

Galaxy-Galaxy Interactions

**in the general environment
and clusters of galaxies**

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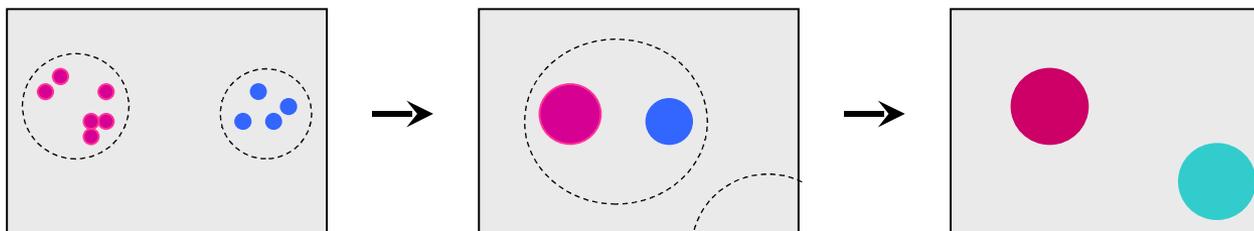
in collaboration with
YY Choi, HS Hwang (KIAS)
JR Gott (Princeton)
MS Vogele (Drexel)
M Blanton (NYU)



Current idea of structure formation

- Cosmological structures form hierarchically.

Small structures form first & merge to grow larger.



To understand structure formation

- Need to understand the consequences of [galaxy interactions] and [mergers]

Do we understand the consequences of

1. galaxy-galaxy interactions

Star formation activity enhanced?

Structures changed? Morphology changed?

Physical mechanisms responsible for the changes?

2. galaxy-cluster interactions

What are galaxies interacting with?

Are MDR & MRR fundamental?

Same questions as in the g-g interactions

3. galaxy-galaxy mergers

A merger of two spirals yield an elliptical?

Why not mergers yielding spirals?

Evolution of merger products





Observational findings

- A. Galaxy interactions in the general environment
- B. Galaxy interactions in the cluster environment

Summary - Key facts

Morphology Classification

Automatic classifier
(reliability, completeness $\sim 90\%$)

+

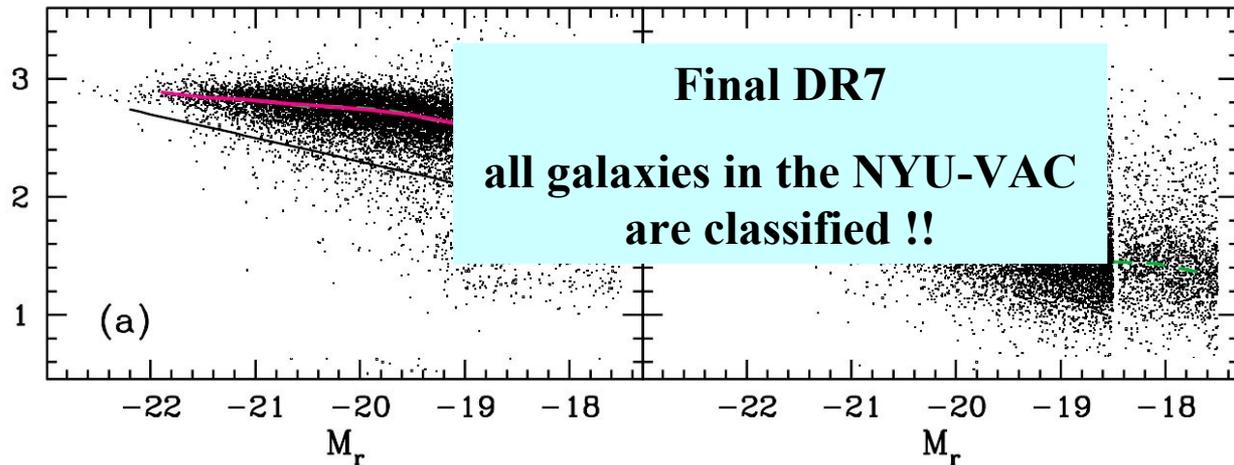
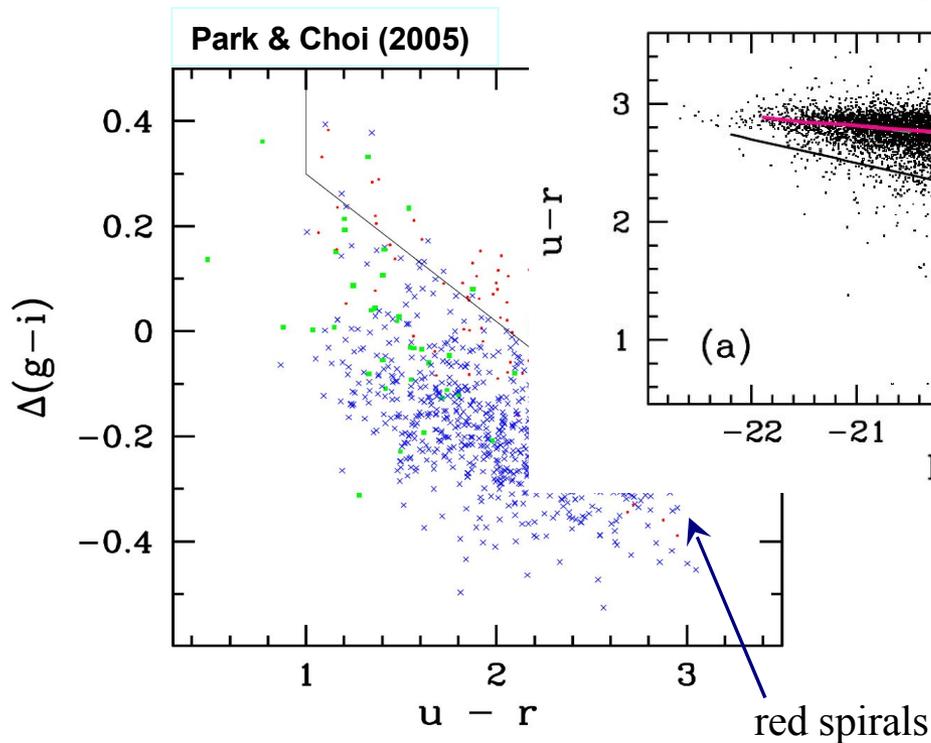
visual check

