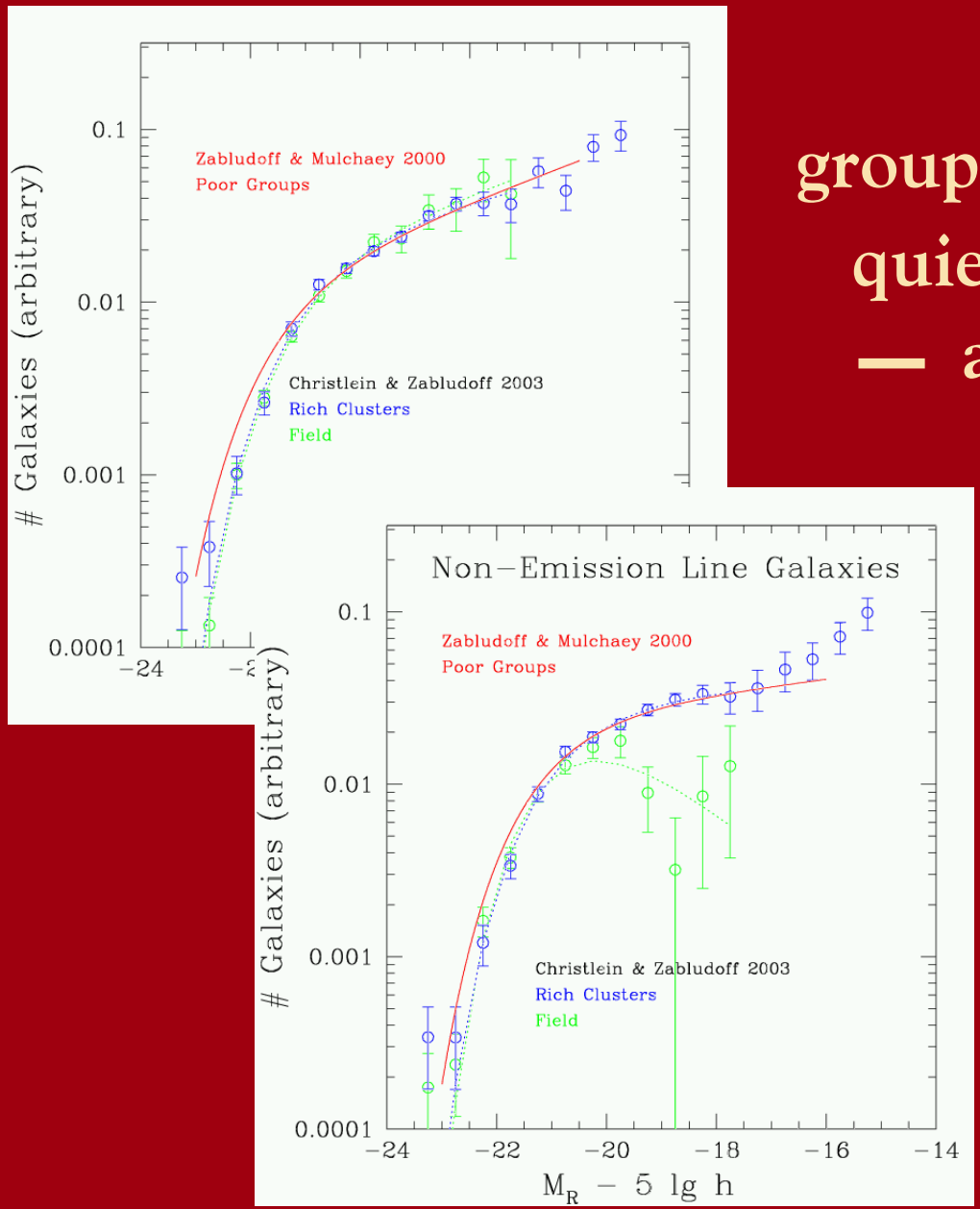
Another Solution...

mergers in groups, group-cluster correlation, and increased infall at higher z produce B-O Effect (Zabludoff et al. 1996)

morphology-environment relation saturates when mergers become less likely (Zabludoff & Mulchaey 1998)

galaxy-galaxy interactions could dominate group, and cluster, galaxy evolution

Are Groups Where the Action Is (or Was)?



groups, clusters have similar quiescent dwarf-to-giant ratios — another saturation point

