Environment and Large Scale Structure Across the Coma Supercluster

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Abstract

As part of a larger project to assess the role of environment in galaxy evolution, and the importance of pre-processing in groups, out to z≈2, we examine Large Scale Structure (LSS) and projected galaxy surface density across the nearby Coma Supercluster region using a combination of Minimal Spanning Tree (MST) and Voronoi Tessellation (VT) techniques. We select ~4000 galaxies from SDSS DR8[1] with spec-z's consistent with Coma over the 500 sq. deg supercluster region. We detect 36 sub-structures in the supercluster, including the two massive galaxy clusters (A1656 & A1367), and find that our sub-structures agree well with known groups and clusters in Coma. Our next steps are to use data in hand from SDSS, *GALEX*[7], WISE[11], and archival HI obs. to compare star formation activity, color, morphology, and gas content to local galaxy density and proximity to LSS.

Introduction and Motivation

Galaxies exhibit a strong dependence between environment and color, star formation rate (SFR), and morphology at low-to-intermediate redshifts, with over-dense regions containing primarily red, quiescent, and bulge-dominated galaxies that are comparatively rare at lower densities[e.g., 3, 4, 6, 10]. Understanding the dominant process(es) responsible for galaxy transformation between these different environments is a key goal in galaxy evolution studies, but is complicated by intrinsic differences with galaxy mass[9], redshift[2], and cluster-to-cluster variations[8]. Overcoming these complications requires a study examining a large statistical sample of galaxies in clusters and in surrounding groups and filaments spanning a wide range of redshifts.

To that end, we have undertaken a study of 10 clusters, and the surrounding LSS in which they are embedded, at 0.02<z<1.5. For most of our clusters, we must rely on photo-z's to select galaxies at the redshift of the cluster and surrounding LSS, and then use the photo-z selected galaxies to characterize the environment in and around the cluster. A major concern with our analysis is whether we can accurately resolve the LSS with intrinsic scatter in photo-z measurements, so we are first training our LSS mapping technique on the Coma Supercluster, which is nearby (z=0.023), contains two massive clusters and dozens of galaxy groups, and has complete SDSS spectroscopy for all galaxies down to dwarf masses. Furthermore, we can use measures of star formation activity from UV continuum (*GALEX*[7]), and infrared (WISE[11]) to measure the total SFR, unobscured and obscured, of Coma Supercluster galaxies and examine signs of pre-processing in the groups we identify.

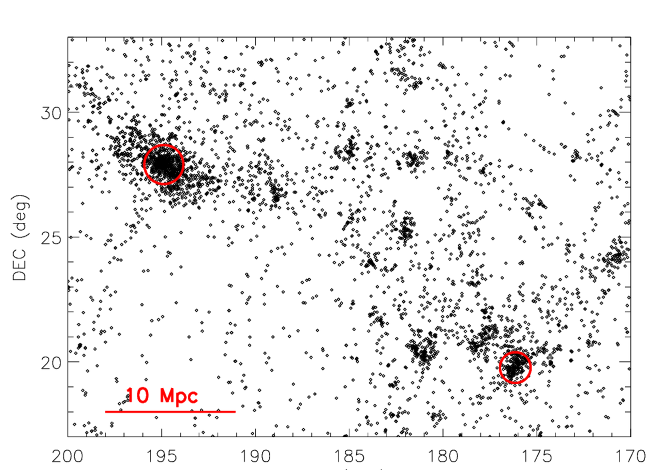

Figure 1: Galaxies in the Coma Supercluster selected from SDSS. A1656 is identified by the NE circle, and A1367 by the SW circle.

Methods & Results

We select galaxies from SDSS DR8[1] with 170° ≤ RA ≤ 200° and 17° ≤ DEC ≤ 33° and *cz* within 2000 km/s of A1656 and A1367. As the SDSS spectroscopic sample of galaxies is complete to r < 17.77, our galaxy sample is complete to M* + 4.7 at Coma. Our two methods of characterizing the environment are described below:

Voronoi Tessellation (VT): decompose a distribution of points (galaxies) into a series of polygons, with one polygon per galaxy, and each polygon encloses the area of the map that is closest to its galaxy. The inverse of the cell area is a measure of local surface density, as smaller cells occupy regions of greater density and larger cells occupy regions of lower density. The benefit of VT is that the cell sizes automatically adjust to an arbitrarily large dynamic range of local densities, and we don't have to select a characteristic smoothing scale, shape, or number of nearest neighbors over which to measure local density.