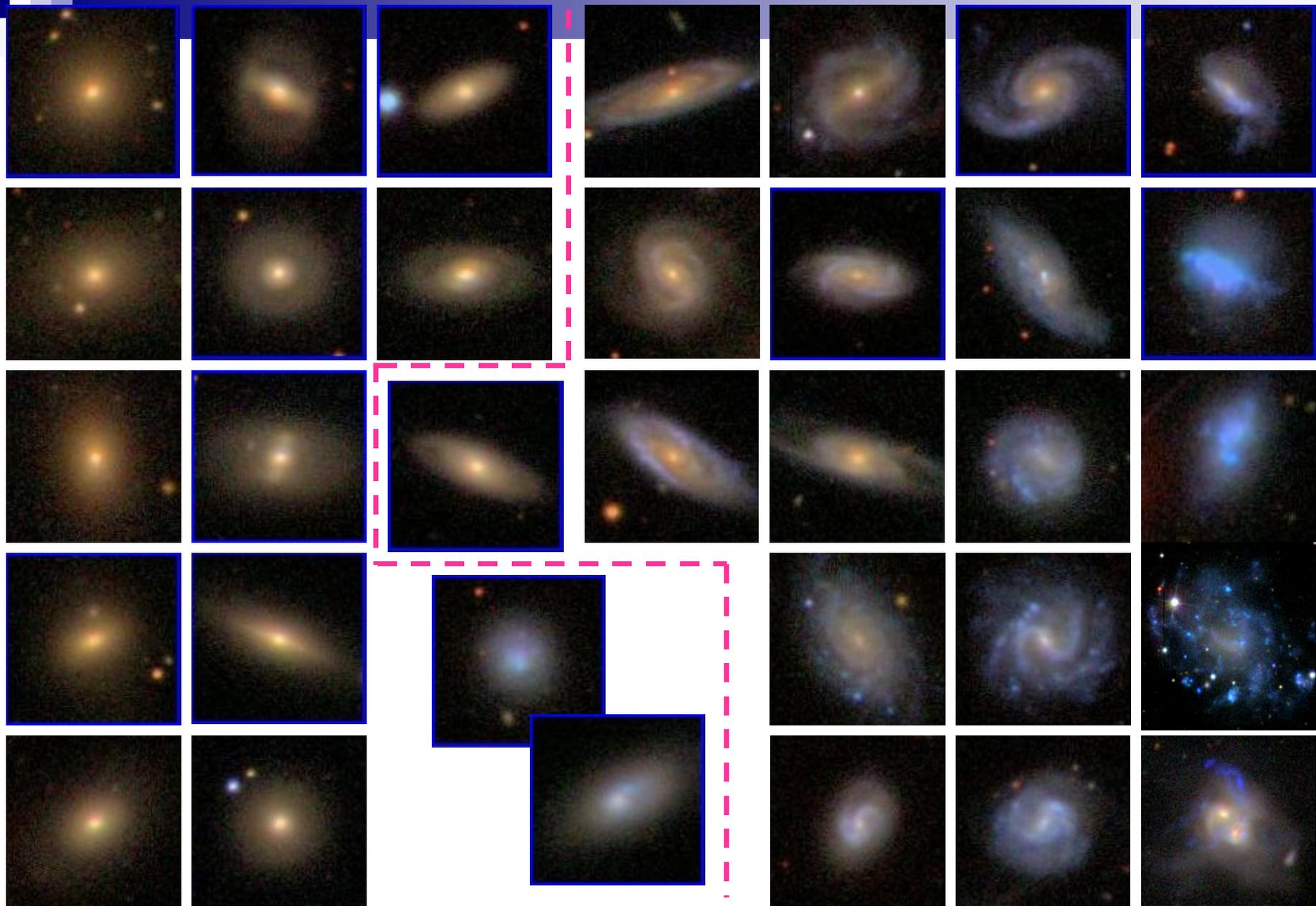


>90% reliable down to $r=17.6$

E/S0

S/Irr





E

S0

S0/Sa

Sa/Sb/Sc

Sc/Sd/Irr

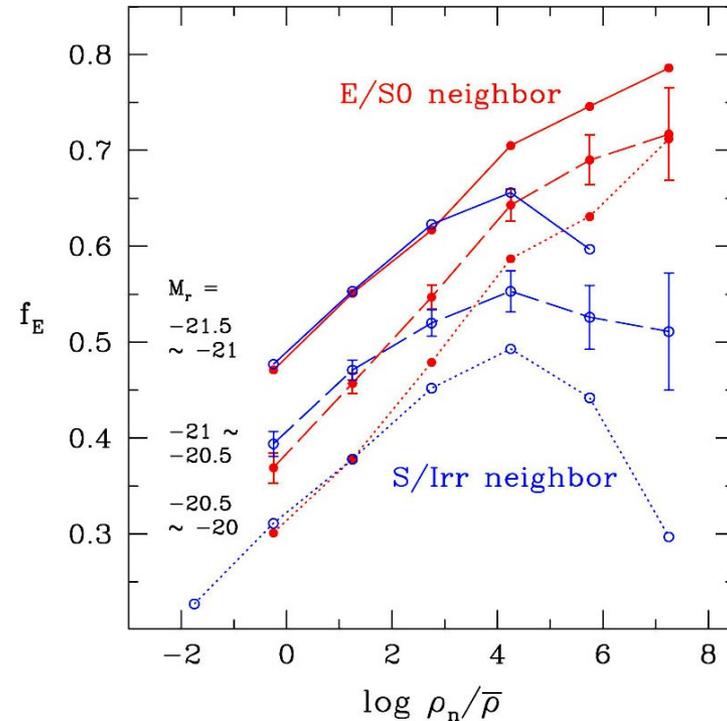
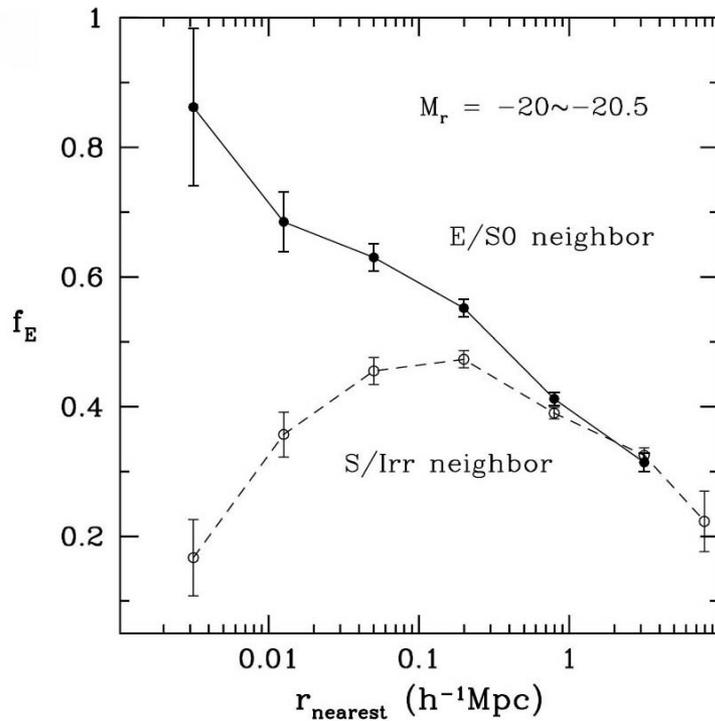


A. Galaxy interactions in the general environment

Morphology

f_E = Probability that a randomly chosen galaxy is an early type

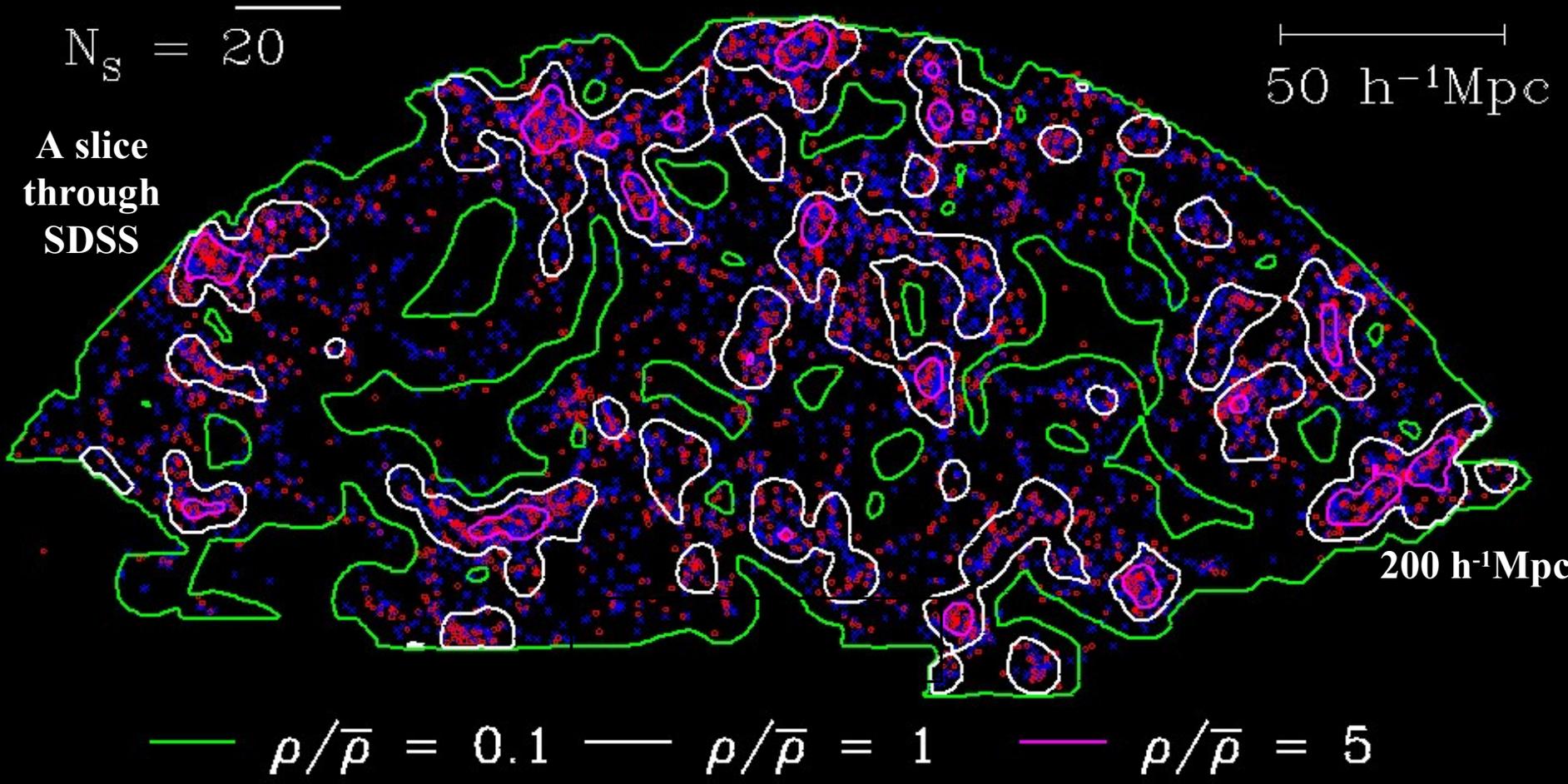
(Park, Gott & Choi 2008)