==> groups important prior to and during infall

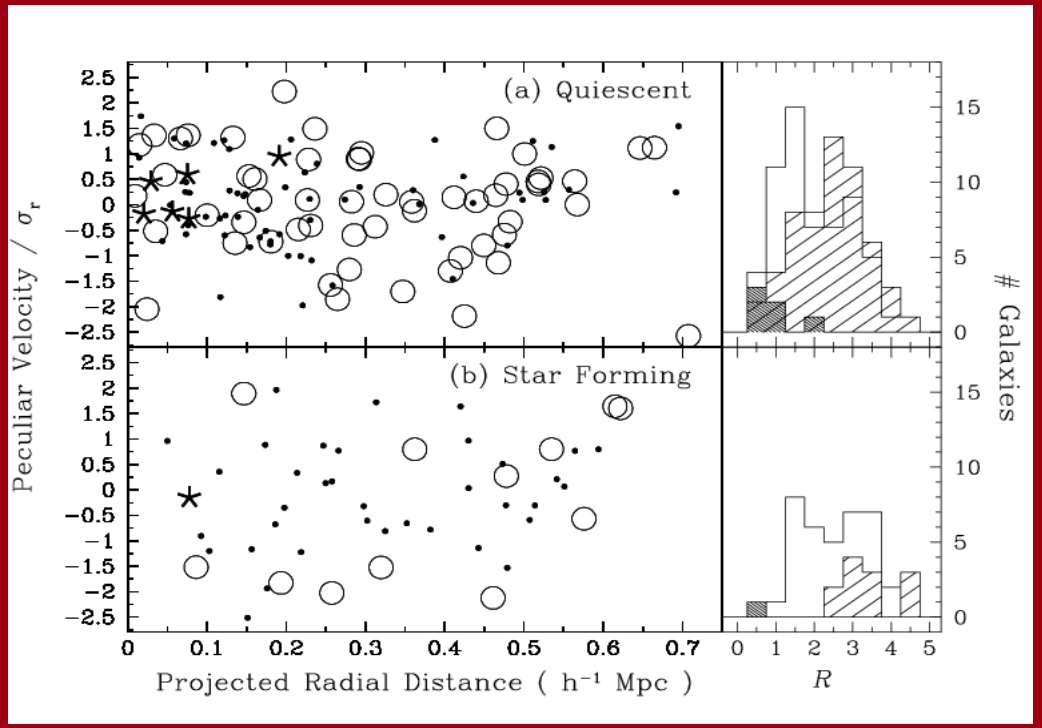
Daniel Christlein

Some Other Saturation Points

BCG's lie in group centers
(then dwarfs, giants)

populations not mixed
==> later formation

BCG velocity dispersions
max out at ~400 km/s



Zabludoff & Mulchaey 2000

suggest BCG formation in groups, not clusters

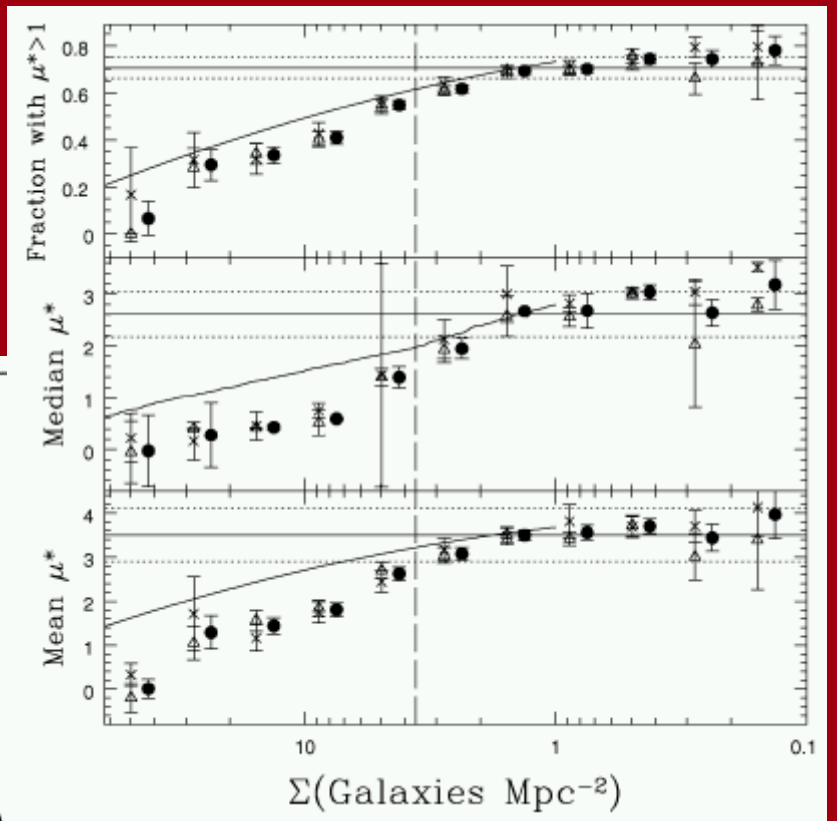
More Evidence for Importance of Groups

break in SFR-density relation

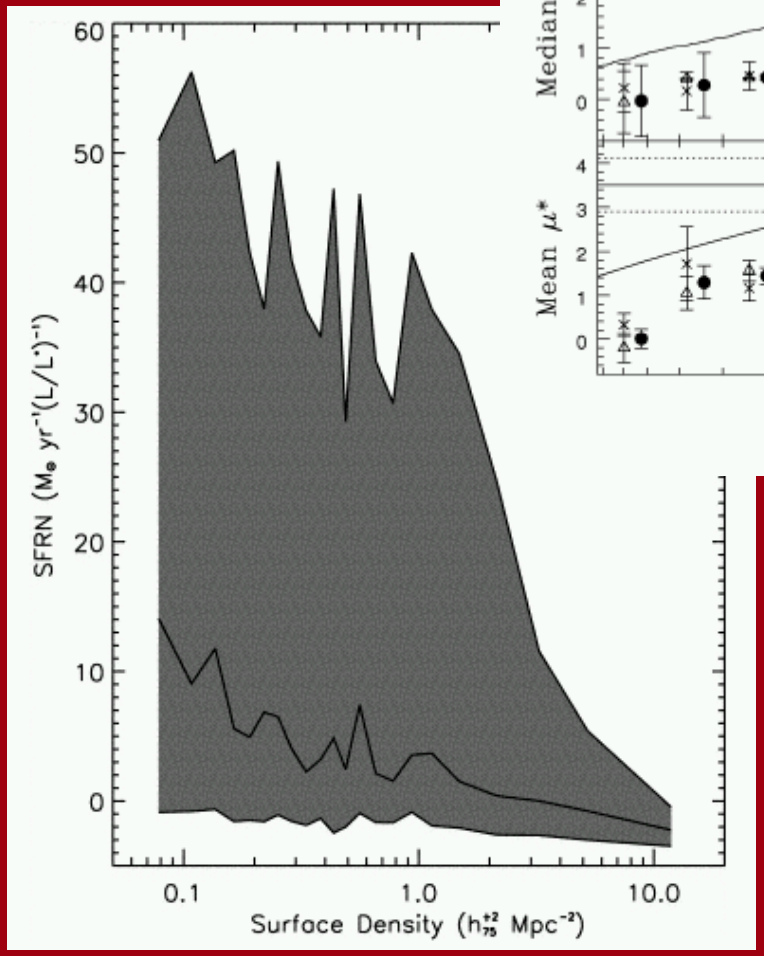
SFR falls at
~ few gal/Mpc^2

~ cluster infall radius (3-4 r_{vir})

