Galaxy morphology, Star Formation and AGN activity in local galaxy clusters

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Star Formation in Galaxy Clusters

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Service d'Astrophysique
Laboratoire AIM

Galaxy vs. Environment

- **Morphology – Environment Relation**
  - **Low z**: Hubble & Humason 31, Oemler 74; Postman & Geller 84; Goto et al. 03; Tanak et al. 04; Weinmann et al. 06; Park et al. 07, 08; Skibba et al. 08; Barford et al. 09; Park & Hwang 09
  - **High z**: Dressler et al. 1997; Treu et al. 2003; Smith et al. 2005; Postman et al. 2005; Nuijten etla. 05; Capak et al. 07; van der Wel et al. 07; Poggianti et al. 08; Hwang & Park 09
- **Star Formation Activity (Color)– Environment Relation**
  - **Low z**: Gomez et al. 03; Kauffmann et al. 04; Balogh et al. 04; Tanaka et al. 04; Owers et al. 07; Park et al. 07; Li et al. 08; Park & Choi 09; Park & Hwang 09; Hwang et al. 10
  - **High z**: Poggianti et al. 06, 08; Elbaz et al. 07; Cooper et al. 07; Koyama et al. 08; Caputi et al. 09; Ideue et al. 09; Patel et al. 09; Ferugulio et al. 10; Popesso et al. 10; Sobral et al. 10; Tran et al. 10; Hilton et al. 10
- **AGN activity– Environment Relation**
  - **Low z**: Miller et al. 2003; Kauffmann et al. 2003a, 2004;Wake et al. 2004; Best 2004; Best et al. 2005; Serber et al. 2006; Sorrentino et al. 2006; Constantin et al. 2008a,b; Ellison et al. 2008; Li et al. 2008; Choi et al. 2009; Koss et al. 2010 Haggard et al. 2010; Lee et al. 2010; Schawinski et al. 2010b,a Padilla et al. 2010
  - **High z**: Waskett et al. 2005; Silverman et al. 2009; Montero-Dorta et al. 2009; Cisternas et al. 2011

➔ **Whether these relations are the consequence of environmental-driven evolution? (nature vs. nurture)**

➔ **Which relation is fundamental?**

➔ **How they evolve with redshift?**

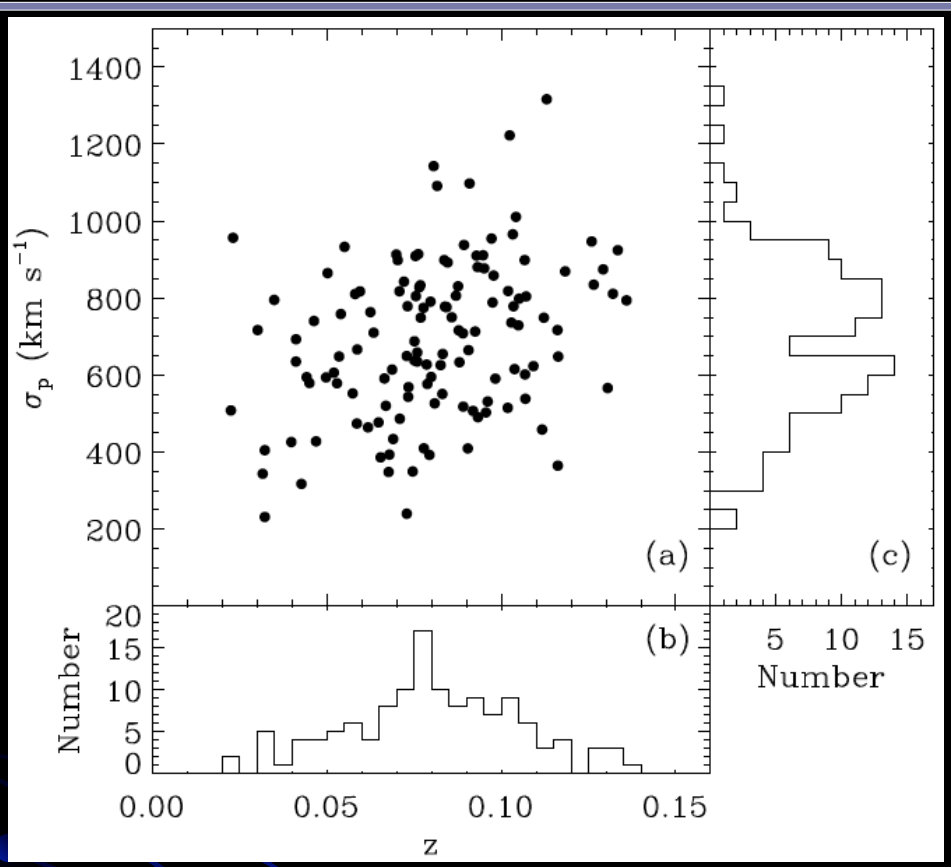
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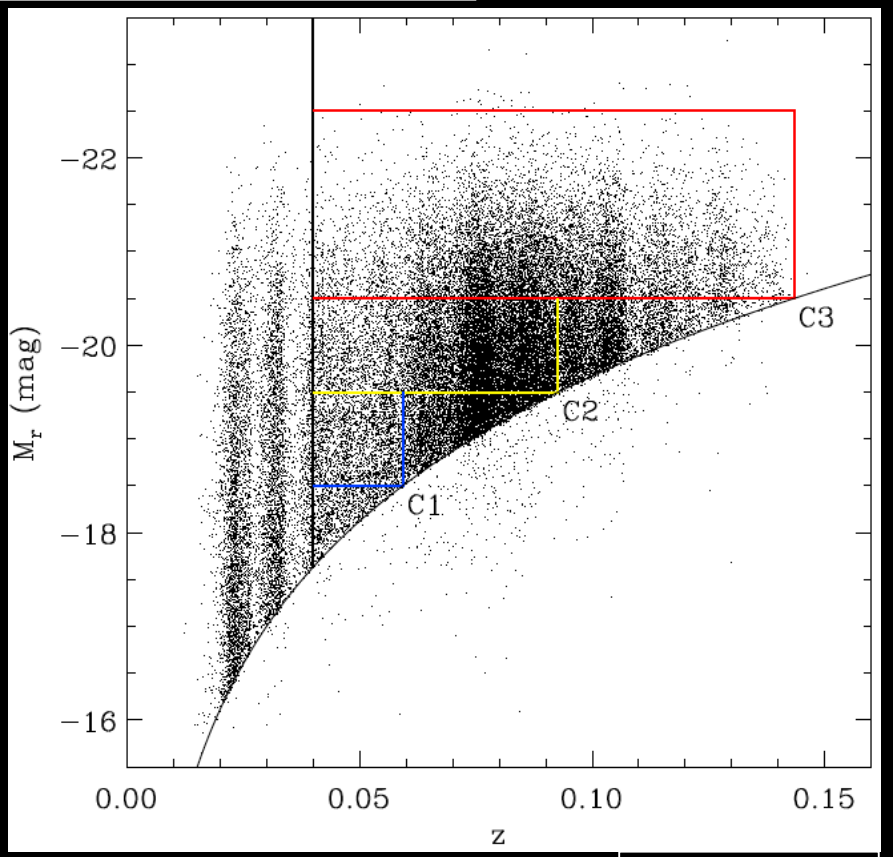
Galaxy Properties	Environments	Redshifts	
		Local (SDSS)	High-z (z~1) (GOODS)
Morphology	Fields		
	Clusters		
SFA	Fields		
	Clusters		
AGN activity	Fields		
	Clusters		
…	Fields		
	Clusters		

In this talk, I will

- **compare morphology, SF and AGN activity between cluster & field galaxies**
- **briefly mention the connection between galaxy morphology, SF and AGN activity**

Data : Galaxies in Abell clusters

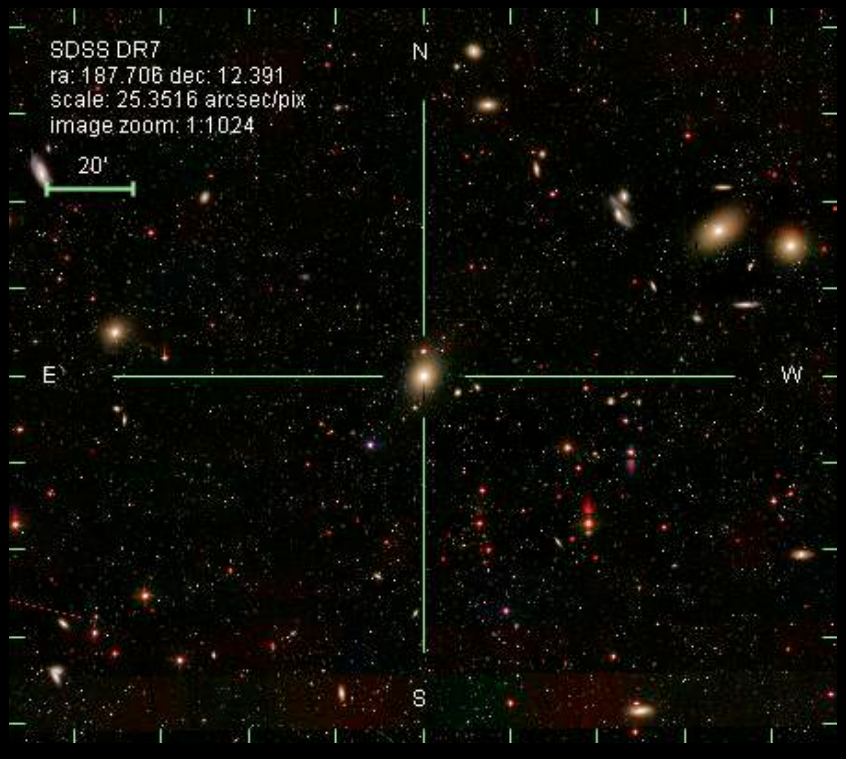




Hwang +11

- 129 relaxed Abell clusters at 0.2<z<0.14 in SDSS DR7
- 48,200 galaxies with spectroscopic redshifts at $r_{200,cl}$<10
- Galaxy Morphology from KIAS VAGC
- Spectroscopic parameters from MPA/JHU VAGC

