Does Environment Matter? A Lesson from the Coma Supercluster

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Of Course, It Matters....
Motivation

- Test environ. mapping technique (with Voronoi Tessellation & Minimal Spanning Tree) on Coma Supercluster ($z=0.023$), identifying cluster, group, filament, and void populations

- Use WISE all-sky survey [22] to get dust-obsured SFRs in Coma, combined with GALEX for total SFR

- Quantify the degree to which pre-processing affects galaxies at $z \sim 0$ by measuring fraction of SF and blue galaxies as a function of environment
Coma Supercluster

- $z=0.023$ [ +/- 2000 km/s ]
- 2 massive clusters
- Dozens of groups
- Large dynamic range of densities over 500 sq. deg.
- SDSS spect. complete to $r\leq 17.77$ mag
Sample

- 3505 galaxies with: $8.5 \, M_\odot < \log M^* < 11.5 \, M_\odot$
- $r \leq 17.77 \, \text{mag}$
- SDSS spec-z ($\text{SPECPRIMARY}=1$ & $\text{ZWARNING}=0$)
- Detections in WISE [3.4] & [4.6] (for $M^*$)
- SFR$_{\text{UV}}$ from GALEX, and SFR$_{\text{IR}}$ from WISE [22]
  
  $0.02 \, M_\odot / \text{yr} < \text{SFR} < 5 \, M_\odot / \text{yr}$
Star Formation Rate (SFR)

- **SFR(IR)**
  - From WISE 22 mm (>4.7 mJy)
  - \( L(\text{IR}) > 2 \times 10^8 \, L_\odot \) or \( \text{SFR}(\text{IR}) > 0.2 \, M_\odot /\text{yr} \)
  - 1039/3505 galaxies detected
- **SFR(UV)**
  - GALEX NUV (60-30,000 secs)
  - \( L(\text{NUV}) \rightarrow \text{SFR}(\text{UV}), \, \text{SFR}(\text{UV}) > 0.02 \, M_\odot /\text{yr} \)

- Adopted the calibration by Murphy et al. (2011)
Mapping the Supercluster Environment

Voronoi Tessellation (VT)
- Local den. $\propto (\text{cell area})^{-1}$
Minimal Spanning Tree (MST)

- Define continuous structures by "pruning" sections of branches connected entirely by branches of length $\leq L_{\text{crit}}$

- Selecting cluster, group, and filament structures entails more than one $L_{\text{crit}}$ value
Choosing $L_{\text{crit}}$

- $L_{\text{crit1}}$: separate cluster/group from filament

- $L_{\text{crit2}}$: separate filament from void

- Use VT dens. thresholds to define these boundaries, exploiting the similarity of VT cell and MST branch length distributions
  
  - For $L_{\text{crit1}}$: 40 gal. $h^2$ Mpc$^{-2}$
  
  - For $L_{\text{crit2}}$: 10 gal. $h^2$ Mpc$^{-2}$
Mapping the Supercluster Environment

MST-defined environments

- cluster, group, filament, void

<table>
<thead>
<tr>
<th>Environ.</th>
<th>N_{gal}</th>
<th>Area (h^{-2} Mpc^2)</th>
<th>\langle \Sigma \rangle (h^2 \ Mpc^{-2})</th>
<th>\log(\langle SSFR \rangle) [\text{yr}^{-1}]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster</td>
<td>741</td>
<td>19.5</td>
<td>108.5</td>
<td>-11.27</td>
</tr>
<tr>
<td>Group</td>
<td>716</td>
<td>57.5</td>
<td>38.7</td>
<td>-11.06</td>
</tr>
<tr>
<td>Filament</td>
<td>1292</td>
<td>423.6</td>
<td>6.3</td>
<td>-10.60</td>
</tr>
<tr>
<td>Void</td>
<td>756</td>
<td>891.0</td>
<td>1.7</td>
<td>-10.40</td>
</tr>
</tbody>
</table>
Distribution of Quiescent Galaxies

- Black dots: quiescent galaxies
- Yellow stars: k+A (post-starburst) galaxies (62 total)
- Obvious abundance of quiescent galaxies in (most) groups
- Significant quiescent pop. extends to 2-3R_{vir} of A1656. (cf., Bahé et al. 2013)
Mapping the Supercluster Environment

Stellar mass distributions of galaxies in each environment

“dwarf”: \( 8.5 \, M_\odot < \log M^* < 9.5 \, M_\odot \)
“massive”: \( \log M^* > 9.5 \, M_\odot \)
star-forming (SF) galaxy:
- $\log(\text{SSFR}) > -11 \ [\text{yr}^{-1}]$
- $D_{n4000} < 1.6$
SFR vs Environment

• Fraction of SF galaxies in each environment, separated by dwarf and massive galaxies

• $f_{\text{SF}}$ declines steadily with increasing density, for both mass bins
Color vs Environment

- g-r colors
- decline in blue fraction with increasing density
- optical extinction artificially lowers $f_{\text{blue}}$, especially for massive galaxies
SFR vs Environment

star-forming (SF) galaxy:
- $\log(\text{SSFR}) > -11$ [yr$^{-1}$]
- $D_{n4000} < 1.6$

Mass Selection
SFR Distribution vs Environment

- Mann-Whitney U test comparing distrib. of SSFRs & SFRs for SF galaxies in each environ.

<table>
<thead>
<tr>
<th>Environments</th>
<th>$P_{\text{USSFR}}$</th>
<th>$P_{\text{USFR}}$</th>
<th>$P_{\text{USSFRd}}$</th>
<th>$P_{\text{USFRm}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster-Group</td>
<td>0.12</td>
<td>0.34</td>
<td>0.018</td>
<td>0.064</td>
</tr>
<tr>
<td>Cluster-Filament</td>
<td>&lt;0.0014</td>
<td>0.030</td>
<td>&lt;0.0014</td>
<td>0.20</td>
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<tr>
<td>Cluster-Void</td>
<td>&lt;0.0014</td>
<td>&lt;0.0014</td>
<td>&lt;0.0014</td>
<td>0.39</td>
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<tr>
<td>Group-Filament</td>
<td>&lt;0.0014</td>
<td>0.0068</td>
<td>&lt;0.0014</td>
<td>0.086</td>
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<tr>
<td>Group-Void</td>
<td>&lt;0.0014</td>
<td>&lt;0.0014</td>
<td>&lt;0.0014</td>
<td>0.0031</td>
</tr>
<tr>
<td>Filament-Void</td>
<td>&lt;0.0014</td>
<td>0.0040</td>
<td>0.0036</td>
<td>0.020</td>
</tr>
</tbody>
</table>

SFR distributions vary for most environ. for dwarf galaxies, but for massive galaxies they all are consistent with being drawn from the same distrib.
Conclusions

• Statistically significant decline in fraction of SF and blue galaxies in progressively denser environments, for both massive and dwarf galaxies! (not a threshold effect)

• Distinct distribution of dwarf SF galaxies for most environment, but not for massive galaxies – an important caution at high-z.

• Pre-processing plays an extremely important role at low-z, as group galaxies are significantly more likely (~50%) to be quiescent than isolated void galaxies

Check the astro-ph for the paper next week!