~ poor group



Lewis et al. 2003 (2df)



Gomez et al. 2003 (SDSS)

Testing the Role of Clusters vs. Groups

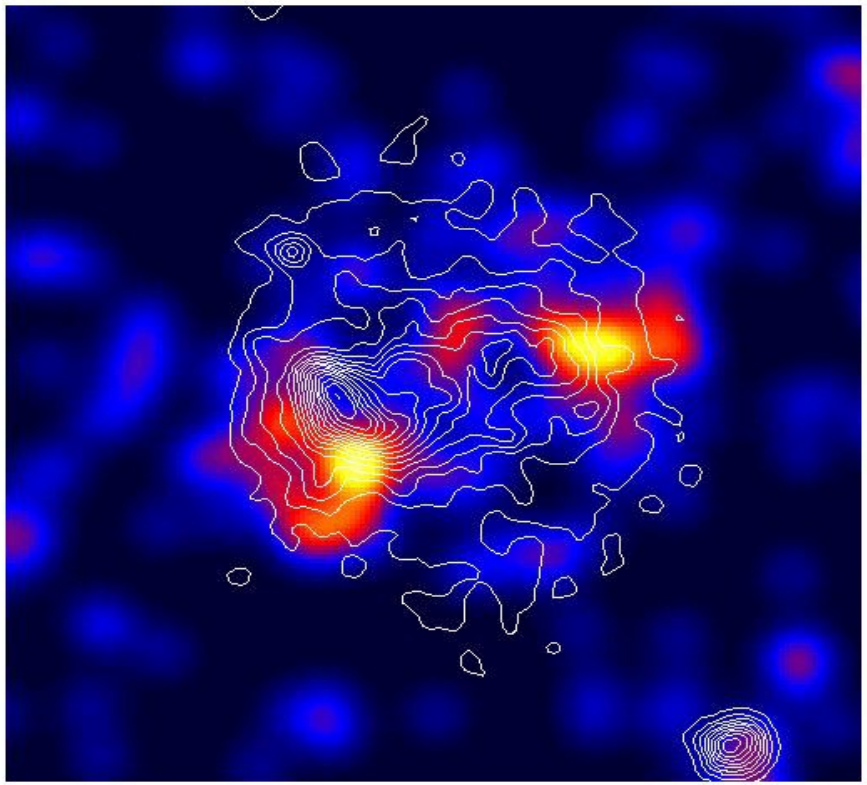
clusters form hierarchically,
interactions occur in groups

so compare accreted groups
with field groups

different morphs, SF, masses
==> cluster important!

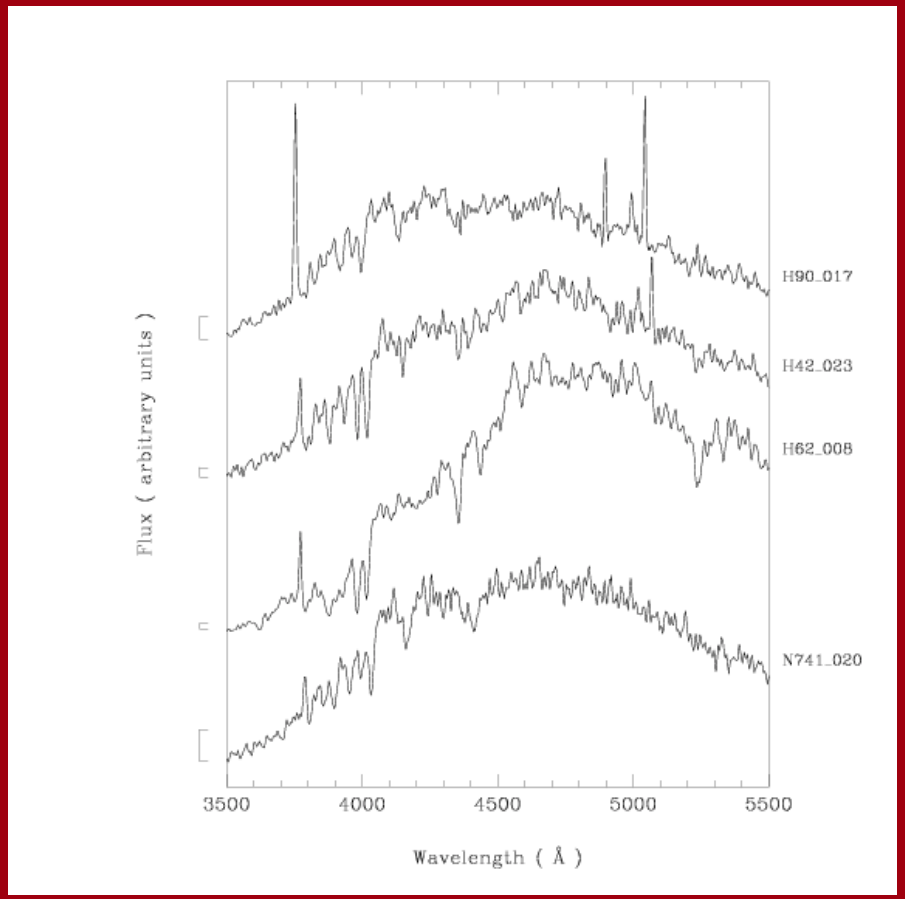
similar galaxies ==> groups
(and interactions) dominate