1. Galaxy Morphology



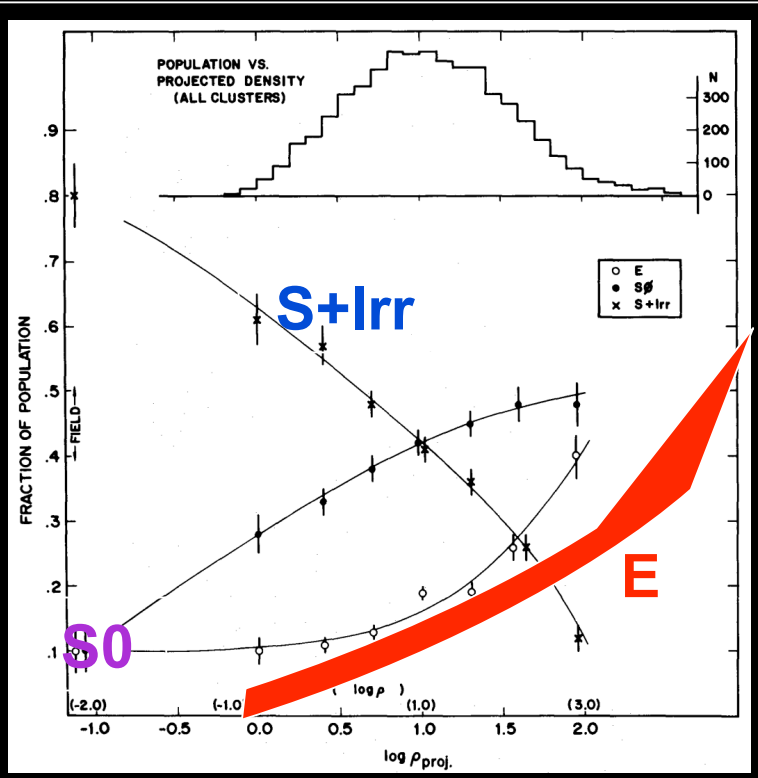
60 EDWIN HUBBLE AND MILTON L. HUMASON

CLUSTERS OF NEBULAE

Virgo cluster (R.A. $12^h25^m\pm$, Dec. $+12°.5\pm$, 1930; gal. long. 256°, lat. $+73°$).[1]—The cluster includes several hundred members scattered over an elliptical area about $12°\times10°$. It is the largest and nearest of the known clusters and includes 16 out of the 34 extragalactic objects in Messier's list. Nebulae of all types except the irregular are represented among its members, but elliptical nebulae and early spirals are relatively much more numerous than among the nebulae at large. The predominance of early types is a conspicuous feature of clusters in general, and the Virgo cluster is exceptional in the considerable number of late-type spirals which are included.

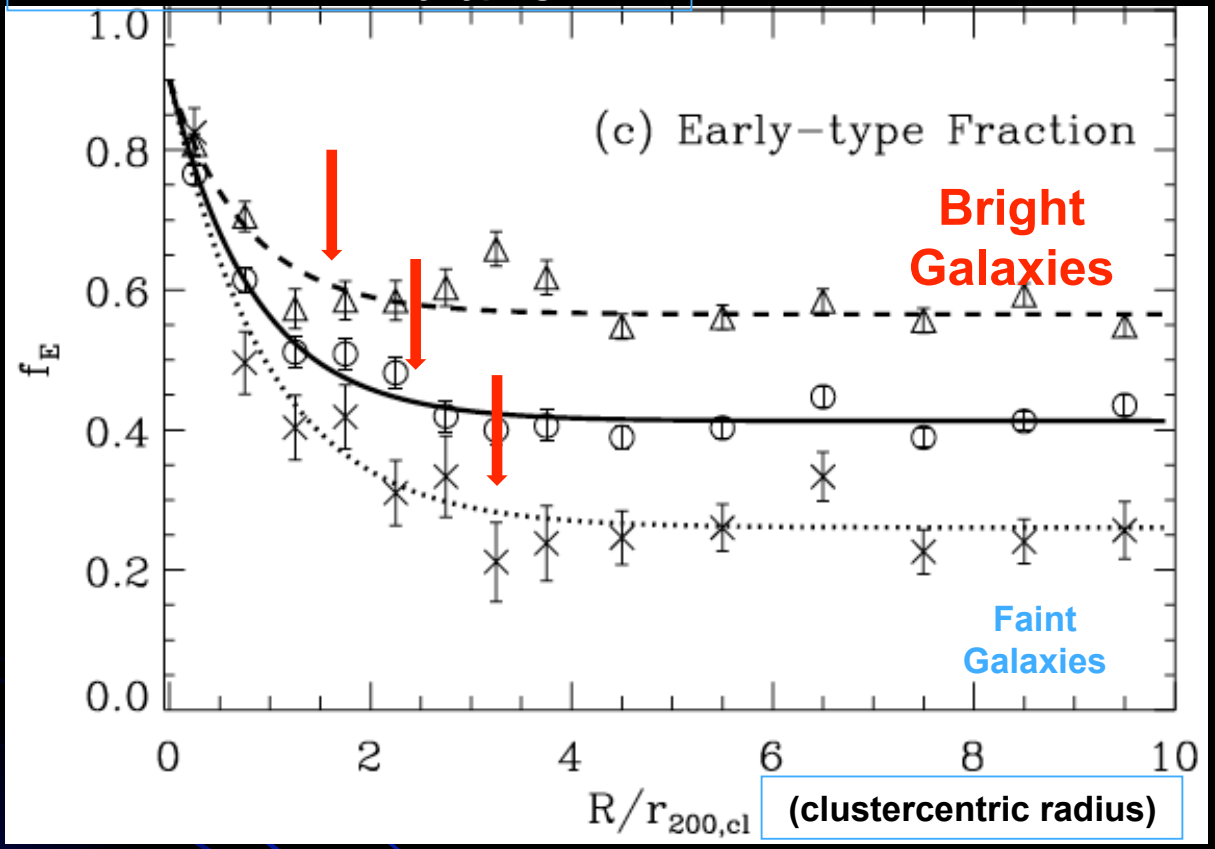
Hubble & Humason (31)

Morphology-Density Relation (Dressler 1980)

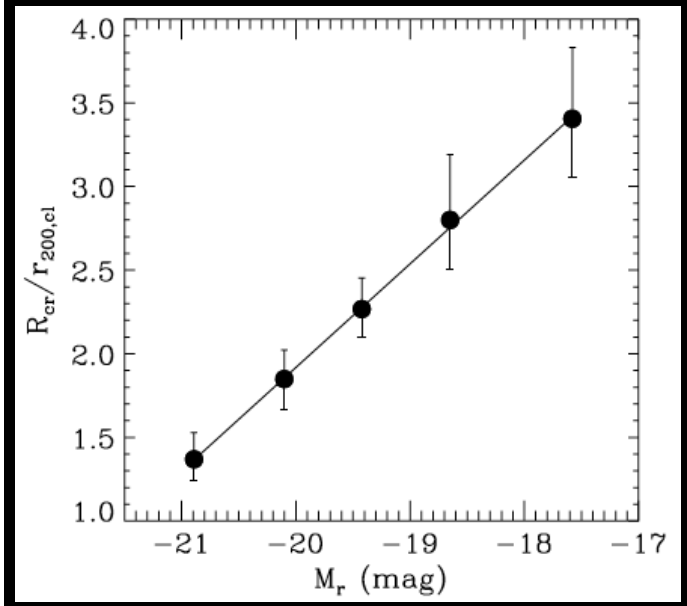


Morphology-Clustercentric Radius-Luminosity Relation

Y-axis : Fraction of Early-type galaxies



(clustercentric radius)

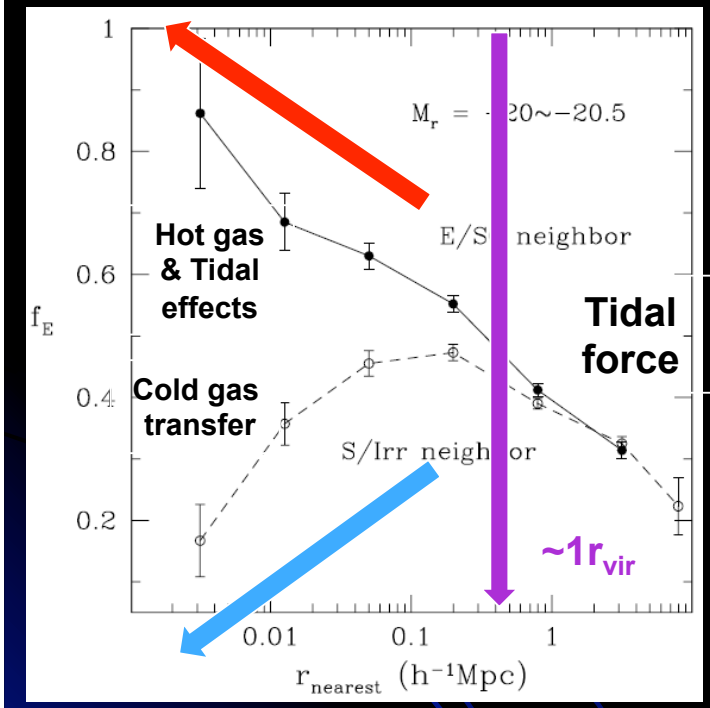


Park & Hwang (2009)

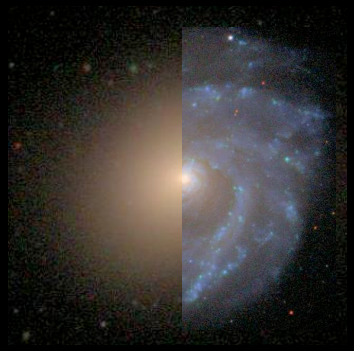
1. Sudden change in early-type fraction!!
2. Galaxy Clusters DO something!!
3. Characteristic radii are different depending on galaxy luminosity

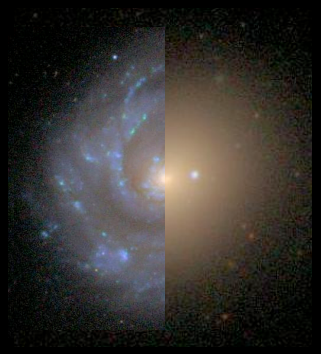
1.1 Field : Role of Nearest Neighbor Galaxy