Consistent with Weinmann et al. (06)'s morphology conformity of satellites

2+1D environmental parameter space: neighbor distance, morphology and

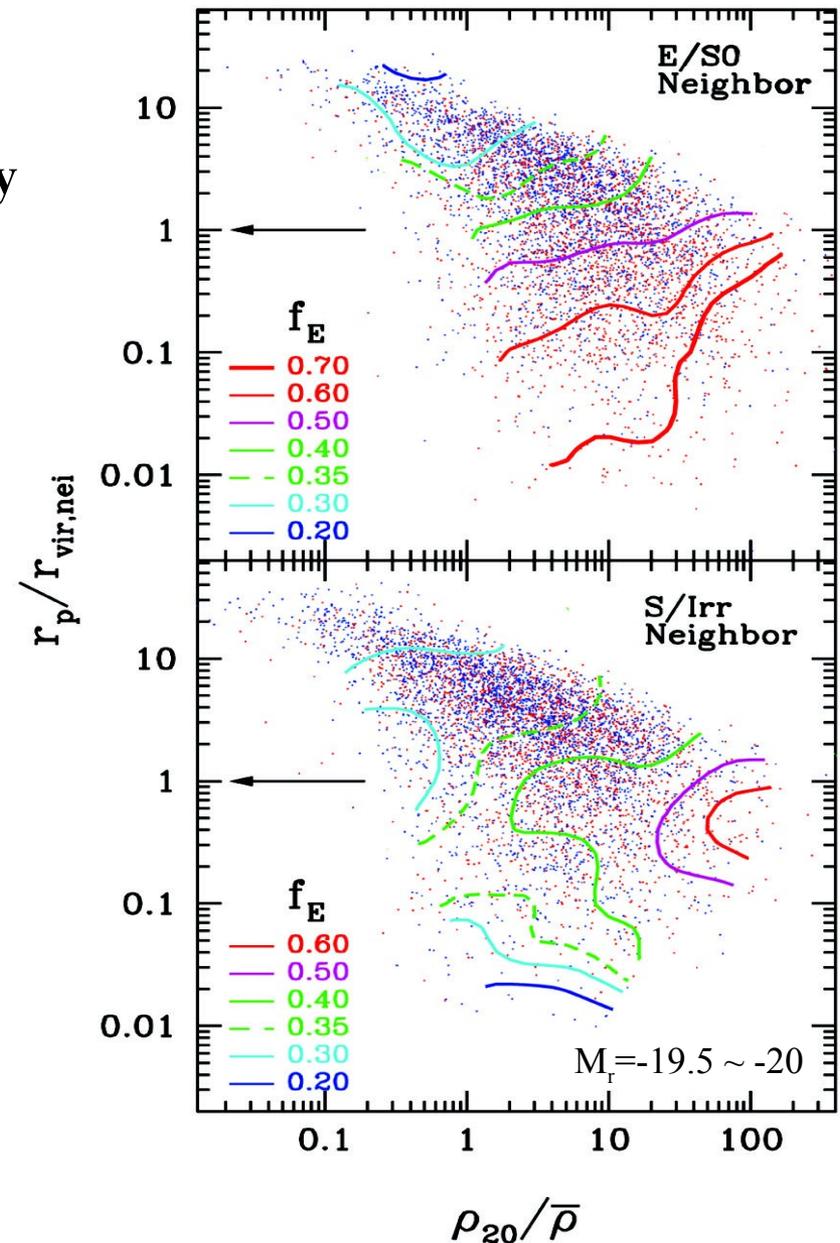
Large-scale background density ρ_{20}



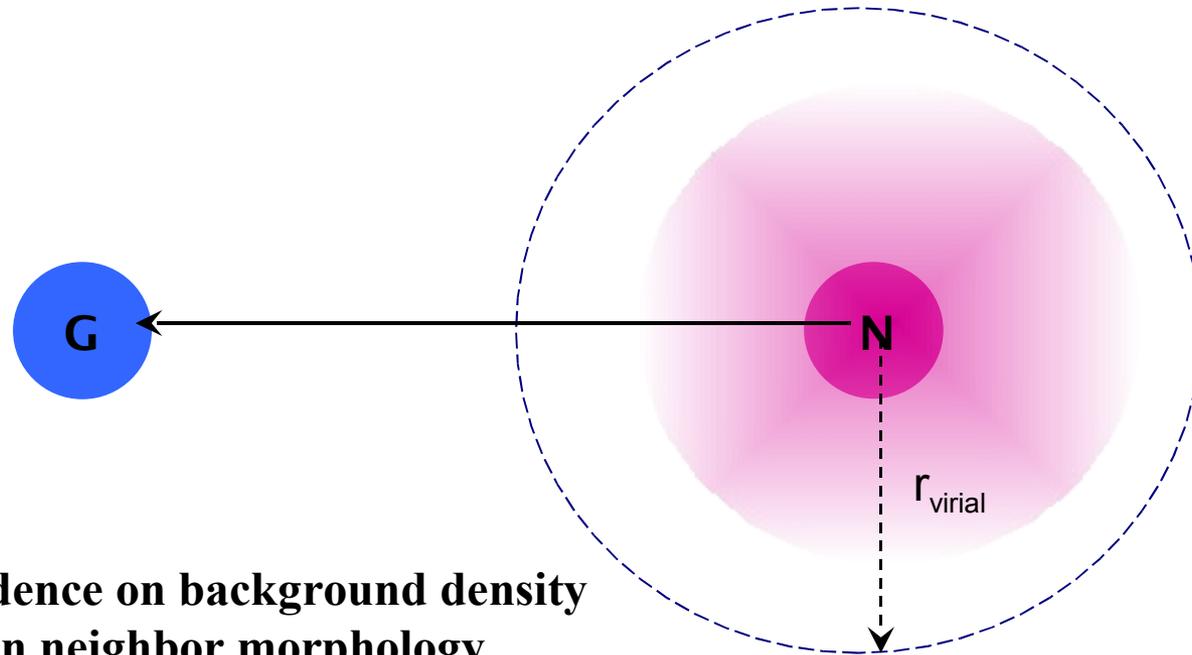
Combined effects of the NN & the LS background density (Park & Choi 2008)

Morphology depends on

1. Local density due to the NN
2. NN's morphological type
3. Background density only within the NN's virial radius



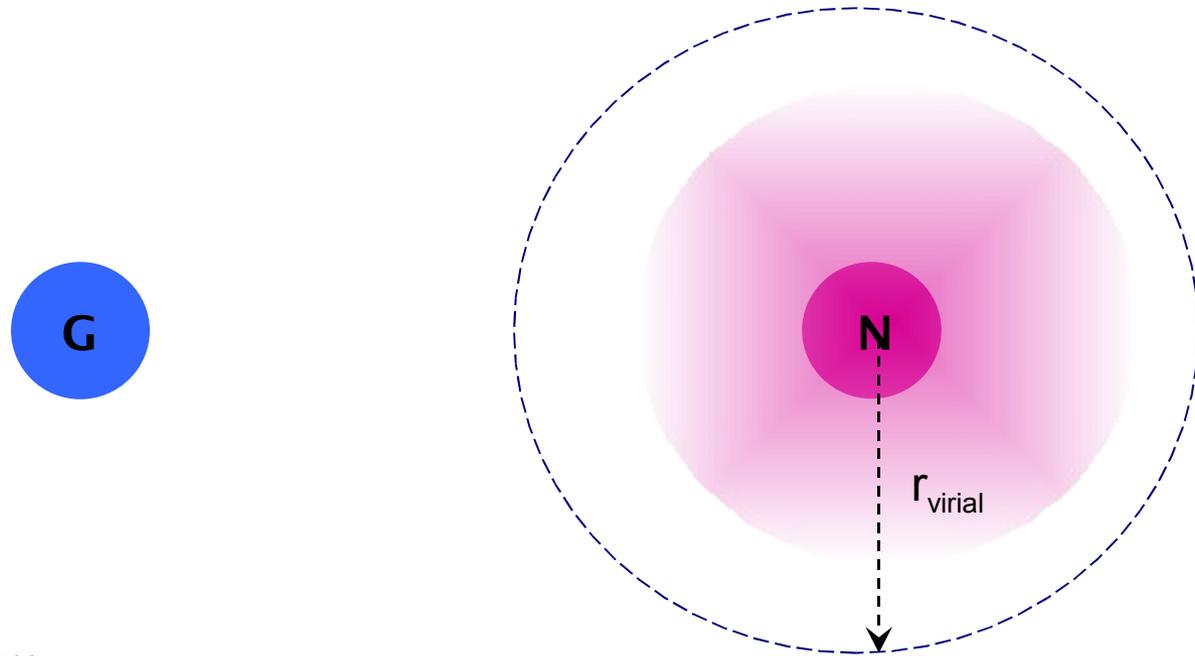
CASE 1: neighbor distance $>$ neighbor's virial radius