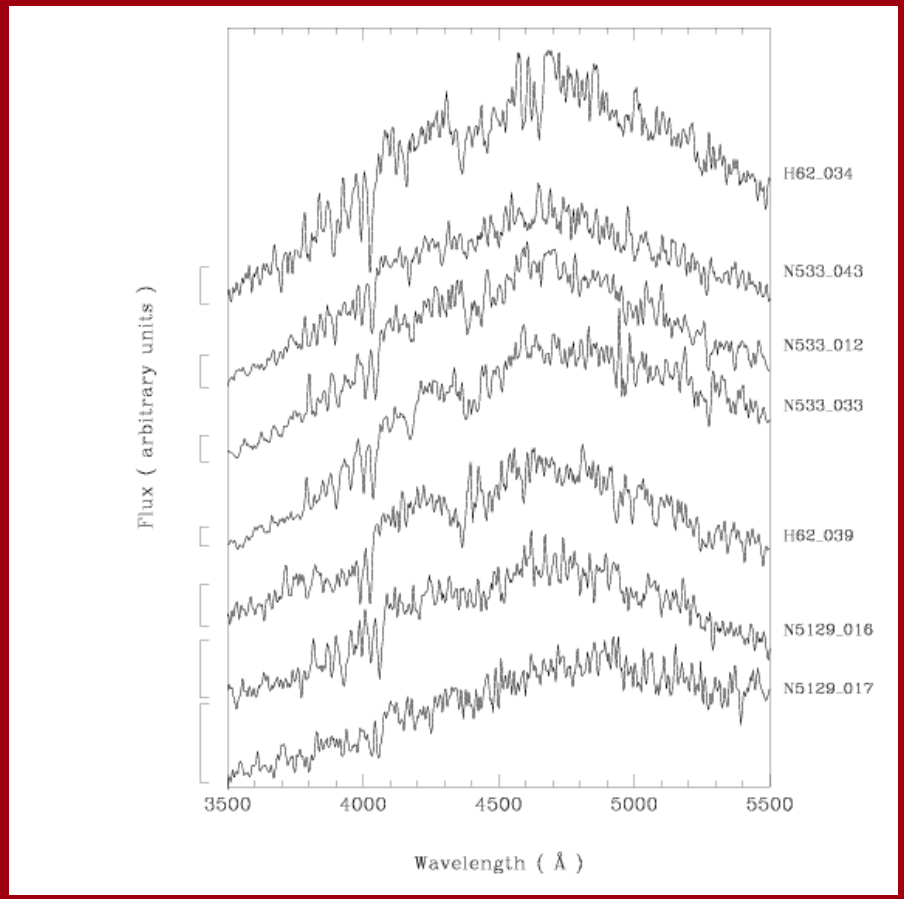
Abell 754



Zabludoff & Zaritsky 1995

Testing the Role of Clusters vs. Groups (cont.)





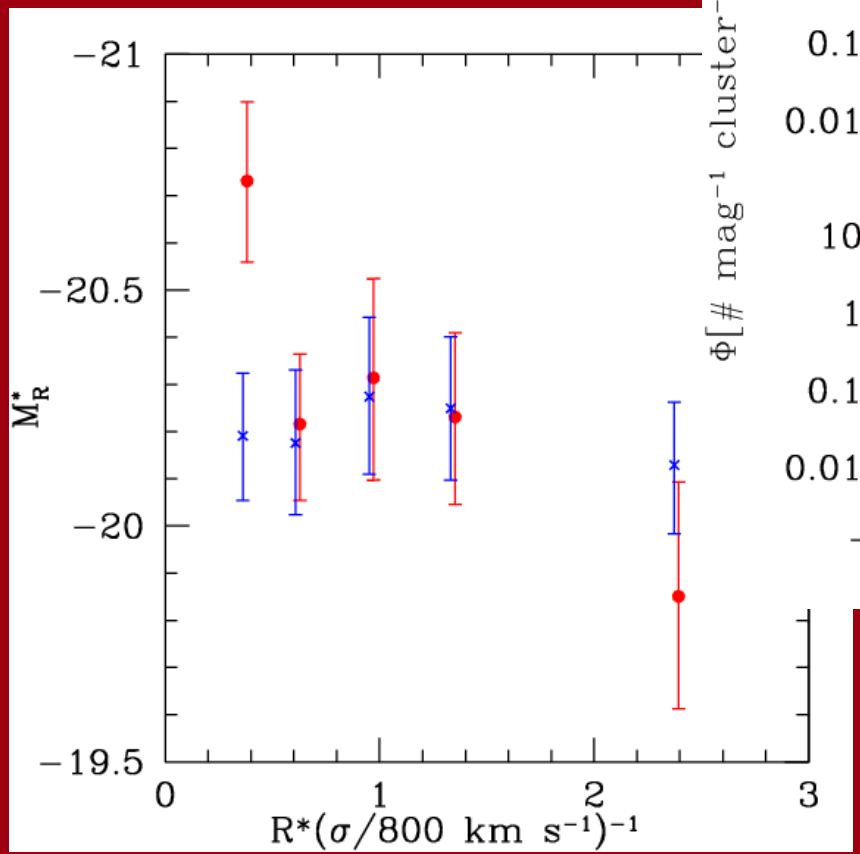
current and recent star formation fractions similar