Our VT of the supercluster sensitively traces the wide dynamic range of local galaxy densities (see Figure 2). We measure the surface density Σ around each galaxy by the inverse of its Voronoi cell area, and then parameterize local density by: $\delta=\log(1 + \Sigma/\Sigma_{avg})$

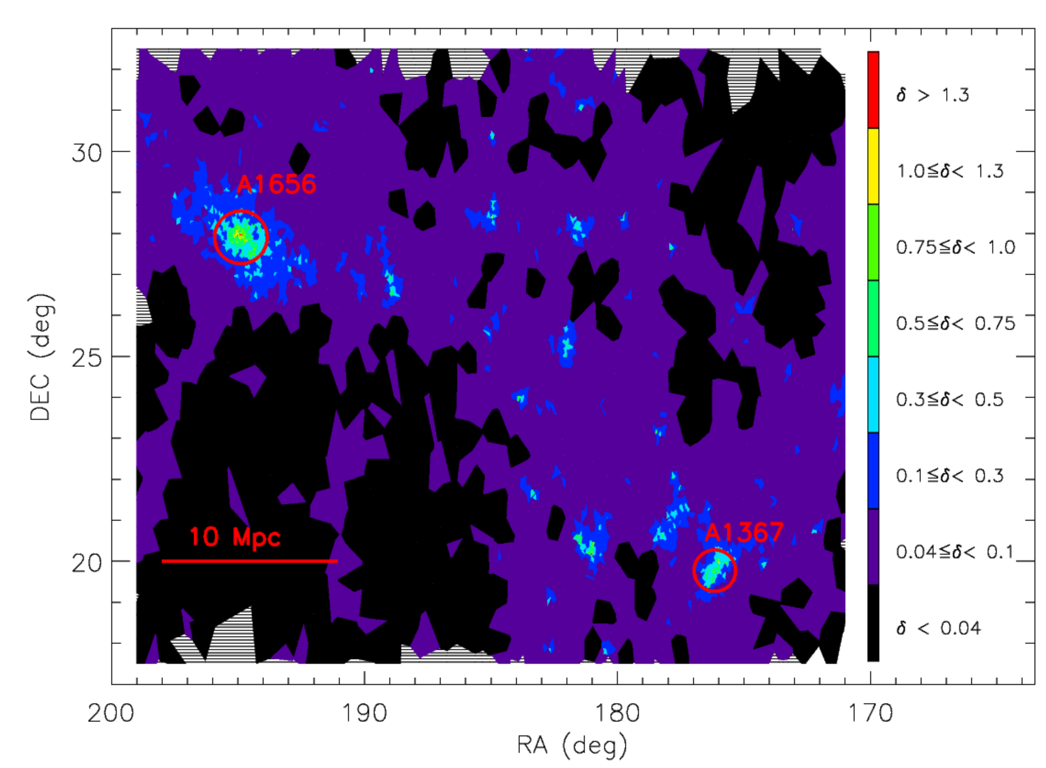

Figure 2: VT of the Coma Supercluster. The Voronoi Cells are color coded by δ.

The **Minimal Spanning Tree (MST):** connect all points (galaxies) in a distribution by branches such that no two branches cross, and the total length of all branches is a minimum. Sub-structures can be selected from the tree by choosing sets of galaxies which are all connected by branch lengths less than some critical length l_{crit}, and which have a minimum number of members. To select a l_{crit}, we use the "stabbing" technique of Gutermuth et al. (2009), which automatically picks out the characteristic branch length scale corresponding to the peak in the galaxy clustering signal.

For our MST analysis of the supercluster, we use a critical length of 10 arcmin (240 kpc at Coma) and a minimum of 8 galaxies, and identify 36 sub-structures. The MST is plotted in Figure 3 with branches as dotted lines and sub-structures identified by colored points. We also overlay with black circles the positions of known galaxy groups in Coma found via a search of the NASA/IPAC Extragalactic Database (NED).