**No dependence on background density
nor on neighbor morphology**

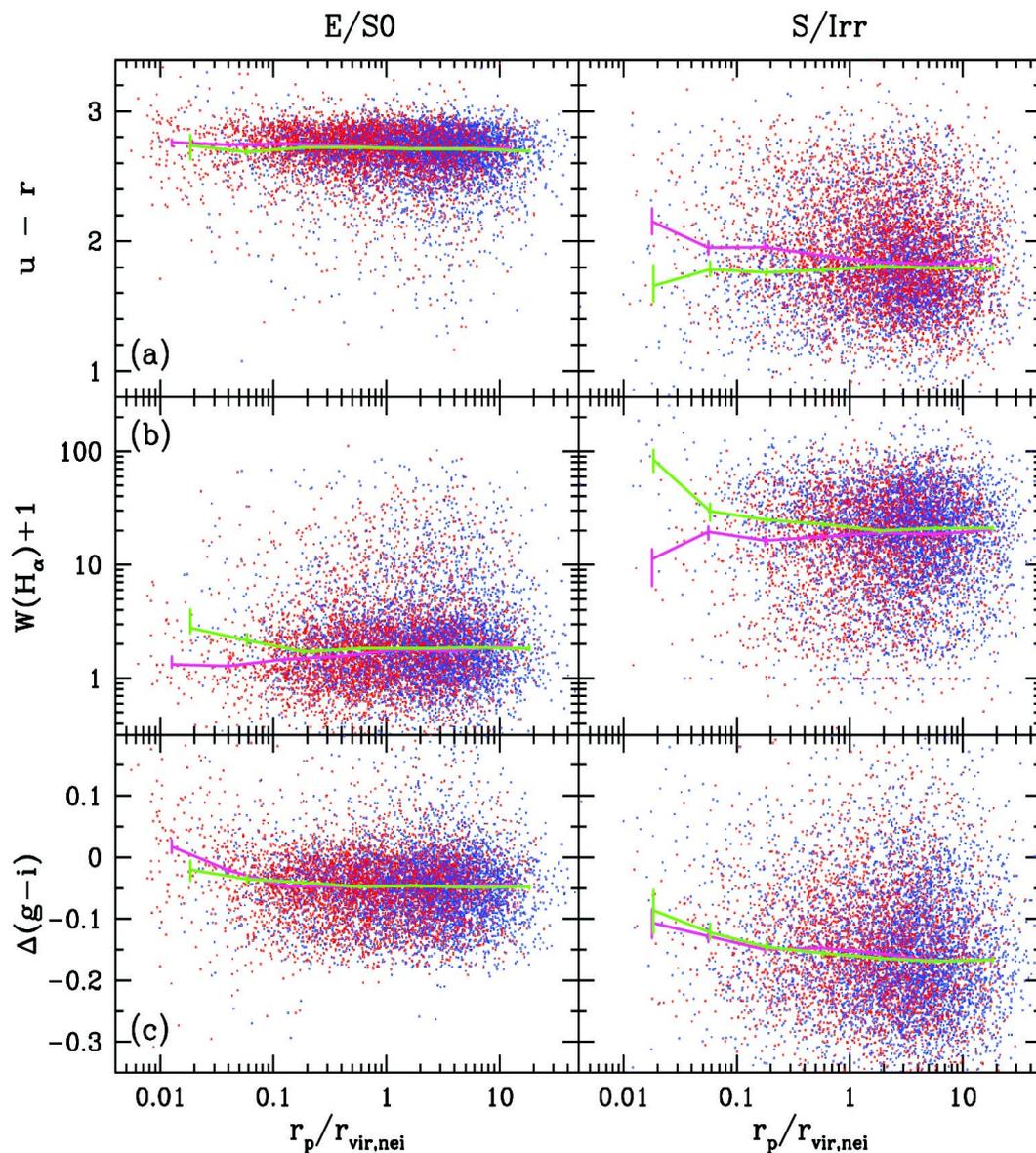
**→ tends to be an early type due to the
tidal force of the neighbor ?**

CASE 2: distance to the neighbor < neighbor's virial radius

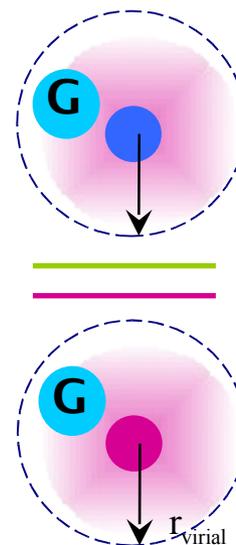


What are

r_{neighbor} , neighbor's morphology, background density ?



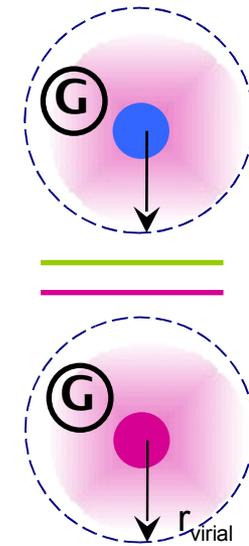
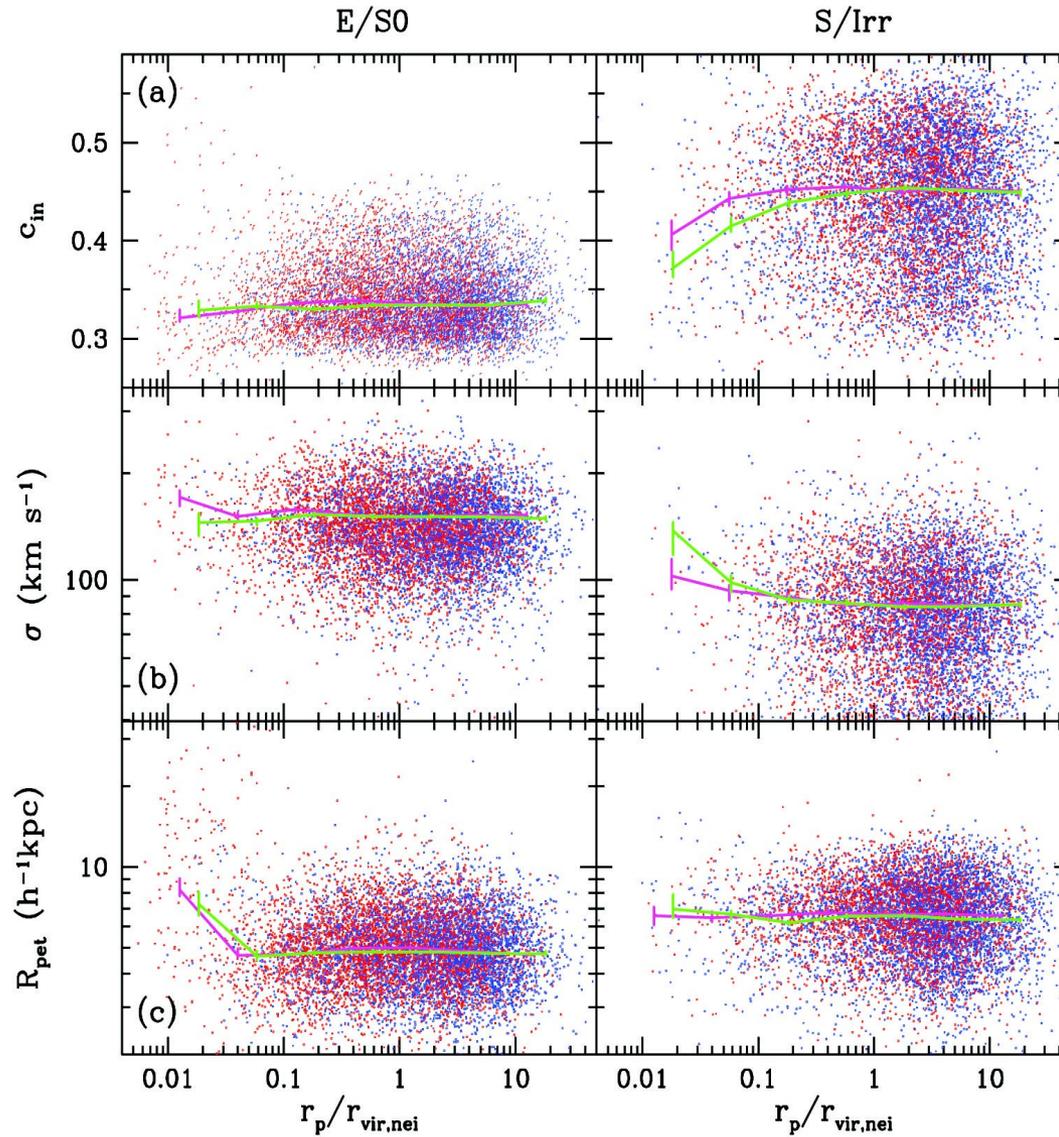
Other galaxy properties



Two characteristic scales!