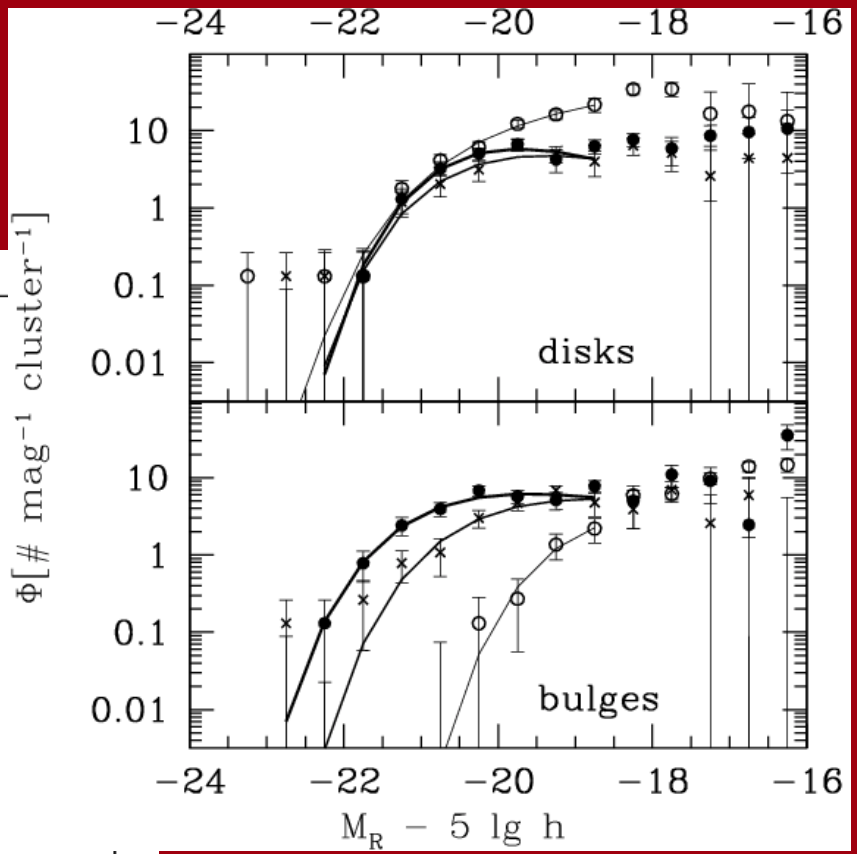
again, suggests driver is in groups, not clusters

Testing the Role of Clusters vs. Groups (cont.)

Can early-type galaxies form from fading the disks of late types?