Nearest Neighbor Galaxies' important Role
[lowz, FIELD galaxies]
(Park +08)

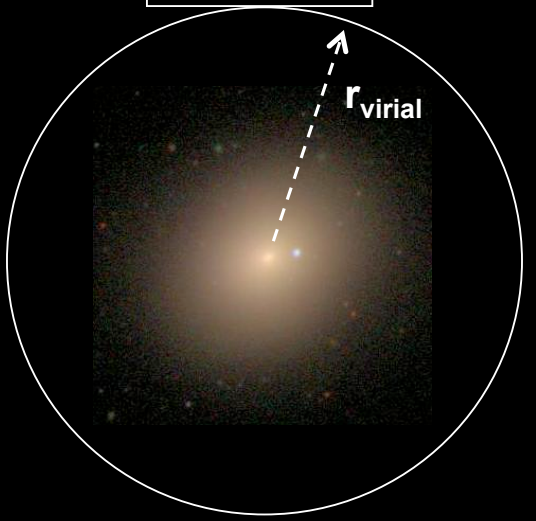


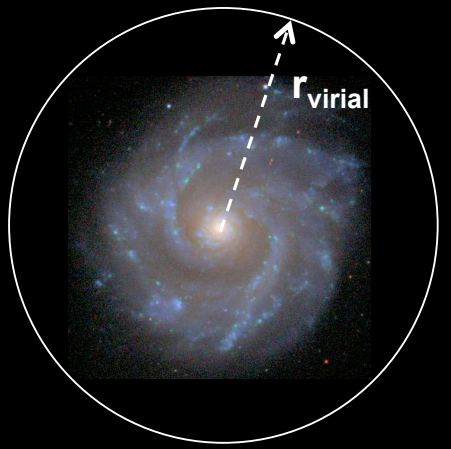
Galaxy



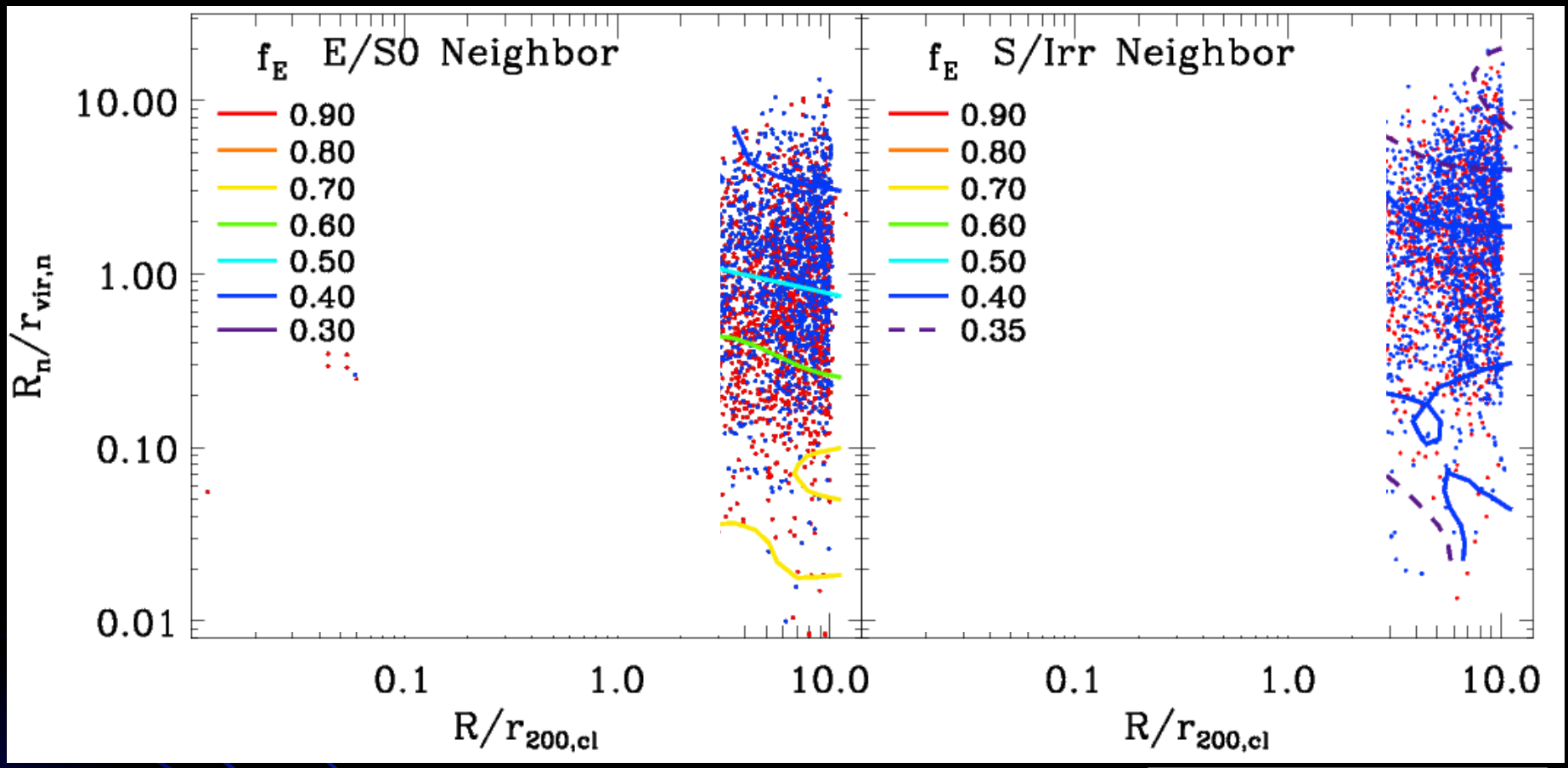


Neighbor Galaxy





1.2 Clusters: Role of Nearest Neighbor Galaxy



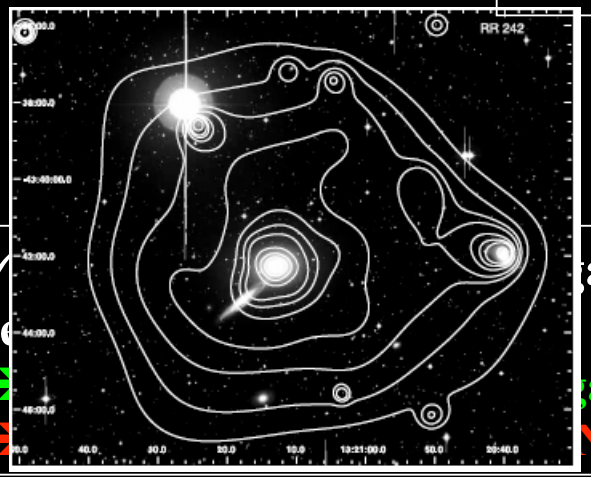
- Galaxies at -20.0>Mr>-20.5 and z<0.0927
- Contour
  - **Horizontal** : Role of Neighbor > Role of Galaxy Cluster
  - **Vertical**: Role of Neighbor < Role of Galaxy Cluster
- If there are no effects of the nearest neighbor, contours in two panels should be the same!!

Park & Hwang (2009)

2.1 Field: Effects on Star Formation Activity

1) normal S/Irr galaxies

Grutzbauch +07



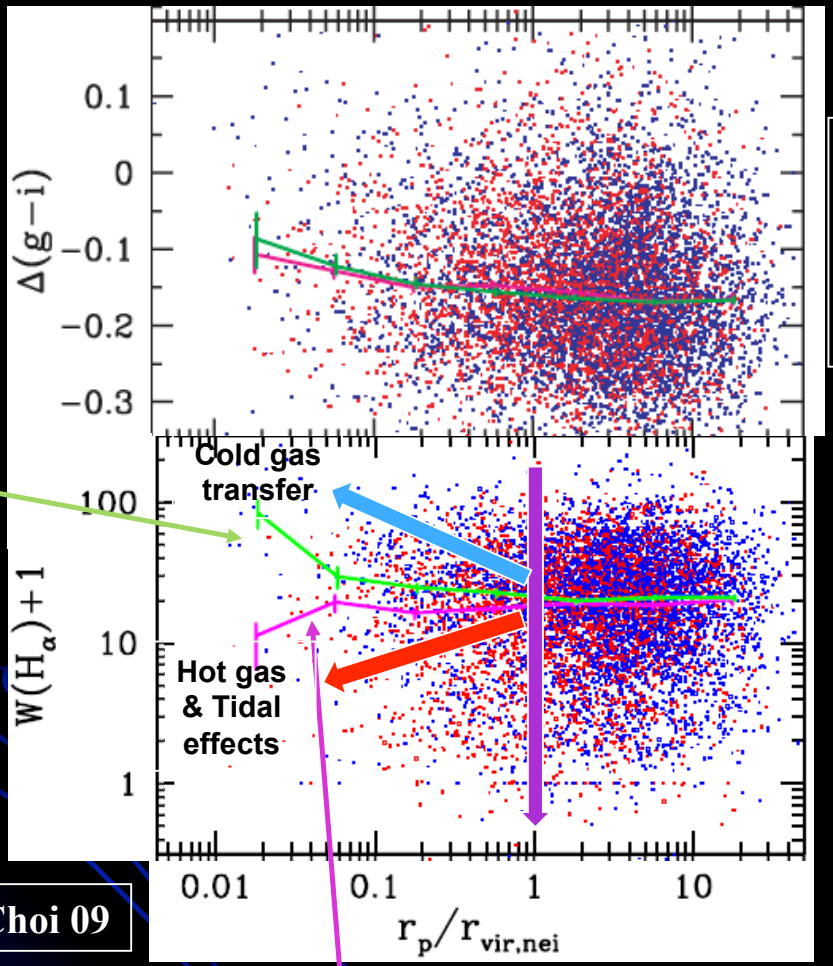
✓ ...alaxies

te...

