Galaxy-Galaxy Interactions
in the general environment
and
clusters of galaxies

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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 ~ 90%) + visual check → >90% reliable down to r=17.6

E/S0

S/Irr

Final DR7
all galaxies in the NYU-VAC are classified!!

Park & Choi (2005)

red spirals
A. Galaxy interactions in the general environment
Morphology

\[ f_E = \text{Probability that a randomly chosen galaxy is an early type} \]

(Park, Gott & Choi 2008)

Consistent with Weinmann et al. (06)'s morphology conformity of satellites
$2+1$D environmental parameter space: neighbor distance, morphology and

Large-scale background density $\rho_{20}$
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?
What are $r_{\text{neighbor}}$, neighbor's morphology, background density?
Star formation activity of galaxies in general locations

Two characteristic scales!
Hydrodynamic interaction!

Other galaxy properties
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)

Characteristic scales \( \sim 1 \sim 3 \) cluster virial radius
Morphology: Early-type fraction vs clustercentric radius

Park & Hwang (2008)
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, smaller size at $R_{cl} < r_{200,cl}$
- ~vertical contours --> instant and/or cumulative effects of cluster/neighbor
### Who's responsible? Cluster/Neighbor, Gravity/Gas

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<th>$\sigma$</th>
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2. Morphology-cluster radius-nearest neighbor distance relation
Implications I. General environment

1. Effects of neighbor are great & reaches ~Mpc!
   - previously thought it was marginal
   - & effective only within << 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 \( r_{\text{vir}} \)
   - 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 $r_{200,\text{cl}}$
   - 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 $R_{\text{cl}}$

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
   - $1\sim3 \times$ 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 !