How empty is empty?

Defining environment, from voids to field to clusters

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Environment, why we care ...

- we can finally do it well
- who wants to be just “average”
- different environment, different physics
1. How we define environment and voids
2. Physical vs. statistical measures of environment
3. Some of my own results
4. An environment project
Defining environment
Defining environment

“Group” finders:

• Close pairs, friends of friends, ...
• Optimal linking length?
• Won’t find voids, but will identify isolated galaxies
Defining environment

N’th nearest neighbour:

• What “n” is optimal?

• How to compare dense with sparse populations?
Defining environment

Fixed aperture:

- What kind of aperture (top-hat, Gaussian, ...)?
- Smoothed on what scale?
- Loss of information on smaller scales (e.g. halo radii typically <2Mpc)
Defining environment

Using the underlying structure itself:

- Halo mass (i.e. bound structures)
- The dark matter density field
- Observation vs. theory
- Dealing with bias
Defining environment

Issues:

• 2D vs. 3D.

• Dealing with selection, incompleteness and volume effects

• Comparing different environment measures
Defining voids

Use the “void finder” algorithm
Defining voids

- “void” galaxies vs. “wall” galaxies (e.g. Hoyle et al. 2005)
- Maximal non-overlapping spheres (e.g. Patiri et al. 2006)
- Grid based (e.g. Colberg et al. 2005)
- Something more clever (talk to Rien)
Defining voids

Issues:

- Selection, incompleteness and volume effects
- How empty do you have to be to be a void ($\delta<-0.6$, $\delta<-0.9$)?
- Comparing different void measures
Do they work?

von Benda-Beckmann & Muller 2008

Millennium Simulation

2dFGRS
Statistical measures of environment

- 2-pt clustering - amplitude links to both environment and halo mass
- Shape statistics - voids, filaments, sheets, clusters
- Voids can be just as clustered as clusters
Environment dependent quenching?
Local (number) density is determined in top-hat spheres of radius $8h^{-1}\text{Mpc}$:

$$\delta_8 = \frac{\delta \rho_g}{\langle \rho_g \rangle}$$

When I say “environment” this is what I mean ...
Millennium Simulation
semi-analytic model
2dFGRS luminosity function

Extreme void: $-1.0 < \delta_8 < -0.9$
Void: $-1.0 < \delta_8 < -0.75$
Mean: $-0.43 < \delta_8 < 0.32$
Cluster: $\delta_8 > 6.0$
2dFGRS luminosity function

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2dFGRS
Schechter parameters vs. environment
2dFGRS
Schechter parameters vs. environment
HOD model interpretation

- faint later-type galaxies tend to live in less massive halos, which are present in all density environments
- faint ellipticals tend to mostly reside in cluster-sized halos
- denser regions exhaust the gas supply faster, resulting in redder objects
The environment dependence of galaxy properties can be accounted for by the dependence of halo mass on environment.
Croton et al. 2005

2dFGRS

\[ \phi (h^3 \text{Mpc}^{-3} \text{mag}^{-1}) \]

Cluster ($\delta_h > 6.0$)

Void ($\delta_h < -0.75$)

\[ M_{bj} - 5 \log_{10} h \]
Galaxy formation models
Galaxy formation models

AGN \left( \propto m_{\text{BH}} \sigma^3 \right)

SN \left( \propto \text{SFR} \right)

Croton et al. 2006
The Millennium Simulation semi-analytic galaxy formation model
So what’s special about early-type void galaxies?

Croton & Farrar (2008)

Halo mass function in different environments
The red/blue void galaxy abundance can be accounted for by the dependence of halo mass on environment.
An environment project
An environment project

Apply multiple environment/isolated/void measures to a common mock catalogue:

• How do different measures of environment compare?

• How are our end results coloured by the environment measures we use?
An environment project

• fixed aperture (spherical, cylinder) on small and large scales
• N'th nearest neighbour
• group finders and isolation criterion
• halo mass and the underlying DM density field
• 2D vs 3D measures
• others?
An environment project
An environment project
An environment project
Please join us!