...alaxies (LN)

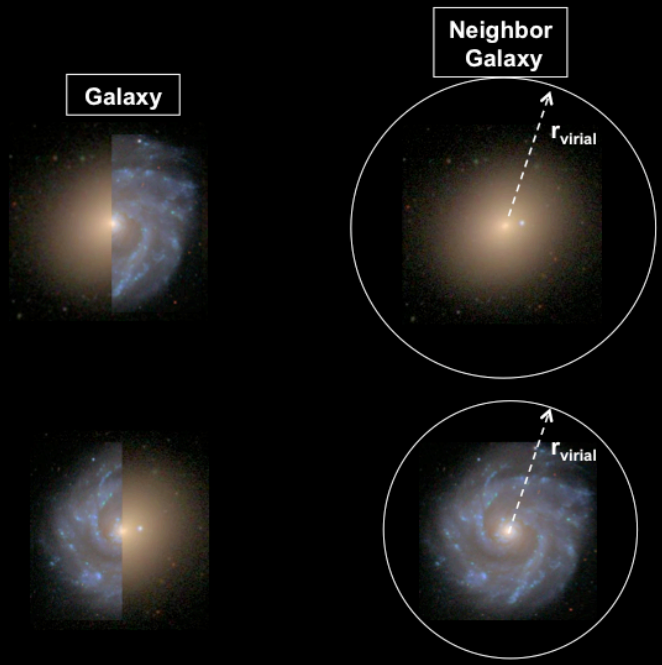
...N)

S/Irr Neighbor

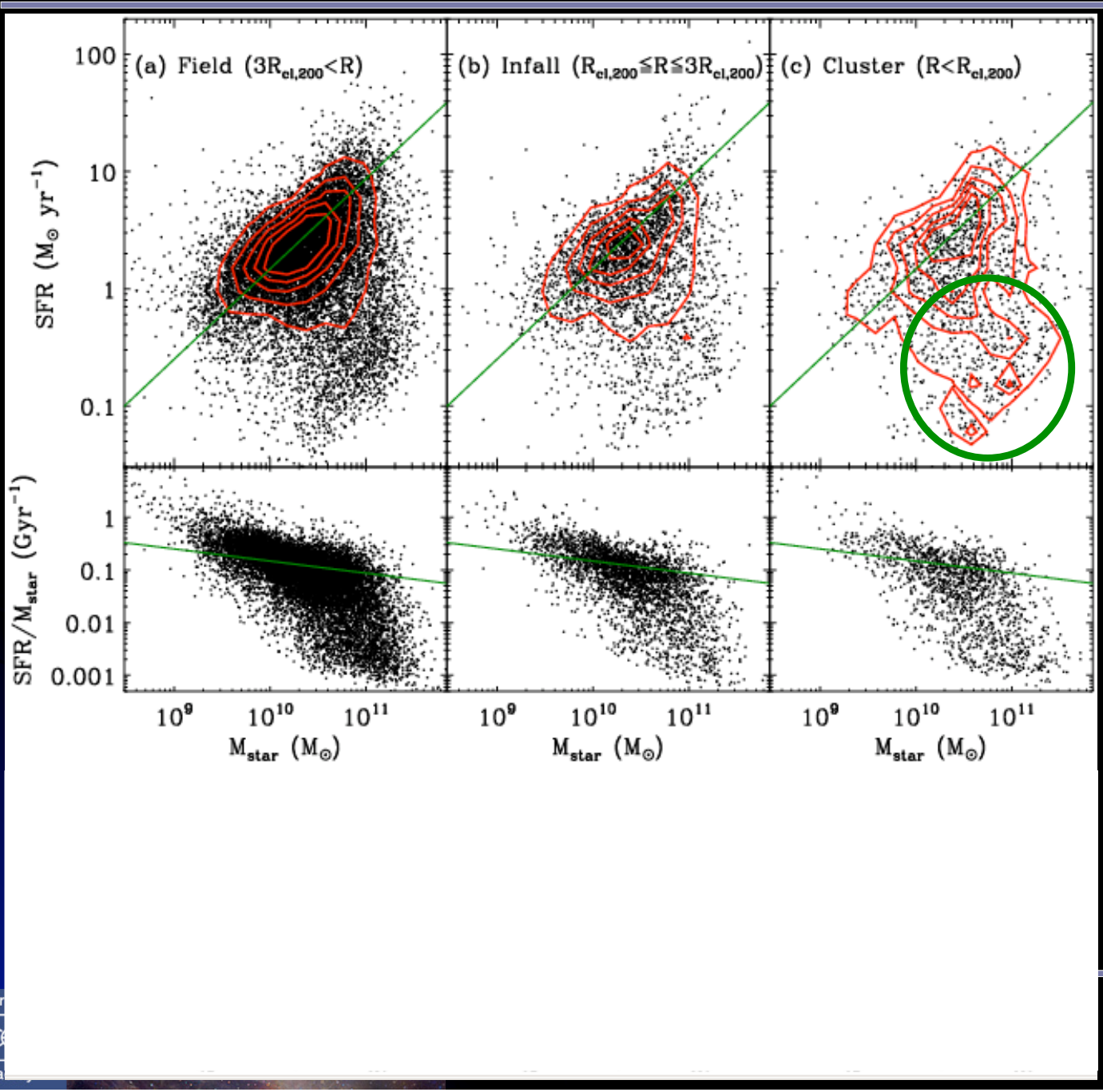


Park & Choi 09

E/S0 Neighbor



2.2 Clusters: Effects on Star Formation Activity

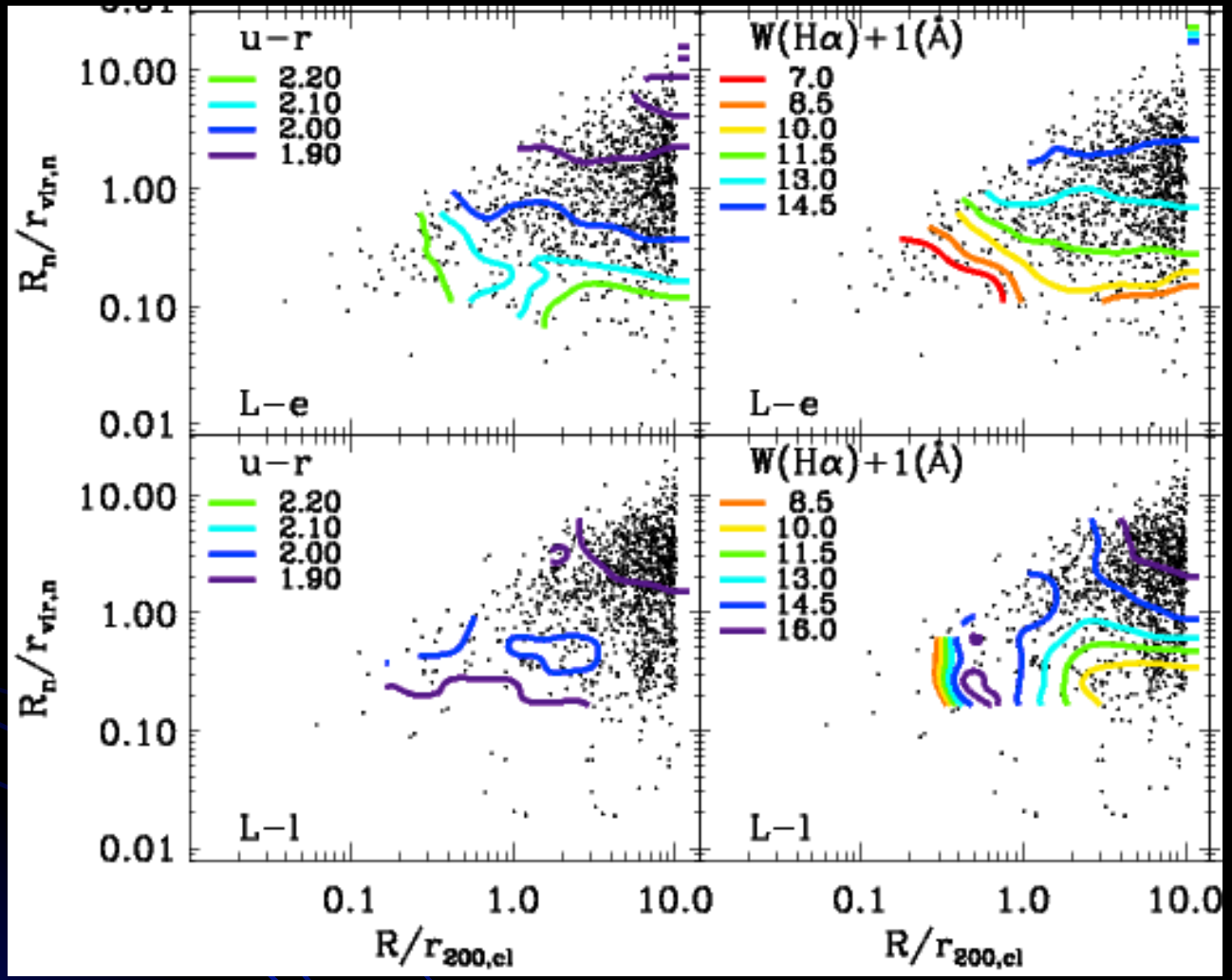


Late types
AGNs rejected
Hα>0 and S/N(Hα)>3
0.04<z<0.14

Hwang & Elbaz, in prep.