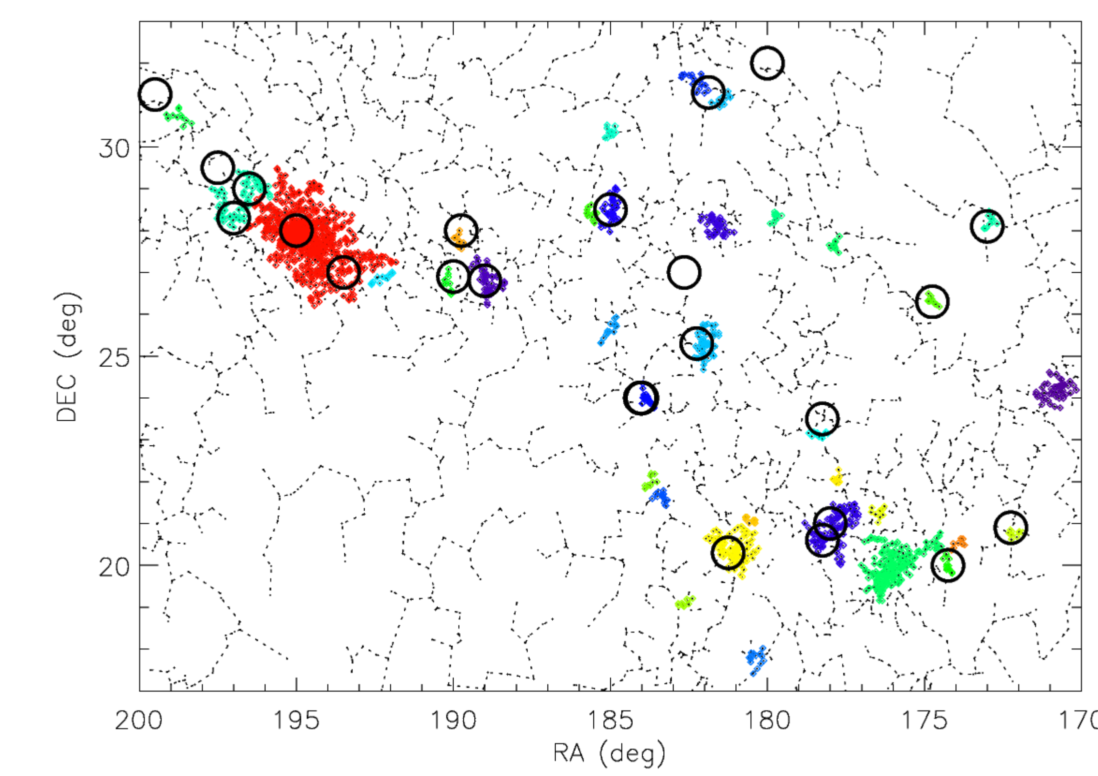

Figure 3: MST of Coma Supercluster. Branches are displayed as dotted lines. Colored dots denote the positions of galaxies in sub-structures. Black circles correspond to positions of known galaxy groups in the supercluster.

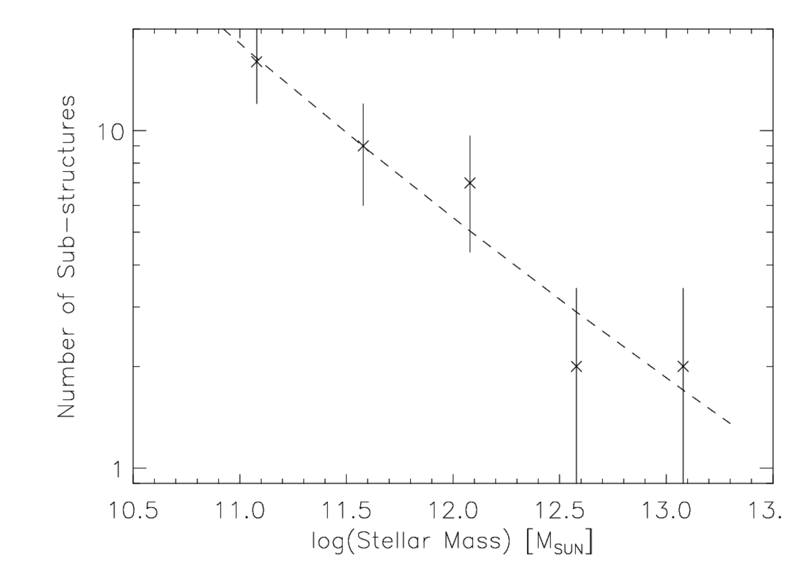

Figure 4: Distribution in total stellar mass for sub-structures identified using MST in Coma. The stellar masses of galaxies are from Aihara et al. (2011). The dashed line gives a power law fit to the points.

Conclusions and Next Steps

We have shown that a combination of VT and MST techniques can provide a complimentary characterization of environment. While VT is a powerful tool for measuring projected density over a large dynamic range of environments, it is less effective at resolving continuous structures traced by galaxies. Coupling the VT with a MST approach allows us to reliably identify groups and filaments as well as measure the local galaxy density. Next, we will use data from SDSS, *GALEX*, WISE, and archival HI observations to examine the relationship between star formation activity, color, morphology, and gas content with:

- group, cluster, or filament mass
- proximity to the center of the group, cluster, or filament
- local galaxy density
- galaxy mass

to explore how galaxies are shaped by environmental processes at low z.

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