Hydrodynamic interaction!

Structure of galaxies in general locations

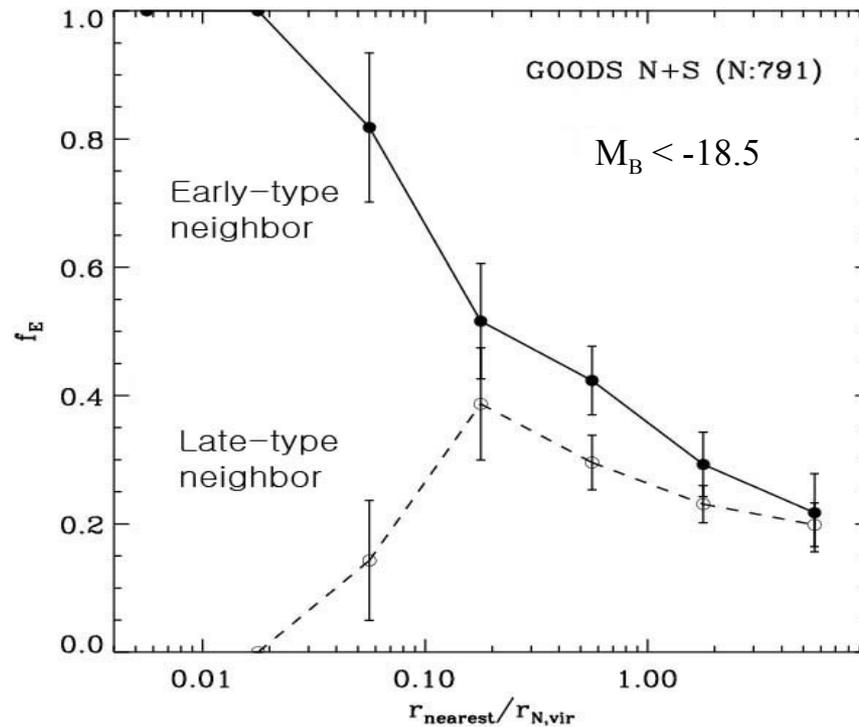


Park & Choi (2008)

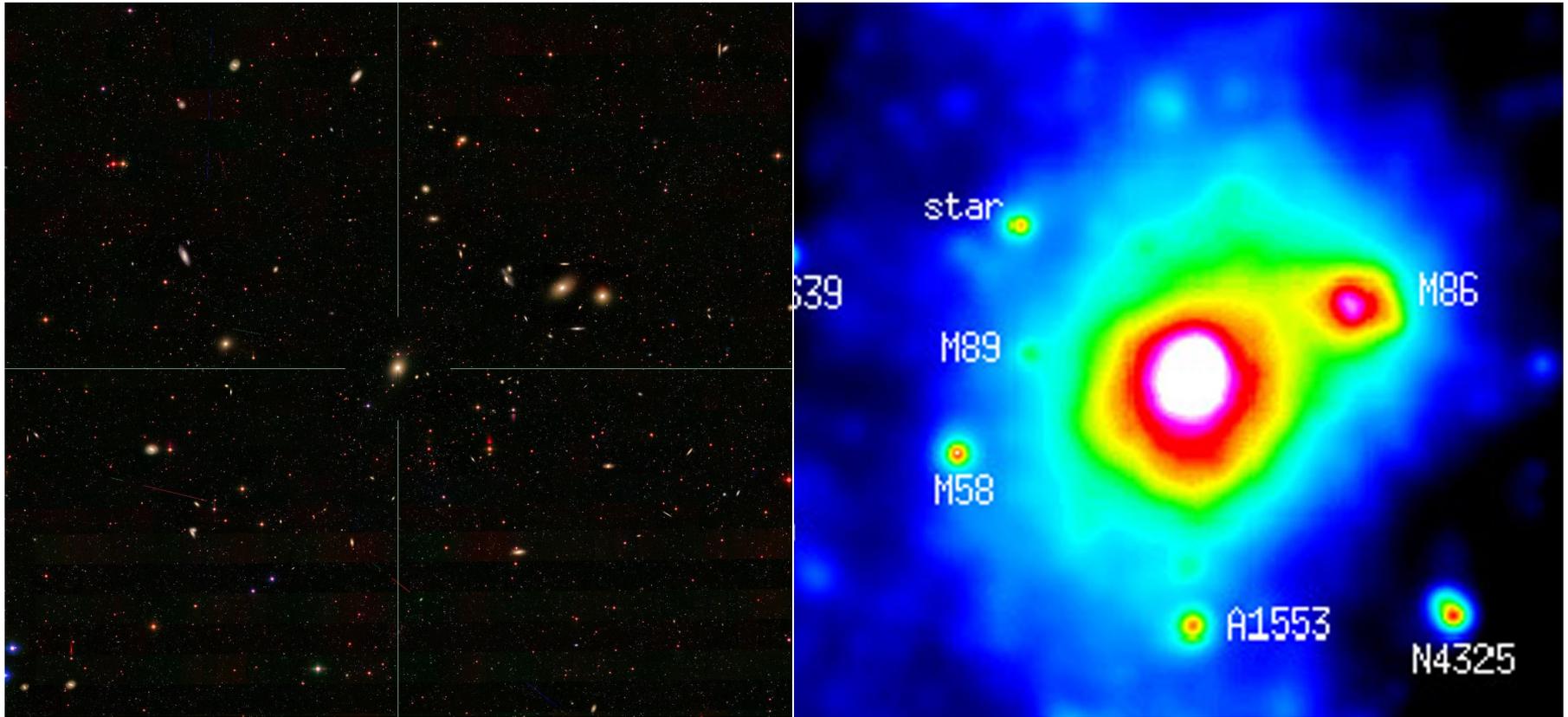
Galaxy-galaxy interactions at higher-z

GOODS-North & GOODS-South (Hwang & Park 2008)

~4000 Galaxies with $M_B < -18.0$, $0.4 < z < 1.0$. Visual morphology classification