- **Quenching of SF in clusters!**
- **No preprocessing at infall regions?**

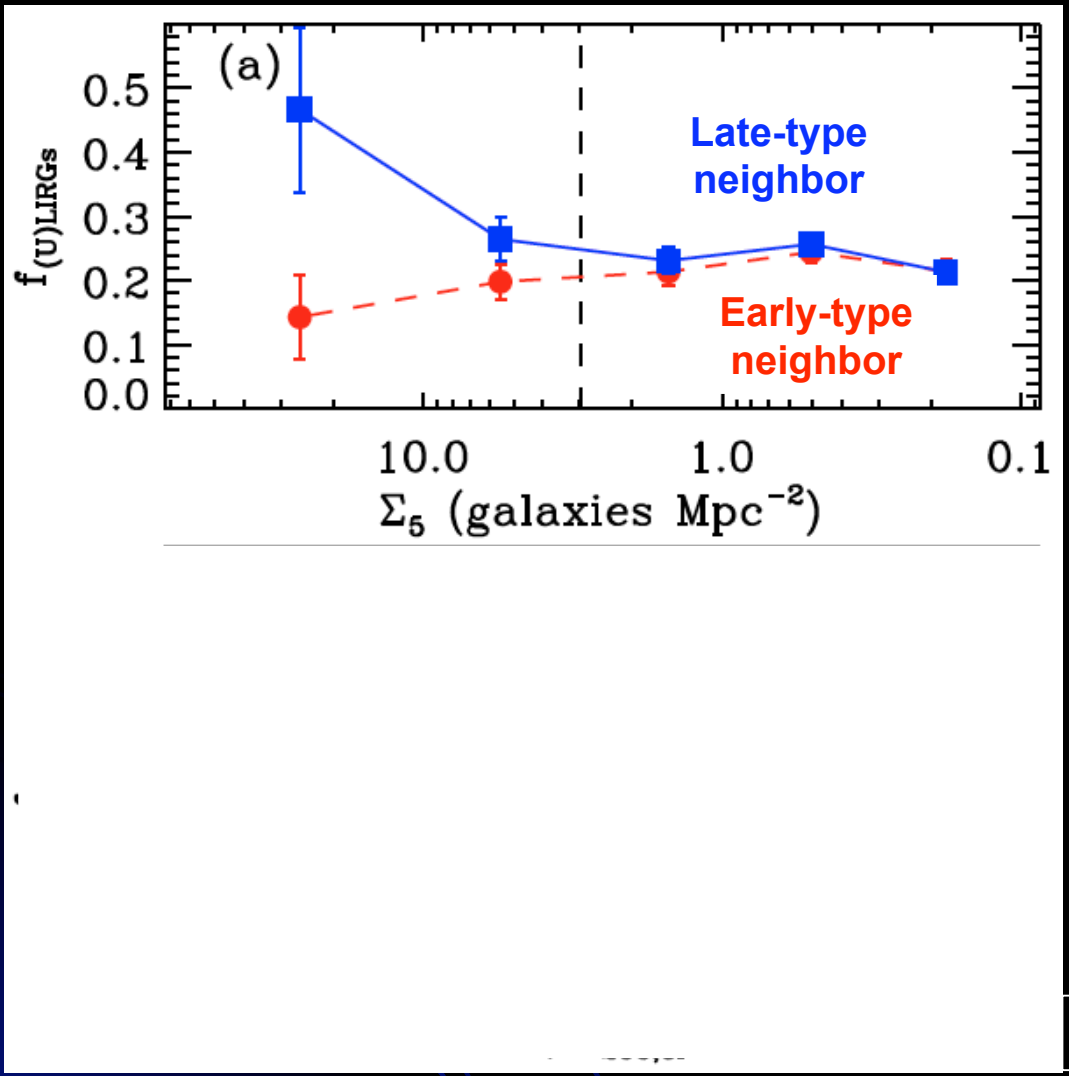
2.2 Clusters: Effects on Star Formation Activity



Park & Hwang (2009)

Horizontal Contour! : Role of Neighbor > Role of Galaxy Cluster
→ Hydrodynamic interactions between individual galaxies

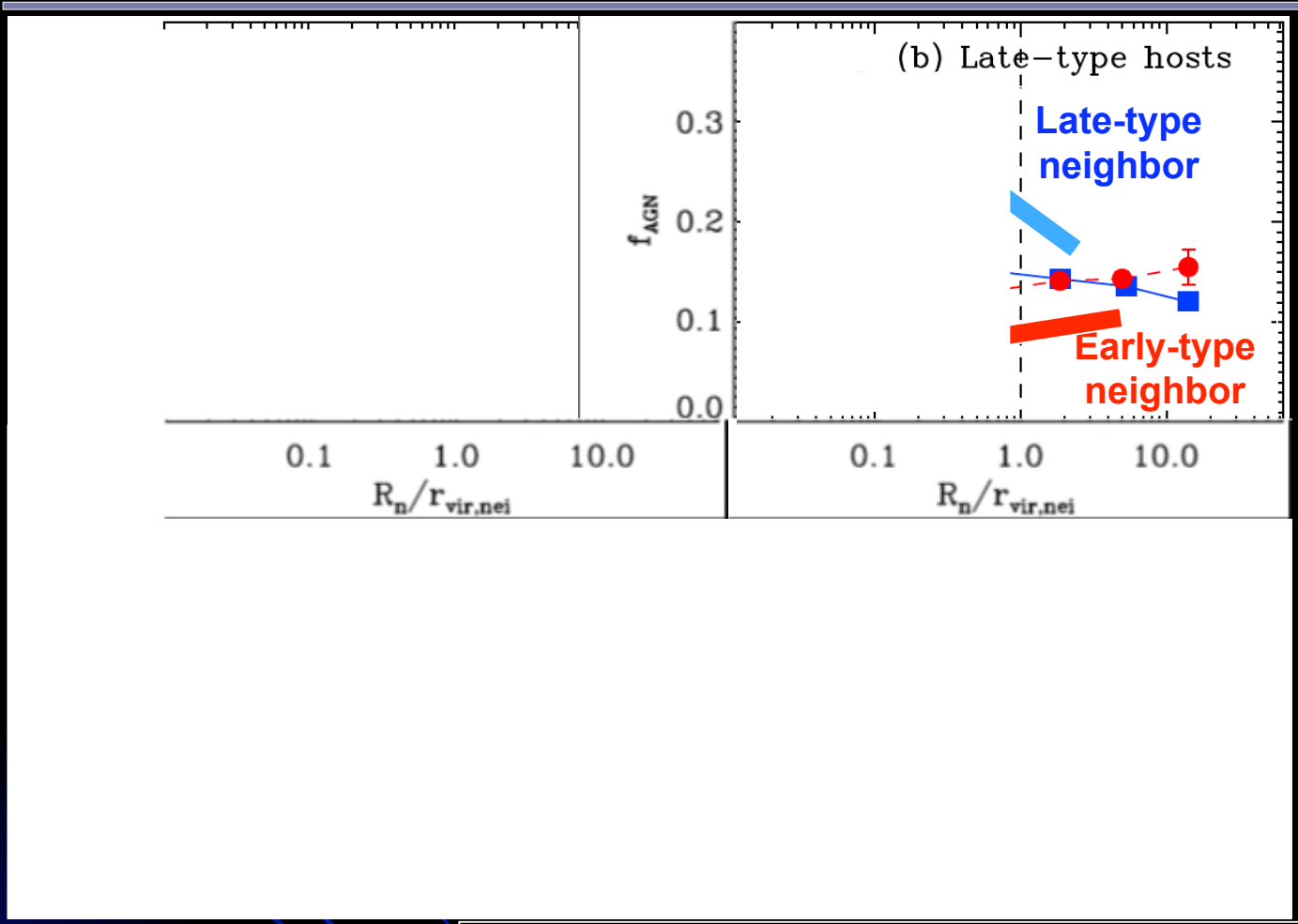
2.2 Clusters: Effects on Star Formation Activity



✓ Although galaxies are in high density region, their SFA can be enhanced if they interact with gas-rich, late types

Hwang +10

3.1 Field : Effects on AGN Activity

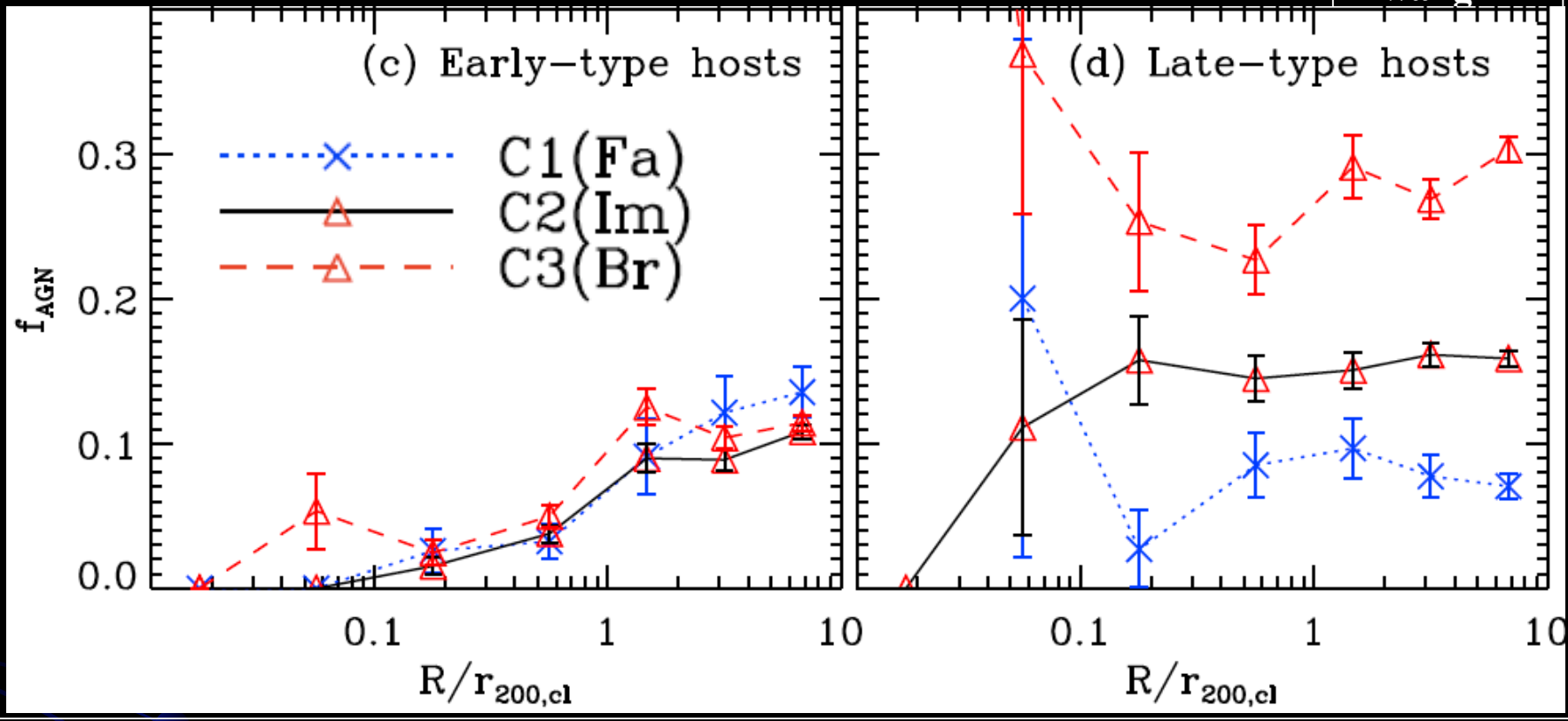


Choi +11, in prep.