Christlein & Zabludoff 2004



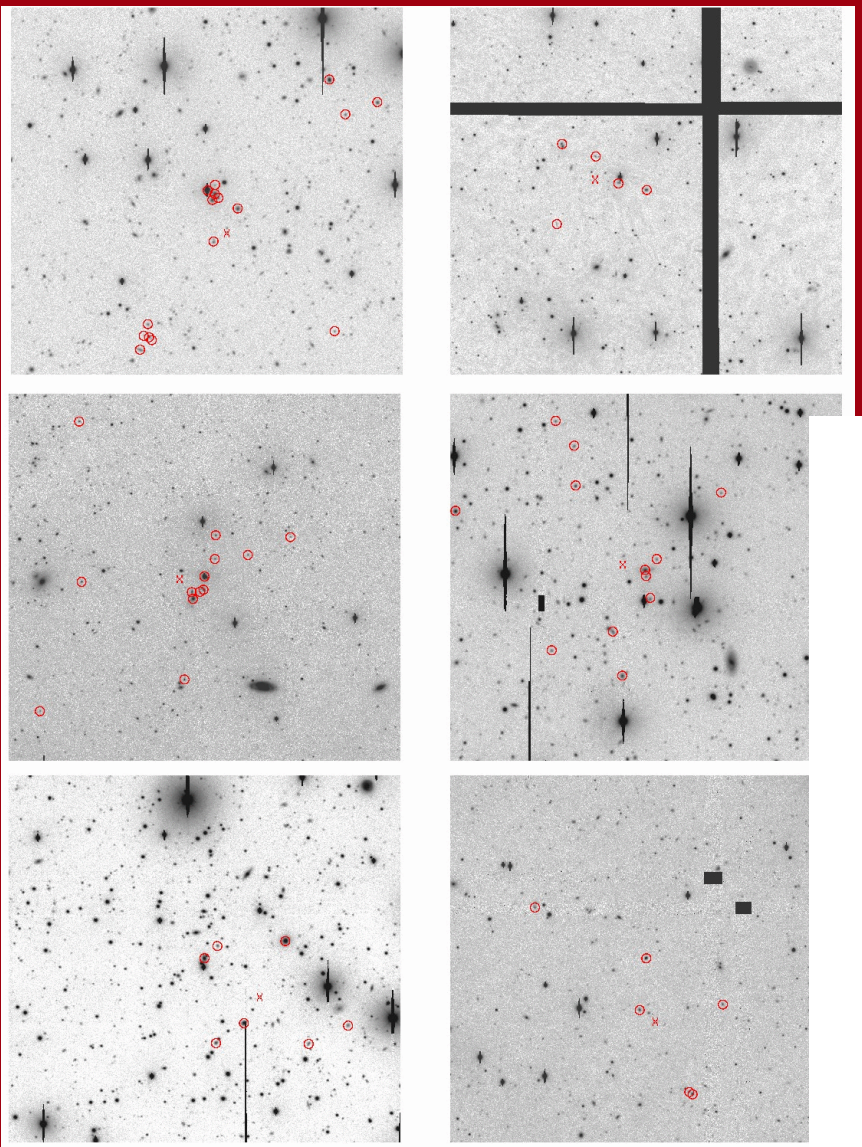


bulges brighter from late to early types, disks not fainter

morph-enviro relation due to brighter bulges

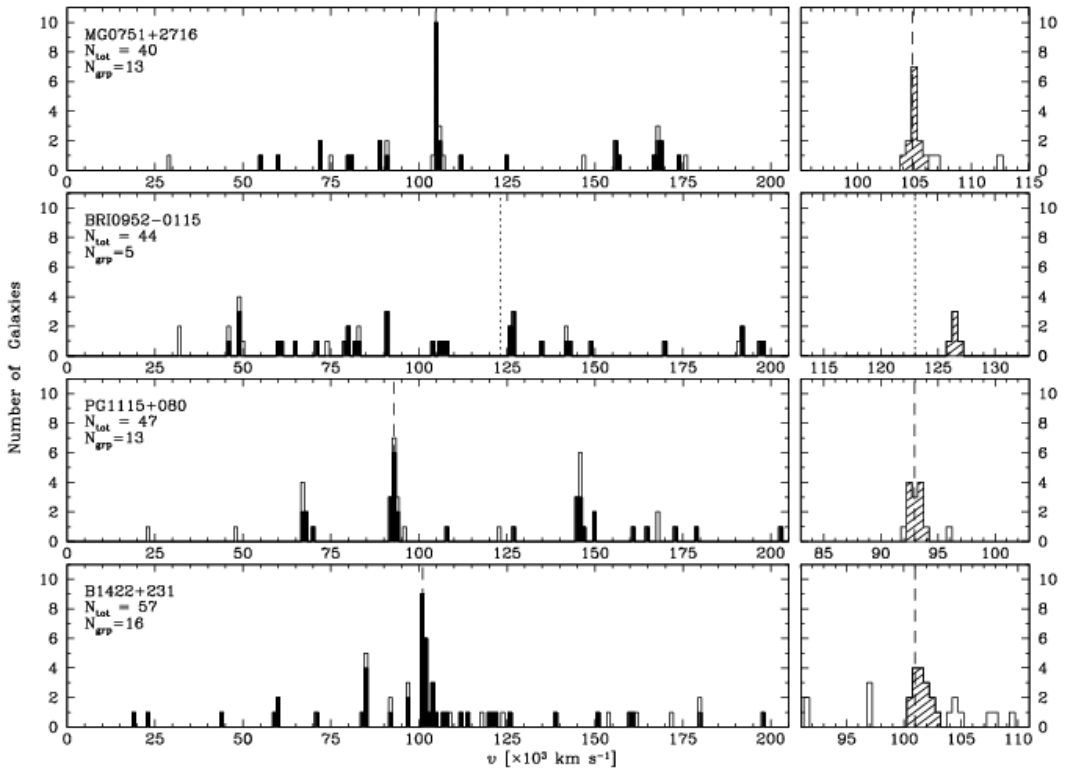
galaxy-galaxy interactions favored

Measuring Group Galaxy Evolution Directly



groups at high redshift?

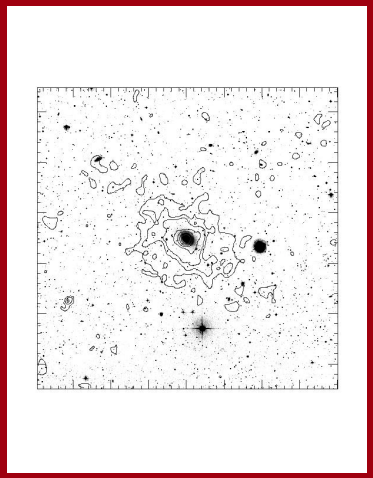
at least 25% of lenses in groups



poor model ==>
group potential

Momcheva et al. 2005

Summary



explanations of empirical relations lacking

transitions from star forming, gas-rich, rotationally-supported ---> quiescent, gas-poor, pressure-supported galaxies via mergers in groups

formation of "power law" ellipticals and young star clusters

evidence for dwarf-to-giant ratio evolution in groups

Summary (cont.)

some groups like clusters in galaxy morphology, dwarfs-to-giants, BCG properties, SF properties

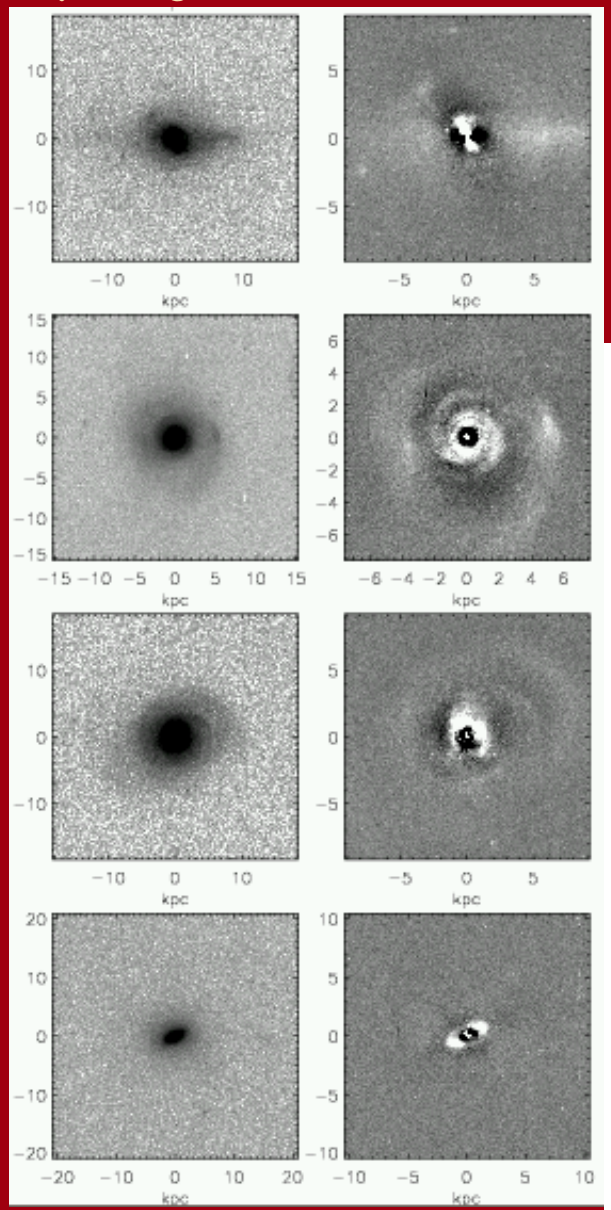
groups more important than clusters to galaxy evolution in general, Butcher-Oemler Effect and morphology-environment relation in particular