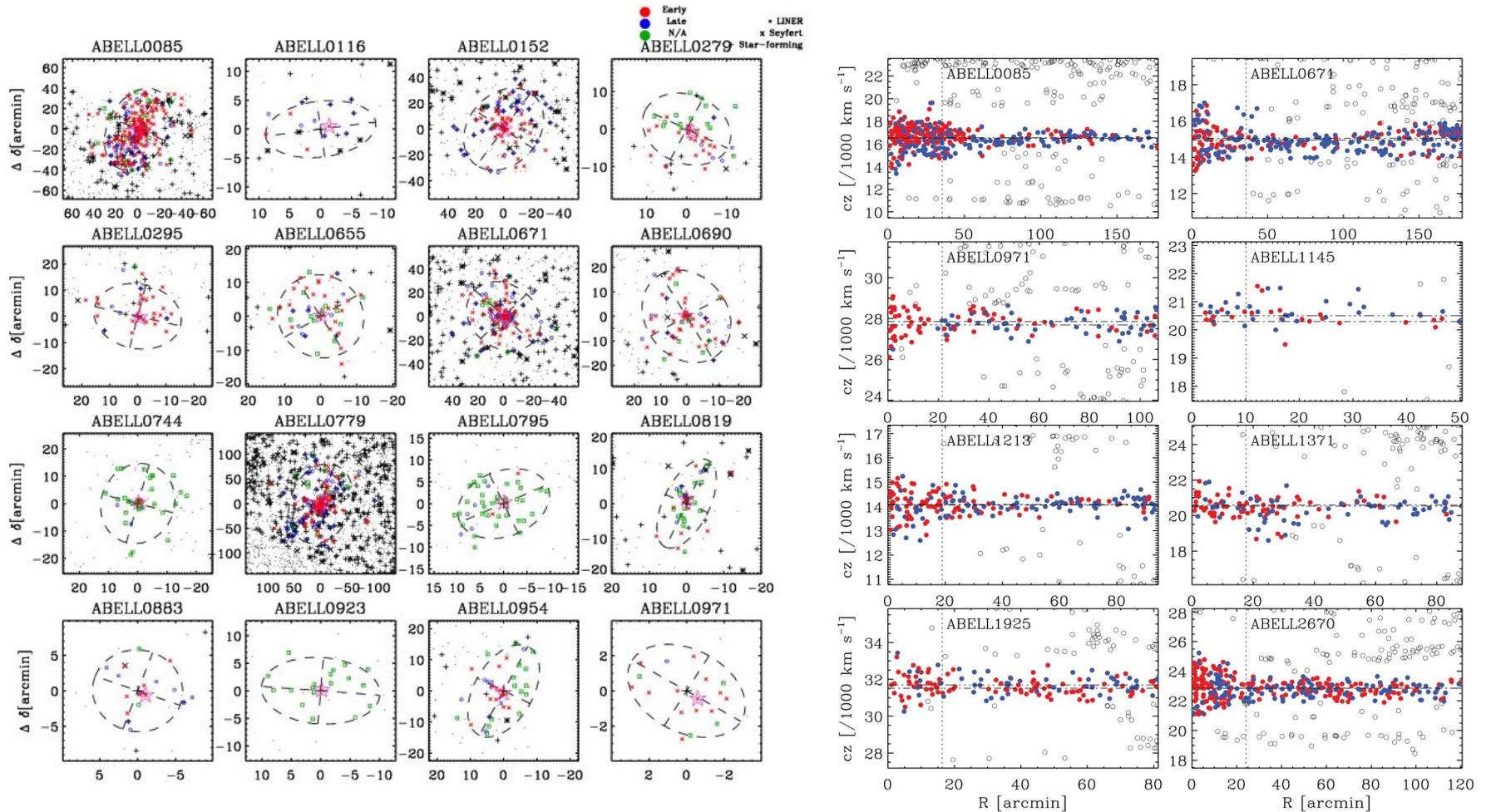
B. Galaxy interactions in the cluster environment



Virgo : optical

Virgo : X-ray

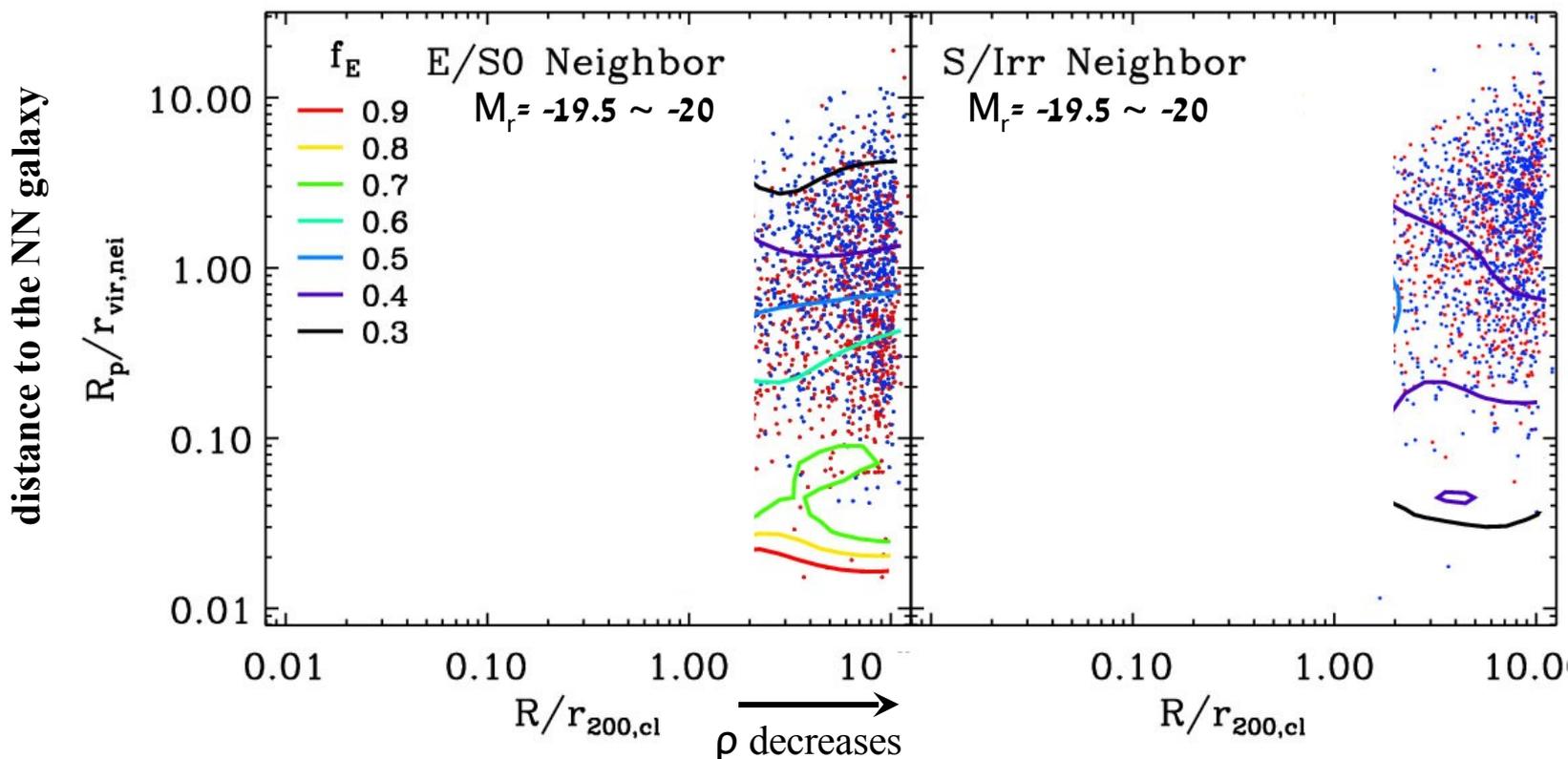
SDSS galaxies within and near the Abell clusters



Morphology in 2+1D environmental space

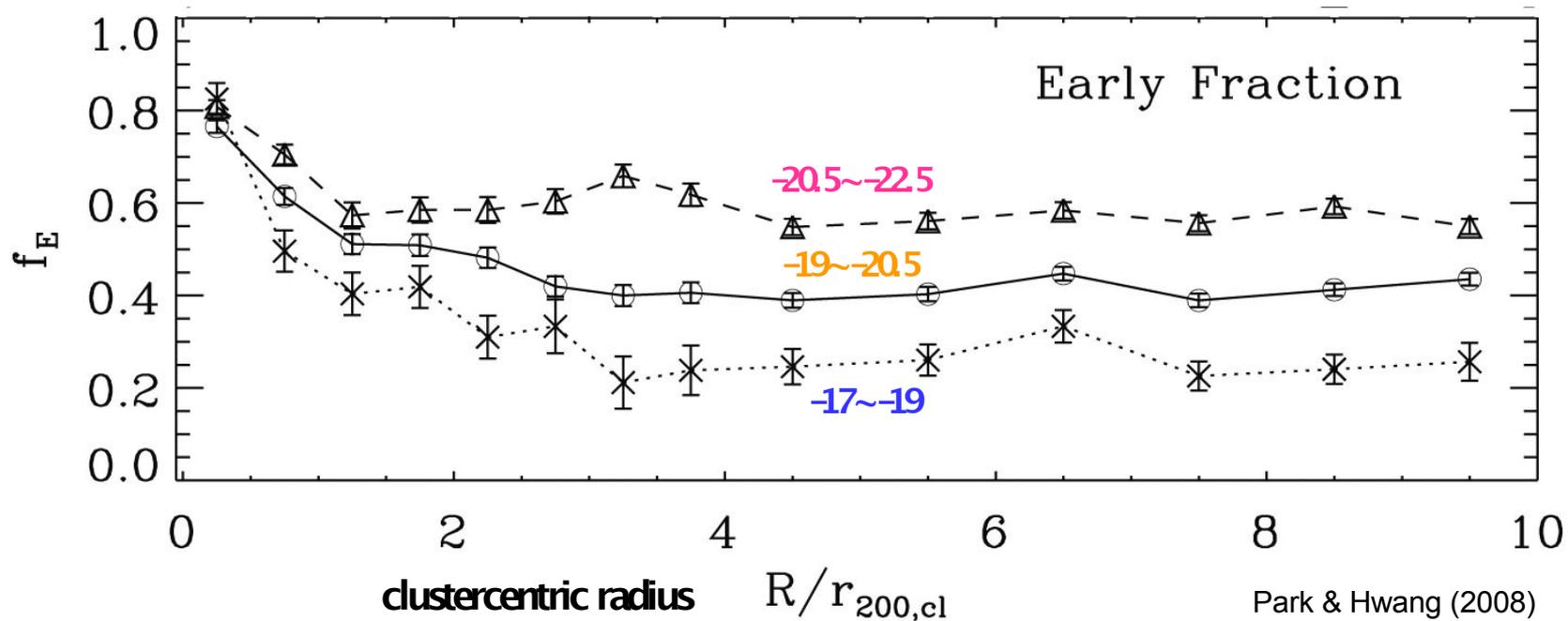
SDSS galaxies within $10r_{200,cl}$ of 93 relaxed Abell clusters (BCGs excluded)

