The Evolution of the Galaxy Cluster Red Sequence at Intermediate Redshift

Josefina Michea\(^1,2\), Felipe Barrientos\(^2\), Thorsten Lisker\(^1\)

\(^1\)Astronomisches Rechen-Institut, Zentrum für Astronomie der Universität Heidelberg (ZAH)
\(^2\)Instituto de Astrofísica, Pontificia Universidad Católica de Chile

**Motivation**

Evolving Universe

- Galaxy formation and evolution.
- Galaxy cluster assembly process.

Under the ΛCDM paradigm of hierarchical structure formation, galaxy clusters progressively build-up as the Universe ages.

It is possible to characterize the evolution of galaxy clusters across redshift space by studying their red sequence: a tight relation in color-magnitude space constituted by their early-type galaxies.

**The Data Sample**

- HST/WFC3 multi-wavelength coverage of 37 galaxy clusters.
- Clusters located at an intermediate redshift range: \(0.18 < z < 0.66\), with a median \(z \approx 0.44\).
- The F606W (visual; \(\lambda_p = 588.7\) nm) and F160W (near-IR; \(\lambda_p = 1536.9\) nm) bands are selected to effectively straddle the 4000 Å break, the characteristic SED feature of red-sequence galaxies.
- Subsample of 19 galaxy clusters imaged in these two bands considered in this study.

**Red-Sequence Fits**

To isolate the color-magnitude locus of early-type galaxies, cluster galaxies are visually inspected.

Elliptical S0 Spiral Irregular

Red Sequence Blue Cloud

Morphologically-selected red-sequence galaxies are then robustly fit using a linear relation.

Shown above, the progressive build-up of the red sequence of a galaxy cluster from the Illustris simulation. See C. Engler’s poster.

**Red-Sequence Parameter Evolution**

- Apparent Color
- Slope
- Redshift
- Intrinsic Scatter

With increasing redshift...

- The apparent color of red-sequence galaxies shifts towards the red. This is a combined effect of using fixed-wavelength bandpasses in an expanding Universe.
- No evident evolution of the red-sequence slope.
- The scatter of the red sequence increases. This is possibly an indication of the progressive build-up of the red sequence with time.

**Red-Sequence Models**

Color evolution models are constructed based on synthetic SEDs of stellar populations from Maraston (1998, 2005).

**Properties of the SEDs:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tested values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formation mechanism</td>
<td>(\tau = 0.1) Gyr</td>
</tr>
<tr>
<td>Formation redshift</td>
<td>(z_f = 2, 3, 5)</td>
</tr>
<tr>
<td>Metallicity</td>
<td>(Z = 0.5, 1.0, 2.0 Z_\odot)</td>
</tr>
<tr>
<td>IMF</td>
<td>Salpeter, Kroupa</td>
</tr>
<tr>
<td></td>
<td>Single, instantaneous burst: (\tau = 0) Gyr.</td>
</tr>
<tr>
<td></td>
<td>Exponentially-declining SFR: (\tau = 1) Gyr.</td>
</tr>
</tbody>
</table>

**Data vs models (Salpeter IMF):**

- Best model: \(Z = 1.0 Z_\odot, z_f = 3, \tau = 1\) Gyr

Red-sequence galaxies appear to be broadly characterized by stellar populations of solar metallicity. However, we are unable to pinpoint with precision their characteristic ages.