- **For AGN activity,**
  - **Gas fuel : Either target or neighbor galaxy should be late-type for cold gas accretion**
  - **Triggering mechanism : Interaction-induced**

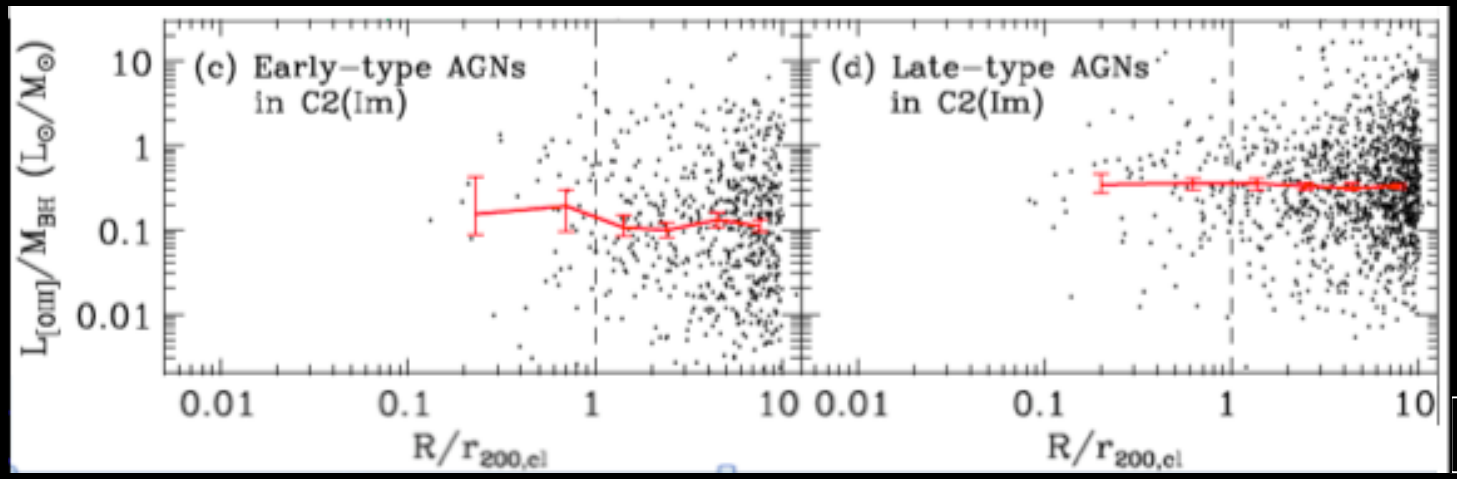
3.2 Clusters : Effects on AGN Activity

Hwang +11

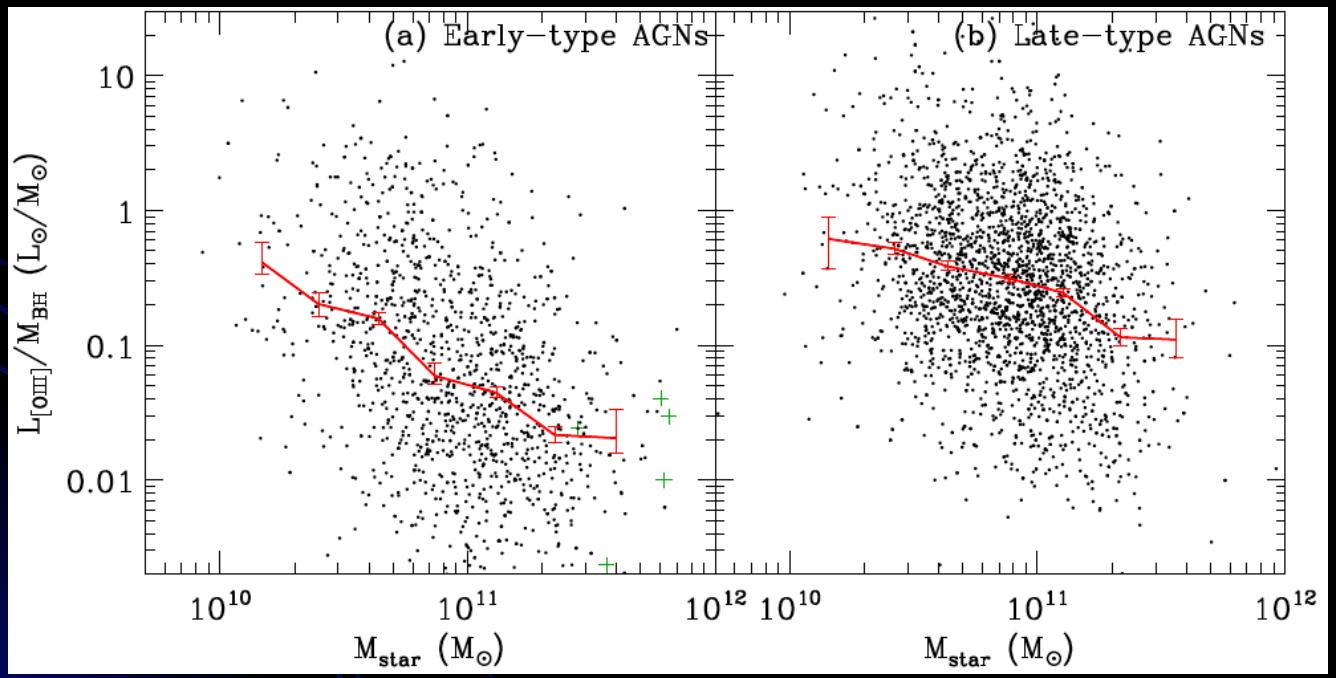


- **Early types :**
  - f_{AGN} starts to decrease around $r_{200,cl}$ as decreasing R
  - $f_{AGN,cl}$ is, on average, lower than $f_{AGN,Field}$ by a factor of ~ 3 (Arnold + 09; von der Linden +10)
- **Late types :**
  - f_{AGN} decreases much closer to the cluster center (~ $0.1 - 0.5 r_{200,cl}$)
  - $f_{AGN,cl}$ is, on average, similar to than $f_{AGN,Field}$