Park & Hwang (2008)



Characteristic scales !! $\approx 1\sim 3$ cluster virial radius

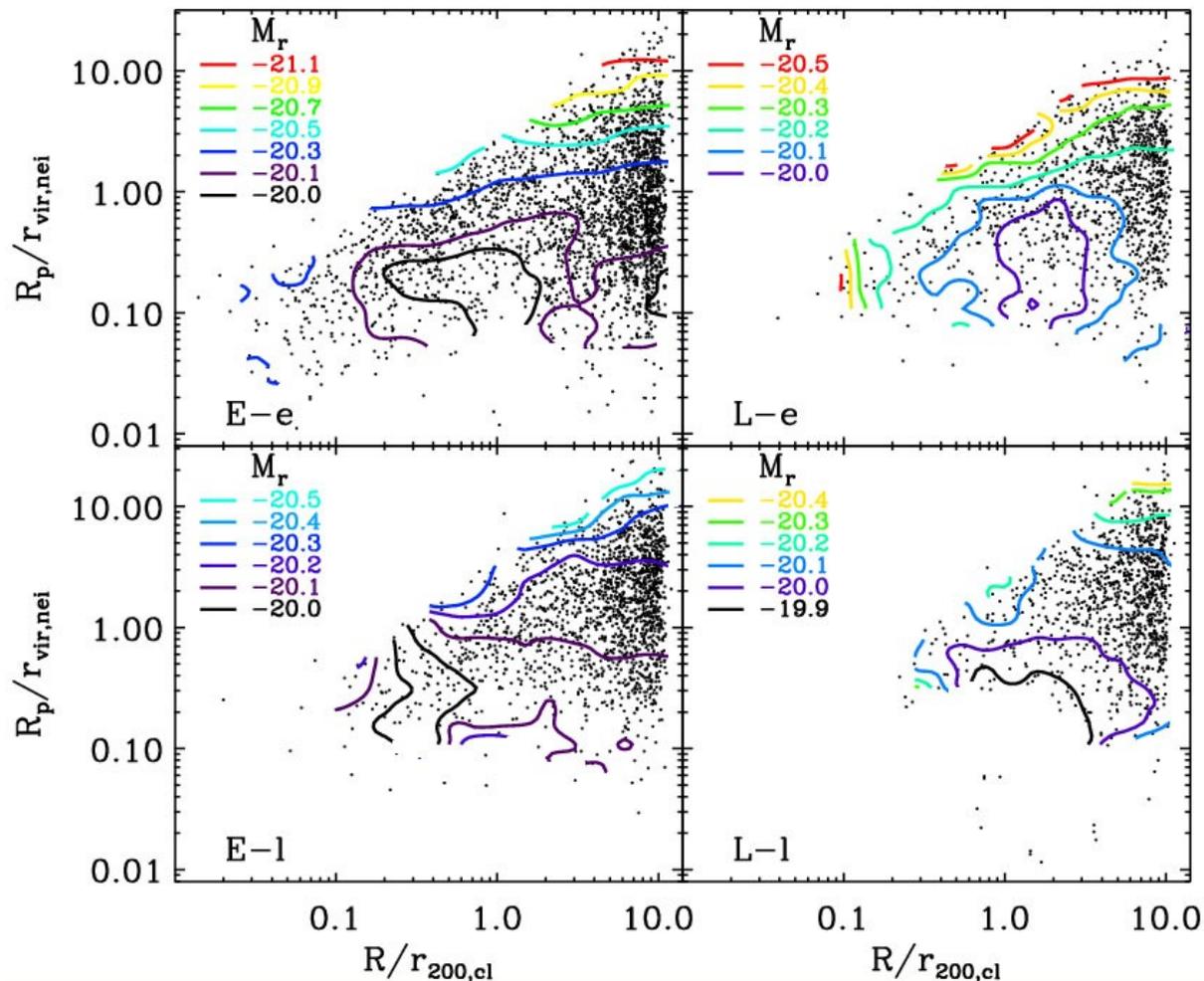
Morphology: Early-type fraction vs clustercentric radius



Galaxies within $r_{200,cl}$

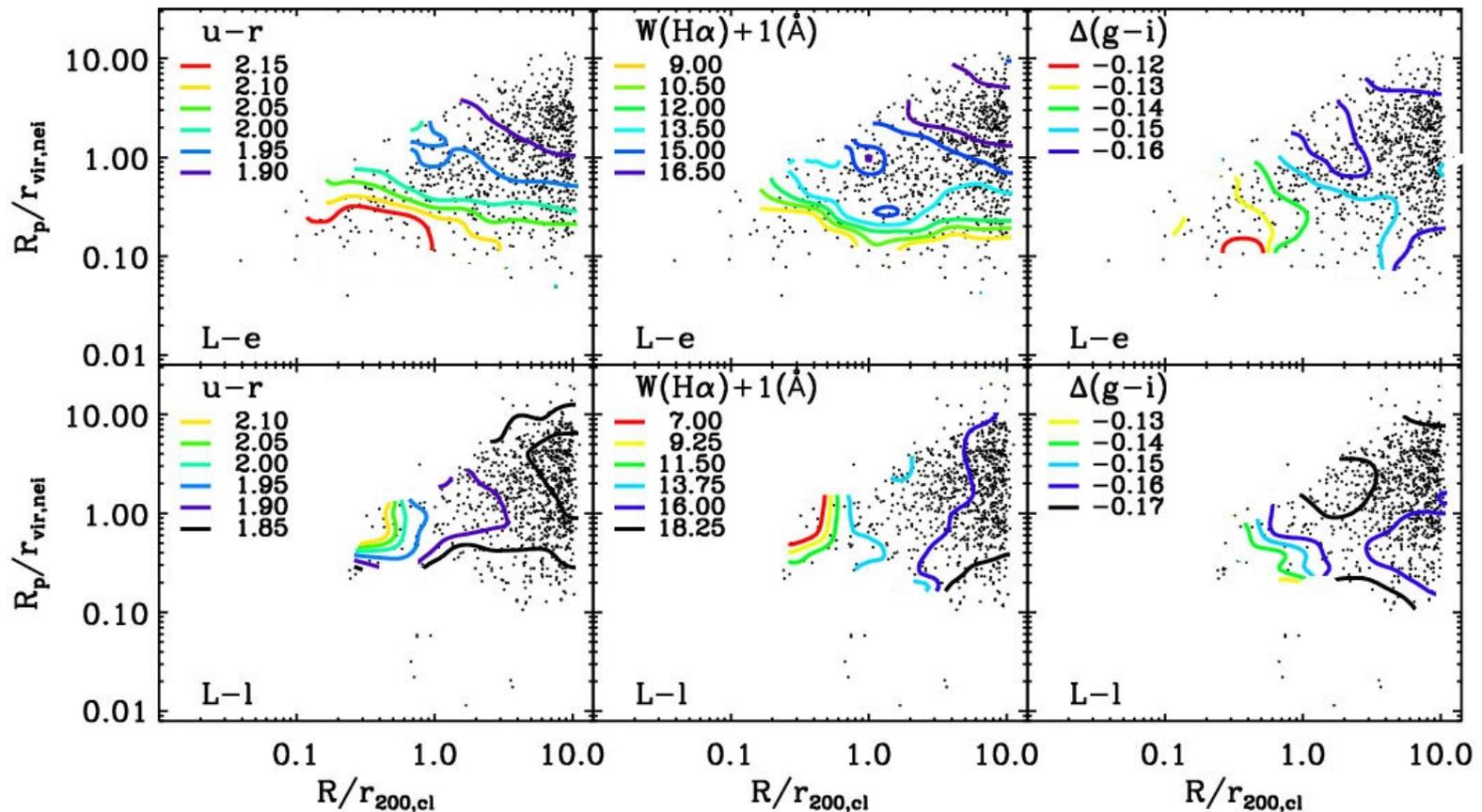
1. lack bright ones
2. still respect L- R_p relation down to $\sim 0.2r_{200,cl}$

Formation of bright galaxies through mergers less efficient?



