EVOLUTION IN SOLITUDE:
Field Galaxies From Half the Age of the Universe to the Present

as part of The Gemini Observatory/Hubble Space Telescope Galaxy Cluster Project

Charity Woodrum
The Evolution of Bulge-dominated Field Galaxies from $z \approx 1$ to the Present

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Abstract

We analyze the stellar populations and evolutionary history of bulge-dominated field galaxies at redshifts $0.3 < z < 1.2$ as part of the Gemini/Hubble Space Telescope (HST) Galaxy Cluster Project (GCP). High signal-to-noise optical spectroscopy from the Gemini Observatory and imaging from the HST are used to analyze a total of 43 galaxies, focusing on the 30 passive galaxies in the sample. Using the size–mass and velocity dispersion–mass relations for the passive field galaxies we find no significant evolution of sizes or velocity dispersions at a given dynamical mass between $z \approx 1$ and the present. We establish the Fundamental Plane and study mass-to-light (M/L) ratios. The M/L versus dynamical mass relation shows that the passive field galaxies follow a relation with a steeper slope than the local comparison sample, consistent with cluster galaxies in the GCP at $z = 0.86$. This steeper slope indicates that the formation redshift is mass dependent, in agreement with “downsizing,” meaning that the low-mass galaxies formed their stars more recently while the high-mass galaxies formed theirs at higher redshift. The zero-point differences of the scaling relations for the M/L ratios imply a formation redshift of $z_{\text{form}} = 1.35^{+0.10}_{-0.09}$ for the passive field galaxies. This is consistent with the $(\text{H}\delta_A + \text{H}\gamma_A)'$ line index which implies a formation redshift of $z_{\text{form}} = 1.40^{+0.06}_{-0.18}$.

Key words: galaxies: evolution – galaxies: stellar content

Supporting material: data behind figure, figure set, machine-readable tables
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SCIENCE QUESTION

Nature vs. Nurture:
What Drives Galaxy Evolution?

Nature: Is there an intrinsic property of galaxies that drives their evolution?

Nurture: Does the environment of a galaxy influence its evolution?
We still use Hubble's classification scheme today - Ellipticals are called "early-type galaxies" and spirals are called "late-type galaxies" even though we now know this is not how galaxies evolve.
Elliptical Galaxies:
* Elongated spherical shape
* Contain very little gas and dust
* $10^5$ to nearly $10^{13}$ solar masses
* Made up of old stars

Spiral Galaxies:
* Flat round disc shape
* Contain gas and dust
* $10^9$ to $10^{12}$ solar masses
* Ongoing star formation
Imaging from *Hubble Space Telescope* in Low Earth Orbit

Spectroscopy from Gemini Observatory in Mauna Kea, Hawaii

Credit: NASA

Credit: Joy Pollard, Gemini Observatory
Figure 1: *Hubble Space Telescope* images of our sample of passive bulge-dominated field galaxies

Figure 2: *Hubble Space Telescope* images of our sample of emission line bulge-dominated field galaxies
Hot Gas Cloud

Continuous Spectrum

Emission Spectrum

Absorption Spectrum

Light Source

Spectroscope

Light
Size versus dynamical galaxy mass

* At a given mass, the passive field galaxies do not change in size between 8 billion years ago and the present
(a) $z = 0.018$ Perseus and A194 clusters
(b) $z = 0.89$ RXJ1226.9+3332 cluster
(c) $z \approx 0.7$ passive field
(d) $z \approx 1$ passive field
(e) $z \approx 0.7$ emission line field
(f) $z \approx 1$ emission line field

$\log \text{C}4668$

$\log \text{Fe}4383$

$\log (\text{H}\Delta + \text{H}\gamma)$
$\log M \sub{dyn} / L_B \left( [M/L]_\odot \right)$ vs $\log M \sub{dyn} \left( [M_\odot] \right)$

(a) $z = 0.68$

(b) $z = 0.89$

- $z = 0.024$ Coma cluster
- $z = 0.89$ RXJ1226.9+3332 cluster
- $z \approx 0.7$ passive field
- $z \approx 1$ passive field
- $z \approx 0.7$ emission line field
- $z \approx 1$ emission line field
The diagram shows the relationship between log Mass\textsubscript{dyn} (\(M_\odot\)) and Time since Big Bang (Gyr). The data points are color-coded and labeled with different values of \(z\text{form}\), indicating the formation redshift. The annotation notes \(z\text{form} = 7.9\) and \(z\text{form} = 8.9\) as significant points on the graph.

Nature: Is there an intrinsic property of galaxies that drives their evolution?
*The mass of a galaxy determines its formation redshift (“birthday”)*

Nurture: Does the environment of a galaxy influence its evolution?
*The environment causes differences in the stellar populations of bulge-dominated galaxies. Namely, the field galaxies are diverse from each other while the cluster environment produces more homogeneous populations of galaxies.*
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How do we determine distances to the galaxies?

Redshift