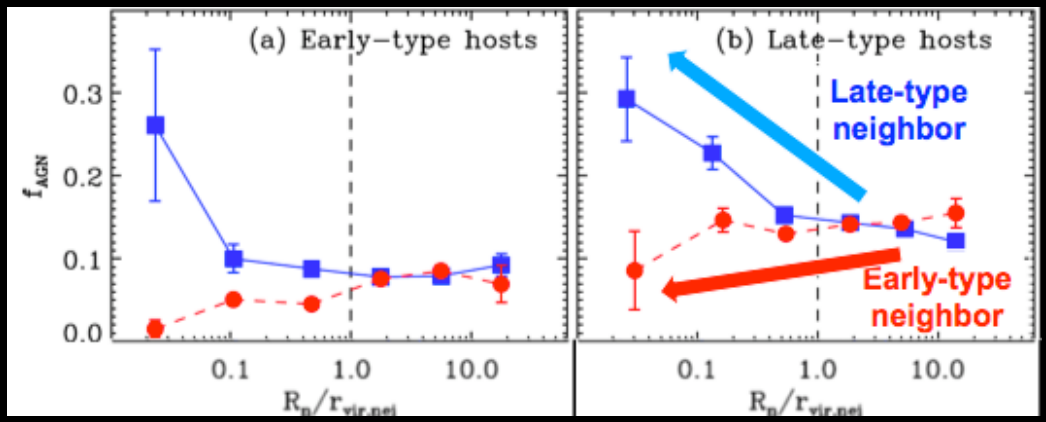
3.2 Clusters : Effects on AGN Activity

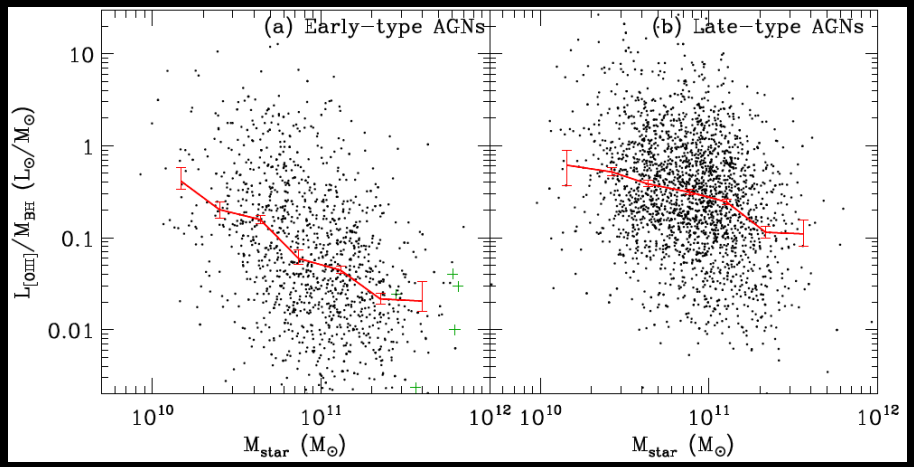


Hwang +11



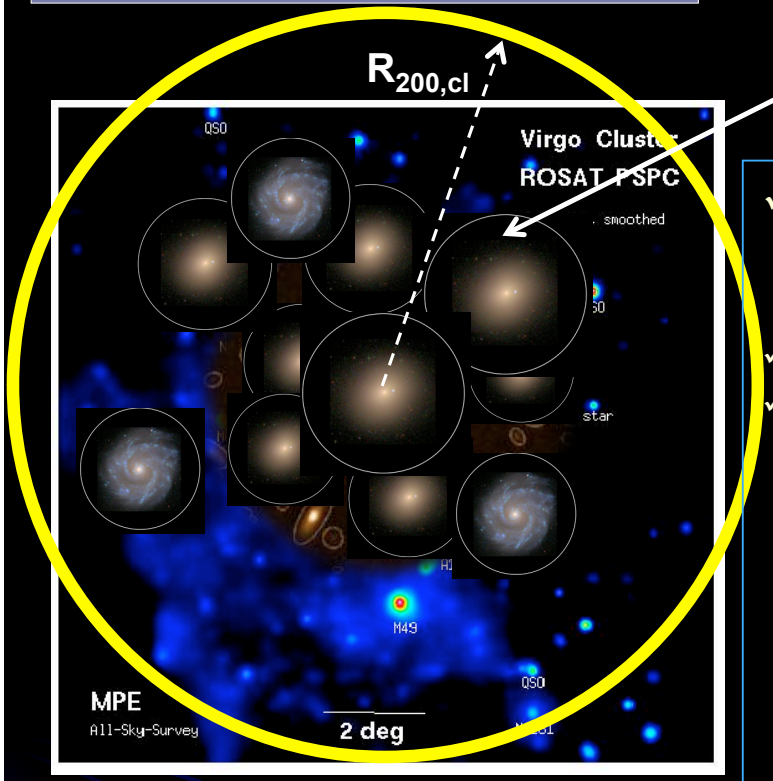
3.2 Clusters : Effects on AGN Activity





• **The AGN fraction** (triggering of AGN activity) strongly depends on the environment (as well as mass & morphology).
• **The Eddington ratio** (AGN power) is NOT controlled by the environment, but by the mass of host galaxies (or SMBHs).

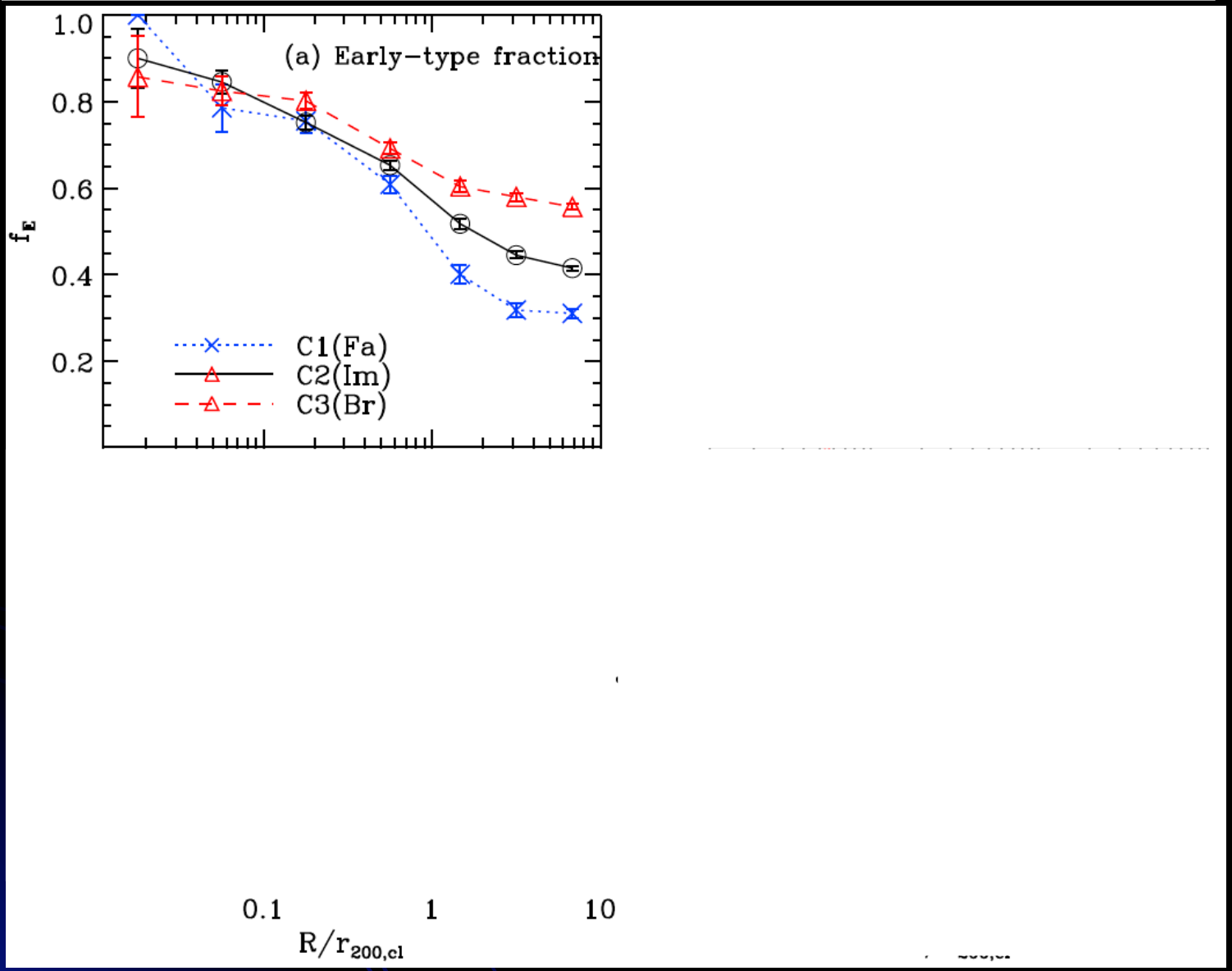
How it really works





- ✓ **Physical Mechanisms (Boselli & Gavazzi 06; Park & Hwang 09)**
- ✓ Ram pressure stripping (Gunn & Gott 72)
- ✓ Cumulative galaxy-galaxy hydrodynamic/gravitational interactions (Park & Hwang09)
  - ✓ As galaxies approach the center of clusters
  - ✓ They experience continuous interactions with other gal axies (mostly early types) because the virial radii of gal axies all overlap with one another
  - ✓ Then the nearest neighbors (mostly early types) can leave significant cumulative effects
    - ✓ decreasing SF/AGN activity hydrodynamically
    - ✓ changing morphology (structure parameters) gravitationally (harassment; Moore +96,98,99)
  - ✓ The amount of the cumulative effects increases monoto nically as the clustercentric radius decreases (or decrea sing interaction frequency with late types)
- ✓ Tidal Interaction between galaxies and the cluster (Merritt 84; Miller 86; Byrd & Valtonen 90)
- ✓ Viscous stripping/thermal evaporation (Nulsen 82; Cowie & Songaila 77)
- ✓ Strangulation (Larson +80) …

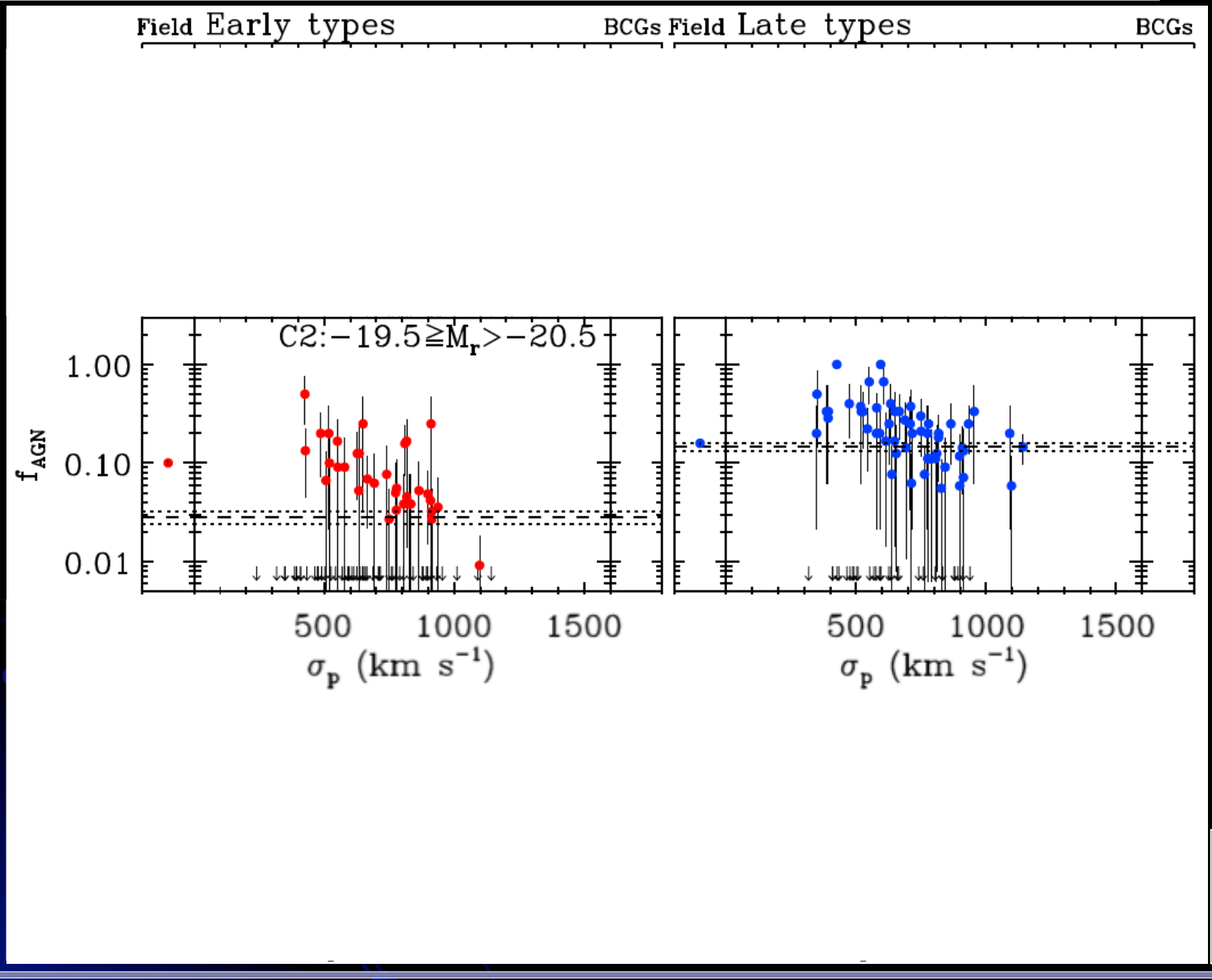
Connection between Morphology, SF & AGN activity



f_E, f_{AGN}, & f_{SF}
⇒ Closely linked!