mechanism enhances bulge, does not diminish disk ==> galaxy-galaxy interactions, mergers

on-going search for high redshift groups via lensing, also improving constraints

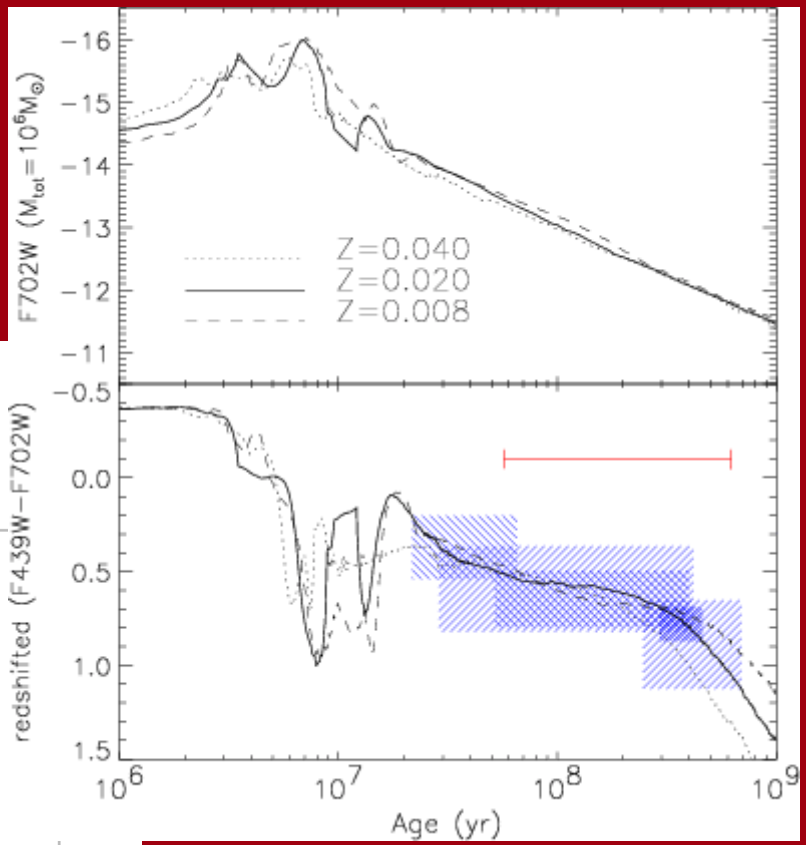
Observed Galaxy Evolution in Groups (cont.)

