In the footsteps of galaxies: Tracing the evolution of environmental effects

Small-Scale Conformity of the Galaxies in the Virgo Cluster

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Environmental Effects on Galaxies

- Galaxies in a dense environment tend to have early-type morphology, red color and low star formation rate (SFR). (Dressler 1980; Poggianti et al 2008; Lee et al 2010)
Galaxy Group Environments

- Galaxy evolution by direct tidal interactions between galaxies is known to be most active in galaxy groups.

- Properties of central bright galaxies are closely related to those of their satellites, in their color, morphology and SFR. (Weinmann et al. 2006; Ann et al. 2008; Phillips et al. 2013; Knobel et al. 2014)

→ “Galactic conformity” in groups
Galaxy Cluster Environments

• Galaxy evolution is known to be accelerated by various mechanisms, such as interaction with cluster potential, harassment and ram pressure stripping.

• Interaction between galaxies in a cluster
  • Galaxies have high relative velocities in a massive cluster.
  • Direct interaction between galaxies is difficult.
    (Merritt 1984; Byrd & Valtonen 1990; Boselli & Gavazzi 2006)

• It was rarely studied whether such group-scale conformity also exists in a galaxy cluster.
Small-scale conformity between bright galaxies and their faint companions remains after a galaxy group falls into a galaxy cluster?
Lee et al. (2014)

WHL J085910.0+294957 (z = 0.3)

RA = 08:59:10, Dec = +29:49:57
Site: McDonald Observatory, USA
Telescope: Otto Struve 2.1m telescope
Detector: CQUEAN 1K CCD
Exposure: r-band 13,700 sec, i-band 17,460 sec
Typical seeing: 1.5″ - 2.0″
In the footsteps of galaxies, Soverato, Italy, 11 September 2015

Lee et al. (2014)

A marginal trend is found that redder bright galaxies tend to have redder faint companions.

- Bright galaxy color
- Bright galaxy luminosity
- Cluster radius
**Target**

- **Virgo Cluster**
  - Dynamically young
  - $D = \sim 16$ Mpc

- **Data**
  - **Extended Virgo Cluster Catalog (EVCC; Kim et al. 2014)**
    - Based on the Sloan Digital Sky Survey Data Release 7 (SDSS DR7)
    - Provides useful information including heliocentric radial velocity, membership, morphology as well as various photometric and structural parameters
    - A total of 1,589 galaxies
  - **SDSS DR12**
    - Used to supplement radial velocities of galaxies

- **Selected 973 genuine members**
Possible Groups in a Cluster

- **Bright galaxies**: galaxies with $M_r \leq -18$ mag (from the bright-end bump in the luminosity function)
  - A total of 187 galaxies

- **Faint companions**: galaxies with $M_r > -18$ mag and within
  - Virial radius of their host bright galaxy (Park & Hwang 2009)
  - Velocity dispersion of the expected group (Li et al. 2012)

<table>
<thead>
<tr>
<th>$\log(&lt;L/L_\odot&gt;)$</th>
<th>$\sigma_v/km,s^{-1}$</th>
</tr>
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<tbody>
<tr>
<td>10.33</td>
<td>133 ± 11</td>
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<tr>
<td>10.40</td>
<td>139 ± 8</td>
</tr>
<tr>
<td>10.47</td>
<td>151 ± 6</td>
</tr>
<tr>
<td>10.53</td>
<td>166 ± 5</td>
</tr>
<tr>
<td>10.61</td>
<td>188 ± 6</td>
</tr>
<tr>
<td>10.69</td>
<td>216 ± 7</td>
</tr>
<tr>
<td>10.77</td>
<td>243 ± 6</td>
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<tr>
<td>10.85</td>
<td>291 ± 8</td>
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<tr>
<td>10.93</td>
<td>338 ± 9</td>
</tr>
<tr>
<td>11.01</td>
<td>385 ± 10</td>
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<tr>
<td>11.09</td>
<td>439 ± 15</td>
</tr>
<tr>
<td>11.18</td>
<td>522 ± 22</td>
</tr>
<tr>
<td>11.26</td>
<td>591 ± 32</td>
</tr>
<tr>
<td>11.35</td>
<td>654 ± 38</td>
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</tbody>
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**Virial radii of bright galaxies**

<table>
<thead>
<tr>
<th>$M_r$</th>
<th>Early Type</th>
<th>Late type</th>
</tr>
</thead>
<tbody>
<tr>
<td>-19.5</td>
<td>$260h^{-1}$</td>
<td>$210h^{-1}$</td>
</tr>
<tr>
<td>-20.0</td>
<td>$300h^{-1}$</td>
<td>$240h^{-1}$</td>
</tr>
<tr>
<td>-20.5</td>
<td>$350h^{-1}$</td>
<td>$280h^{-1}$</td>
</tr>
</tbody>
</table>
Gravitational Potential Index ($P$)

- Gravitational potential index ($P$)

$$P = \langle \frac{M_{87}}{r_{87}} + \frac{M_{49}}{r_{49}} \rangle$$

- Small $P$ roughly corresponds to large cluster-centric distance
The weighted mean color of faint companions shows dependence on the color of their adjacent bright galaxy in the outer region.
Discussion

Galactic conformity in color between bright galaxies and their faint companions is detected in the outer region, while it is not found in the inner region of the Virgo cluster.

→ Conformity may still survive in the area less affected by cluster environment.

A possible scenario: Conformity between bright galaxies and their faint companions may be the vestige of infallen groups, but those groups lose conformity as they come closer to the cluster center.
Discussion

- It is noted that the conformity is found only in the outer region of the Virgo cluster, whereas it appears in the inner region of the WHL J085910.0+294957.
  
  • Difference of cluster environment  
    : If WHL J085910.0+294957 has smaller total mass, a smaller number of member galaxies, or poorer intracluster gas than the Virgo cluster, the conformity may survive even in the inner region due to the weakness of the cluster environmental effects.
  
  • Projection effect  
    : Conformity found in the inner region of WHL J085910.0+294957 may result from the projected outskirt galaxies on the line of sight.
Summary

- We investigated the correlation between bright galaxies and their faint companions in the Virgo cluster.

- Galactic conformity in color is found in the outer region, while it is not found in the inner region.

- Small-scale conformity may be the vestige of infallen groups, but it disappears as the groups come closer to the cluster center.

- Conformity is found in the outer region of the Virgo cluster and in the inner region of WHL J085910.0+294957, respectively.
  - Difference of cluster environment
  - Projection effect

- We need to investigate more clusters in various evolutionary stages to confirm this scenario.
Thank you!!

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