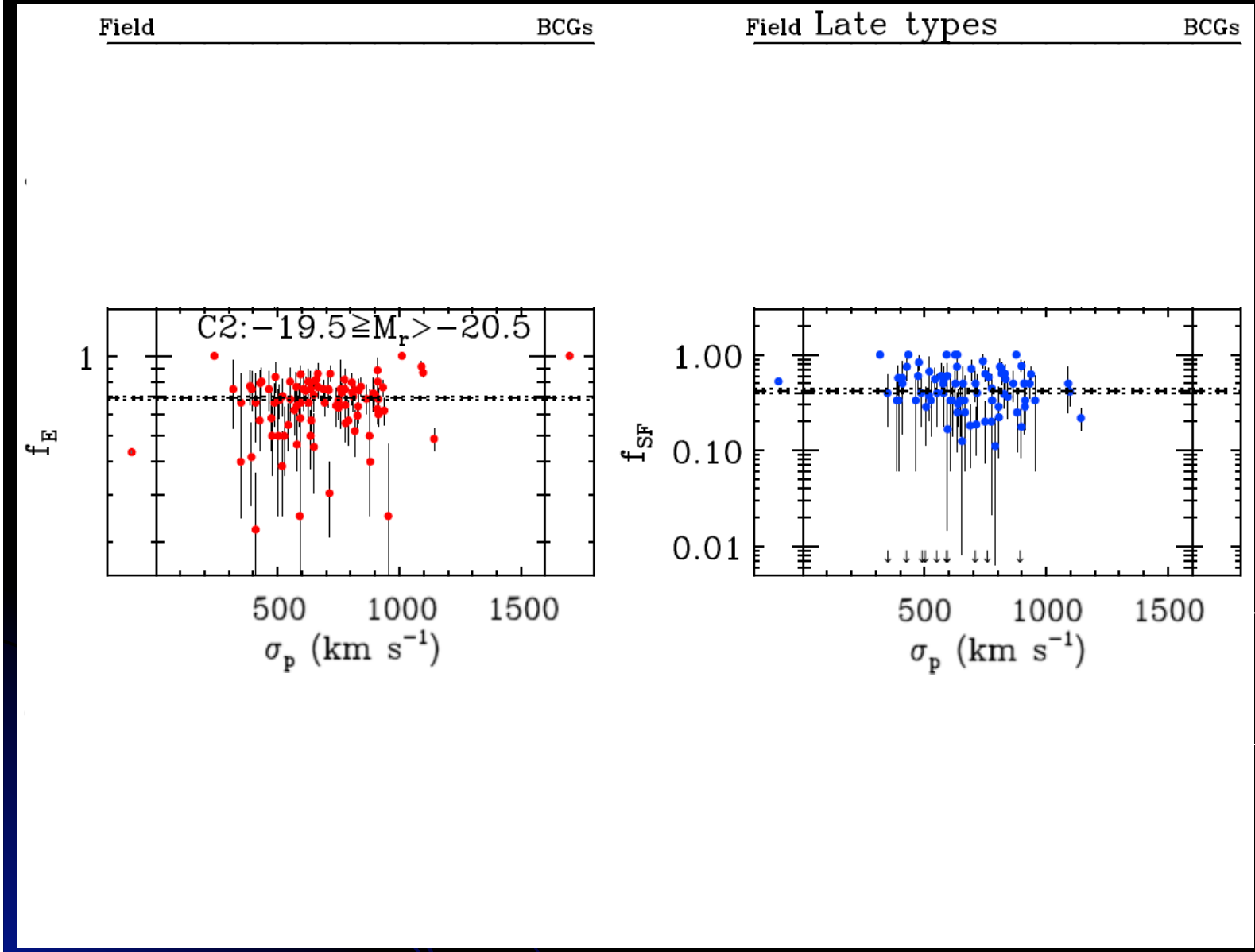
Hwang & Elbaz, in prep.

Connection between Morphology, SF & AGN activity



Hwang & Elbaz, in prep.; Popesso & Biviano 06

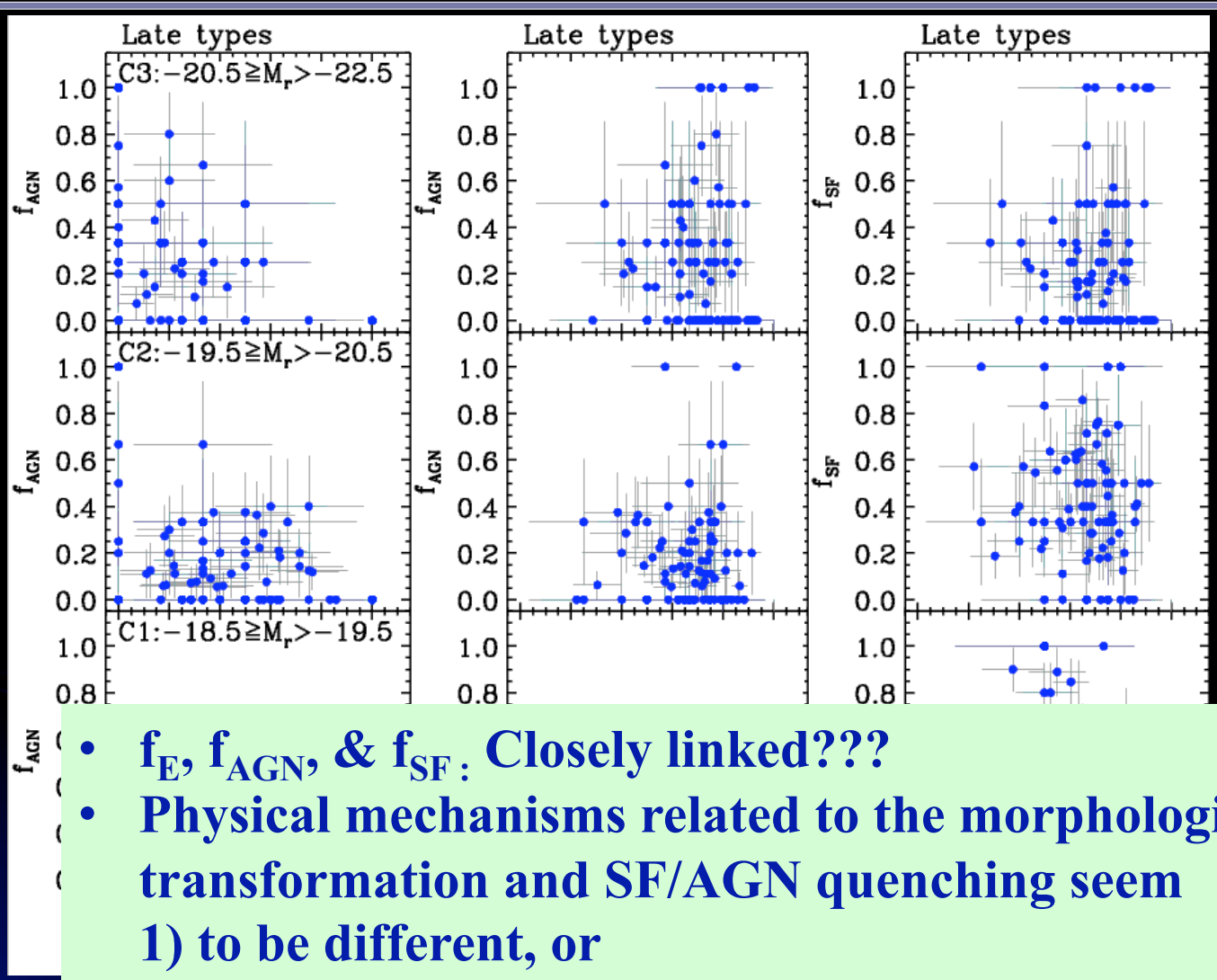
Connection between Morphology, SF & AGN activity

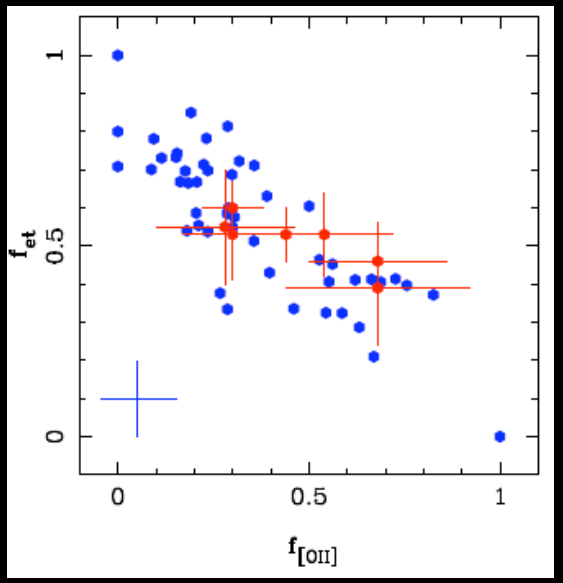


Lack of correlations (e.g. Simard +09)
⇒ Local effects

Hwang & Elbaz, in prep.

Connection between Morphology, SF & AGN activity





Simard +09

- f_E, f_{AGN}, & f_{SF} : Closely linked???
- Physical mechanisms related to the morphological transformation and SF/AGN quenching seem
  1) to be different, or
  2) to work over different timescales (e.g. Sanchez-Blazquez +09)..

Conclusion

- ✓ Galaxy properties (Morphology, SF & AGN activity) are **not always p rimordial**, but are acquired through galaxy-galaxy interactions and m ergers.
- ✓ In clusters, **cumulative galaxy-galaxy gravitational/hydrodynamical in teractions** play important roles in determining galaxy properties in ad dition to other physical mechanisms.
- ✓ Physical mechanisms related to the morphological transformation and SF/AGN quenching seem 1) to be different, or 2) to work over differe nt timescales (e.g. Sanchez-Blazquez +09)..

- **Merci beaucoup!**