Spectrophotometric properties of cluster galaxies: galaxy evolution and cluster structure at $z > 0.8$

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Motivation

- Tight Red-Sequence (RS) at $z \leq 1.5$
  $\Rightarrow$ cluster early-type galaxies are already in place at
  $\sim 4$ Gyr after the Big-Bang

- How do luminous/massive early-type galaxies form at $z > 1.5$?

- How do they suppress their star formation?

- What role does the environment play in their evolution and the formation of the RS?

- Answering the above questions requires a detailed analysis of the star formation history (SFH) of cluster galaxies at $z > 1$
  $\Rightarrow$ At $z > 1$, galaxy transformations and evolution are expected to be more important

- A large sample of galaxy clusters at $z > 1$ is needed to overcome cluster-to-cluster variations and statistical uncertainties

The Red-Sequence at $z \sim 1.4$
(Lidman et al. 2008; Hilton et al. 2009)

First appearance of the Red-Sequence in protoclusters at $2 \leq z \leq 3$
(Kodama et al. 2007)

Massive galaxies at $z \sim 2$
(Cimatti et al. 2004; Glazebrook et al. 2004)
RXJ0152-13

z = 0.84

Eastern Group

Northern Subcluster

Southern Subcluster


dark matter

ACS mosaic of 4 HST/ACS pointings: r (8 orbits), I (8 orbits), z (8 orbits)
Multi-wavelength Data set

Cluster in ACS intermediate-redshift cluster sample (P.I.: H. Ford)

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Redshift</th>
<th>Imaging</th>
<th>Spectroscopy</th>
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<tbody>
<tr>
<td>RXJ0152-13</td>
<td>0.837 (102)</td>
<td>HST (i,r,z)</td>
<td>Chandra</td>
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</tbody>
</table>

Current sample of spec confirmed members: 134
(32 new members: Demarco et al., in prep)

\[ \sigma_{V,134} \sim 1700 \text{ km/s} \]
RXJ0152-13: the cluster red-sequence

76 non [OII] members in Red-Sequence

SofI + ACS photometry

Demarco et al., in prep.
RXJ0152-13: the cluster red-sequence

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BBRS: Bright-Blue Red-Sequence (10)

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BGRS: Bright-Green Red-Sequence (15)

SofI + ACS photometry  Demarco et al., in prep.
RXJ0152-13: the cluster red-sequence

- 76 non [OII] members in Red-Sequence
- BBR: Bright-Blue Red-Sequence (10)
- BGRS: Bright-Green Red-Sequence (15)
- BRRS: Bright-Blue Red-Sequence (12)

SofI + ACS photometry

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RXJ0152-13: the cluster red-sequence

76 non [OII] members in Red-Sequence

BBRS: Bright-Blue Red-Sequence (10)
BGRS: Bright-Green Red-Sequence (15)
BRRS: Bright-Blue Red-Sequence (12)
FBRS: Faint-Blue Red-Sequence (9)

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SofI + ACS photometry
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FGRS: Faint-Green Red-Sequence (11)
FRRS: Faint-Red Red-Sequence (10)

SofI + ACS photometry

Demarco et al., in prep.
RXJ0152-13: the extreme ends of its RS

More prominent Balmer features in FBRS galaxies compared to BRRS galaxies.
RXJ0152-13: SFH in the RS

Spectrophotometric fitting

\[ T_{SFR}(T, \tau) = \frac{\int_0^T (T - t) \psi(t, \tau) dt}{\int_0^T \psi(t, \tau) dt}, \]

\[ \psi(t, \tau) = \frac{1}{\tau^2} \cdot t e^{-\frac{t}{\tau}} \]

T-\(t_{\text{fin}}\): lookback time to last star-forming episode (Gobat et al. 2008)

FBRS galaxies have younger ages and more extended SFH than BRRS galaxies

Demarco et al., in prep.
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Demarco et al., in prep.
RXJ0152-13: local DM density (DMD)

- BRRS
- FBRS

$\Sigma_{DM} = 20 \sigma_{DM}$

$\Sigma_{DM} = 5 \sigma_{DM}$

$\sigma_{DM} = 0.0057 \Sigma_c$; $\Sigma_c \sim 3650 M_\odot$ pc$^{-2}$

SFH determined by the environment

Massive galaxies in high and intermediate DMD regions

Nurture vs Nature

See Gobat’s talk

Jee et al. 2005; Blakeslee et al. 2006; Demarco et al., in prep.
RXJ0152-13: SFH as a function of local DM density

Younger ages and more extended SFH in cluster outskirts

Demarco et al., in prep.
RXJ0152-13: SFH as a function of local DM density

Younger ages and more extended SFH in cluster outskirts

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RXJ0152-13: SFH as a function of local DM density

Younger ages and more extended SFH in cluster outskirts

Demarco et al., in prep.
Two new SpARCS clusters confirmed at $z>1$

The SpARCS galaxy cluster survey: see Wilson’s talk

SpARCS J1616+55: $N_{\text{tot}}=10$ ; $N_{\text{sec}}=7$

SpARCS J1610+55: $N_{\text{tot}}=10$ ; $N_{\text{sec}}=7$

Both clusters in the ELAIS-N1 field
SpARCS J1616+55

- **Cluster**: (5 non [OII] + 1 [OII])
- **Field**: (1 non [OII] + 5 [OII])
- **AGN**: (1)

In GCLASS sample (see Muzzin's talk)

SpARCS J1610+55

Cluster (0 non [OII]+7 [OII])

Field (3 non [OII]+4 [OII])

High fraction of [OII] members

Conclusions

- Non [OII] galaxies in the extreme ends of the RS have different SFHs: bright/massive and red galaxies have older ages and a shorter star formation time scale than faint and blue galaxies (downsizing).

- Bright/massive and red galaxies in the RS are located in high density regions as opposed to faint and blue RS galaxies: environment should play a role in truncating and modulating the SFH of cluster galaxies.

- Two new SpARCS galaxy clusters at $z>1$. The one at $z=1.16$ in GCLASS. The one at $z=1.2$ has a high fraction of [OII] members, a low velocity dispersion, and a filamentary structure: more data needed for a more robust analysis against selection biases and low-statistic uncertainties.

- SpARCS clusters at $z>1$: paving the way for a better understanding of galaxy evolution, cluster structure and the formation of the RS.