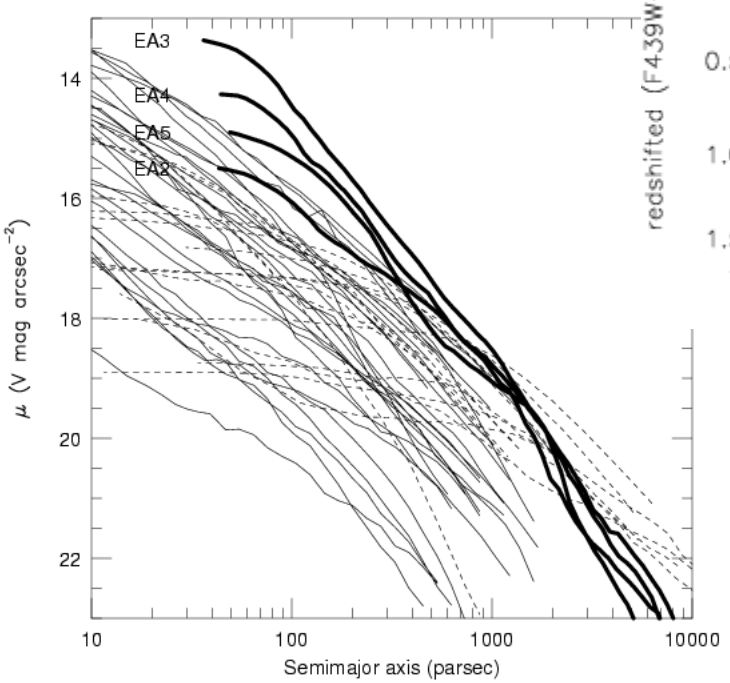
Yujin Yang et al. 2004



bulge-disk decompositions

power-law profiles





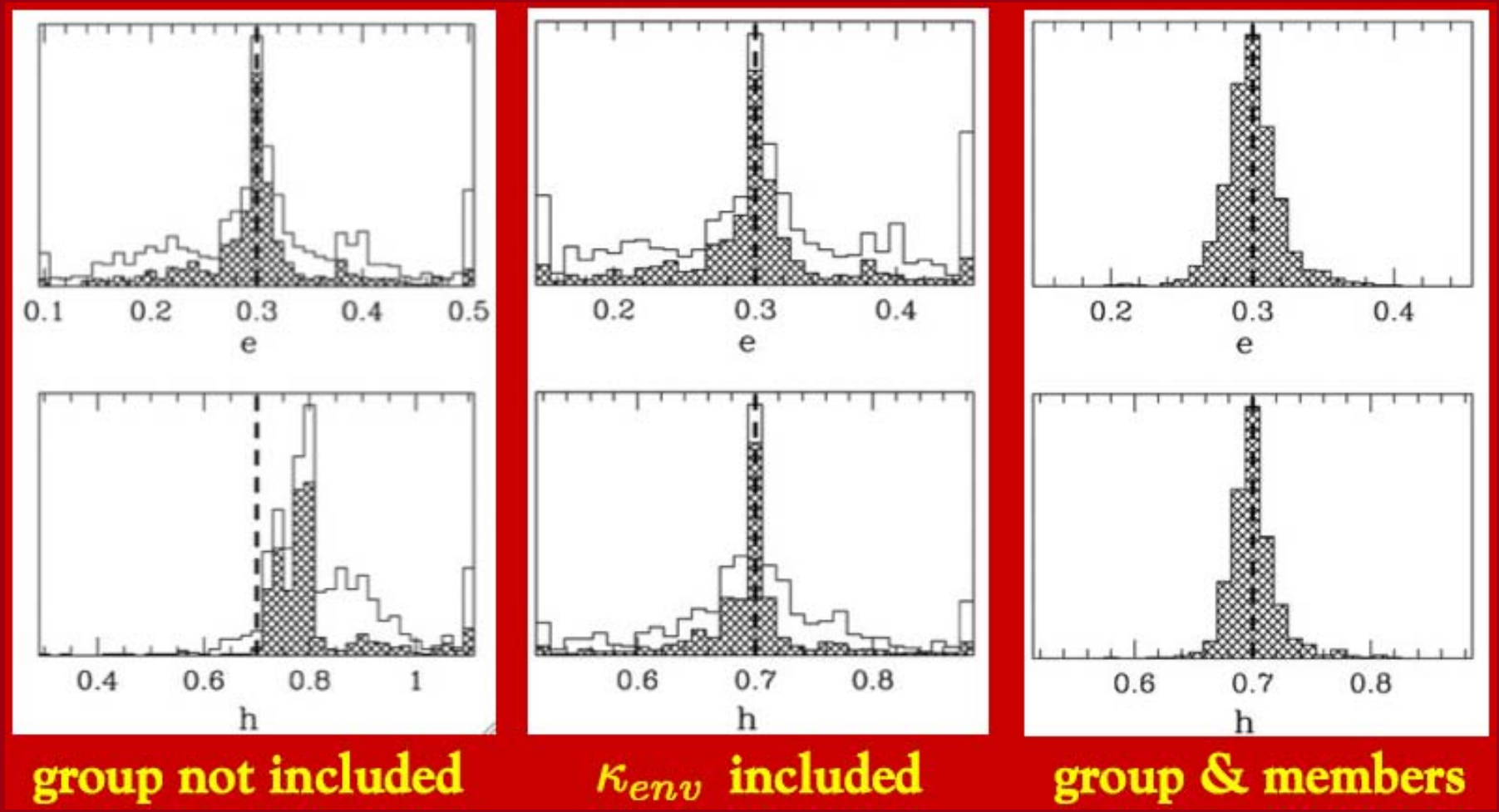
discovery of young clusters

dating mergers

Improving Constraints from Lens Models

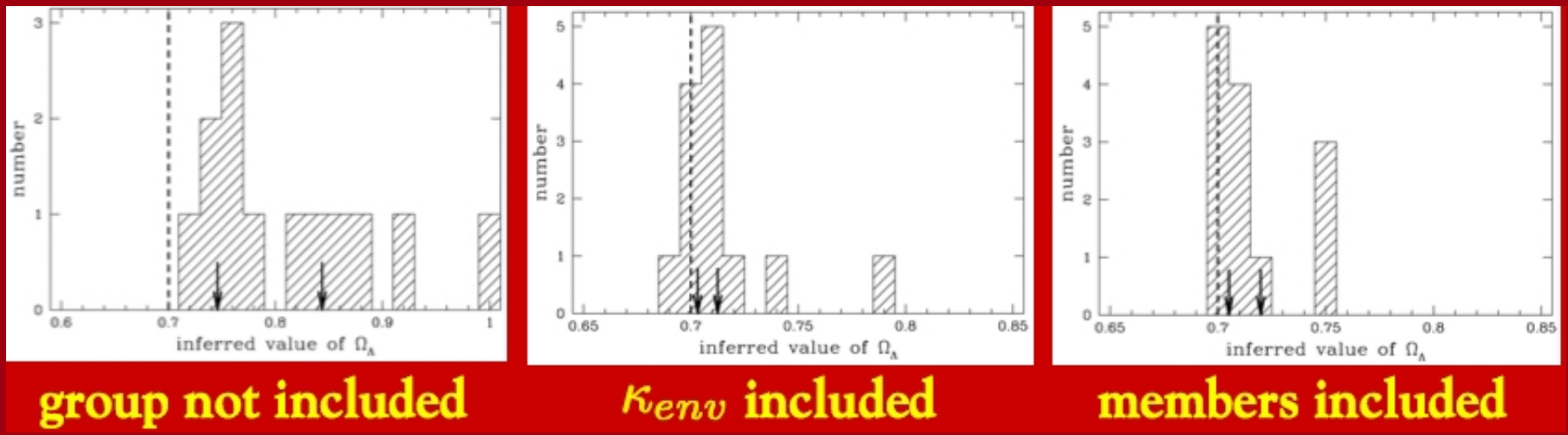
better limits on cosmological and halo parameters, not just group galaxy evolution ...

Keeton & Zabludoff 2004



Improving Constraints from Lens Models (cont.)

Keeton & Zabludoff 2004



most lenses lie in dense environments: at least 5 of 8 (spectroscopy), 9 of 12 (photometry)

environments affect models (double lenses even worse)

possible to improve models