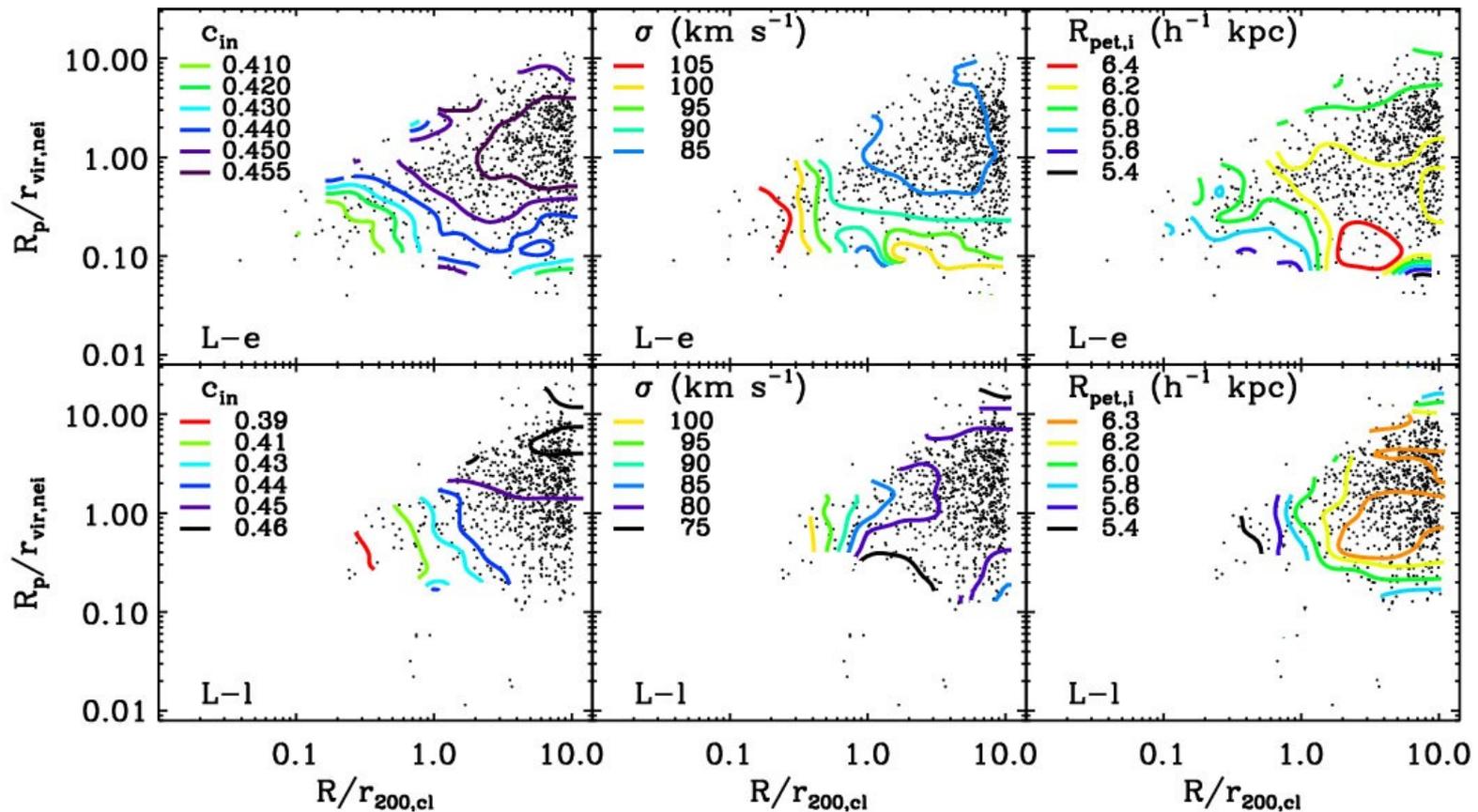
Star formation activity parameters

- ~horizontal contours & sensitive to neighbor type → Instant effects of neighbor
- Color gradient changes at $R_{cl} < r_{200,cl}$



Structure/kinematics parameters

- Compacter, higher c_{in} , smaller size at $R_{cl} < r_{200,cl}$
- \sim vertical contours \rightarrow instant and/or cumulative effects of cluster/neighbor



Who's responsible? Cluster/Neighbor, Gravity/Gas

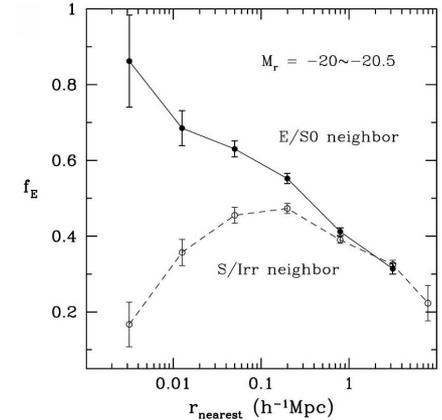
	morphology		color, W(Ha)		c_{in}		σ	
	E-nei	L-nei	L-e	L-l	L-e	L-l	L-e	L-l
Cl-Grav	∇		X		∇		\circ	
Cl-Gas	∇		X		X		X	
Ng-Grav	∇		X		\triangle		X	
Ng-Gas	\triangle		\circ		X		X	

1. Joint responsibility: All 4. But Cluster Gravity + Neighbor Gas ?
2. Morphology-cluster radius-nearest neighbor distance relation

Implications I. General environment

1. Effects of neighbor are great & reaches \sim Mpc!

- previously thought it was marginal
- & effective only within \ll 100kpc



2. Two characteristic radii: virial radius of NN & merger scale

- hydrodynamic processes must be involved (dependence on neighbor morphology)

3. Large-scale density matters only when galaxies are closer than r_{vir}

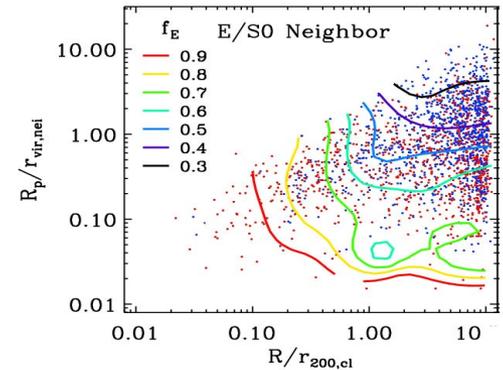
- MD relation is mainly due to g-g interactions rather than the large-scale environment
- previously thought the LS density could be the direct cause for the MD relation

Implications II. Cluster environment

1. Sharp transition of galaxy properties at $\sim r_{200,cl}$

- Morphology, color gradient, structural parameters
- MD relation not working...

No preprocessing beyond g-g interaction

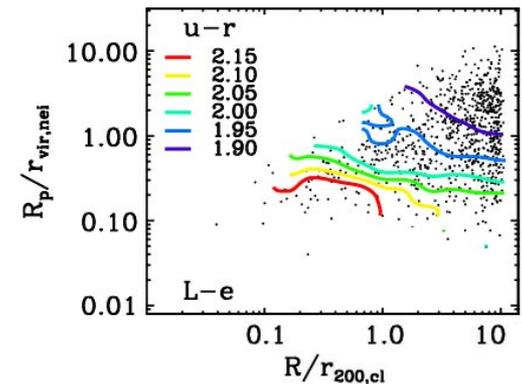


2. Smaller transition scales for brighter galaxies

- due to mass segregation?
- repeated crossings of bound galaxies undergoing cluster & neighbor influence \rightarrow dependence of galaxy properties on R_{cl}

3. Still great effects of the neighbor galaxy

- morphology-clustercentric radius-NN environment relation (distance & morphology)



Conclusions

1. Morphology/SF activity/Structure depend on

- nearest neighbor galaxy's distance
 - NN's morphology (hydrodynamics involved)
 - large-scale background density when $R_n < r_{\text{vir,nei}}$

2. NN does the critical role both in the field & massive clusters!

3. Critical distances

- virial density of the nearest galaxy
- merger scale
- 1~3 x virial radius of the nearest cluster

4. Cluster environment

- morphology - clustercentric radius - nearest neighbor distance relation

Environmental dependence of galaxy properties

**== This was a thesis project Jim recommended me to work on
in 1988 !**

