Leiden
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Virtual

European Astronomical
Society Annual Meeting
EWASS

The effect of the environment on the buildup and structural properties of the passive galaxies at 1<z<1.5

Jeffrey Chan

GOGREEN

Gemini Observations of Galaxies in Rich Early ENvironments

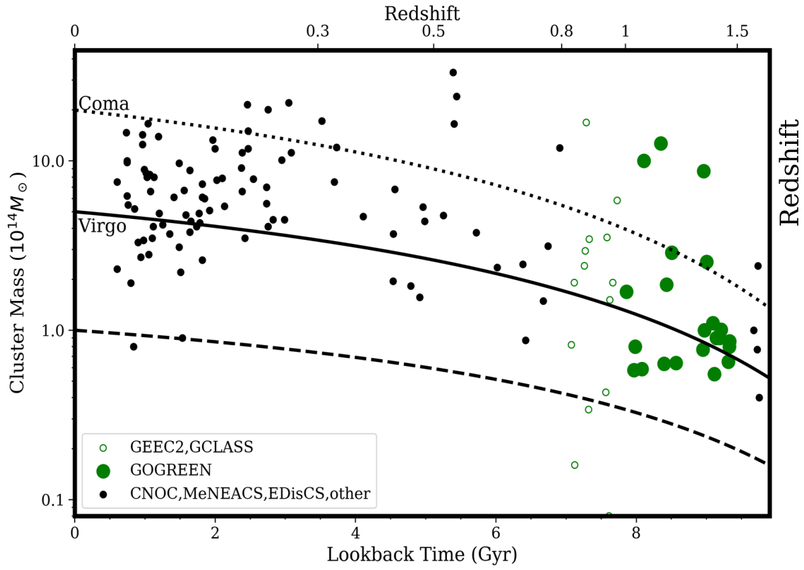
530 hrs of Gemini GMOS spectroscopy of galaxies in 21 groups & clusters at **1 < z < 1.5**
(PI: Michael Balogh) + **> 100 hrs** of deep imaging: ugrizYJK + HST

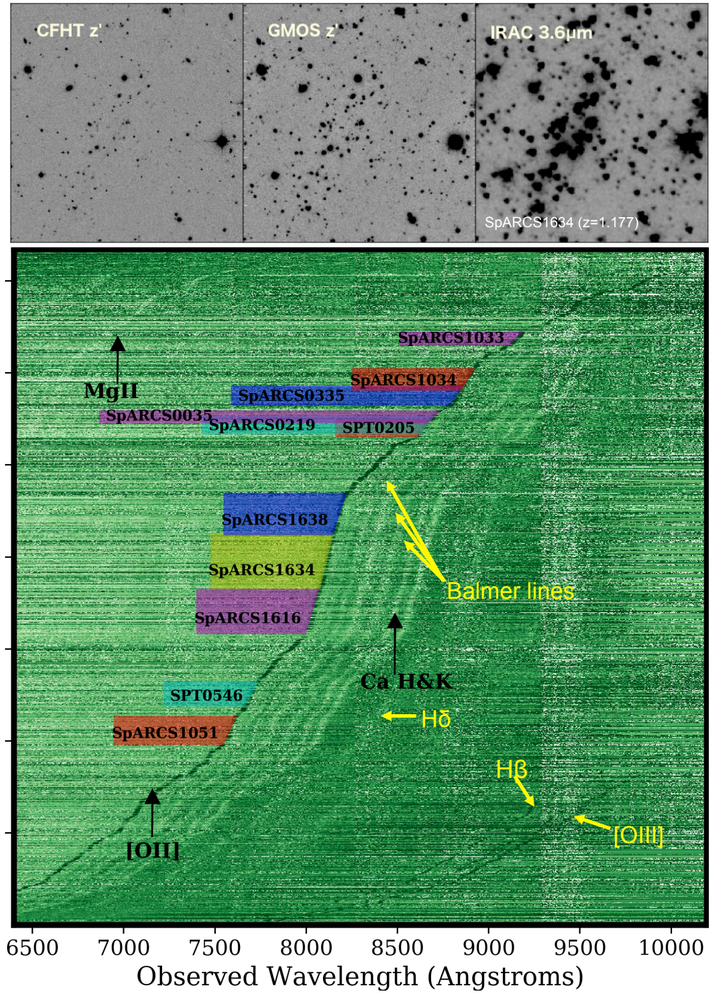
Unique features of GOGREEN:

1. Very deep, unbiased spectroscopy for all galaxy types, probing stellar masses down to 10^{10} M_{Sun} at $1 < z < 1.5$
2. Wide range of halo masses, targeting 21 systems ranging from groups (10^{13} M_{Sun}) to massive clusters (10^{15} M_{Sun})

GOGREEN Science goals:

- Environmental-Quenching of Low Mass Galaxies
- Hierarchical Assembly of Baryons
- Cluster Dynamics and Masses
- Morphologies and stellar populations





GOGREEN

Gemini Observations of Galaxies in Rich Early ENvironments

The Team

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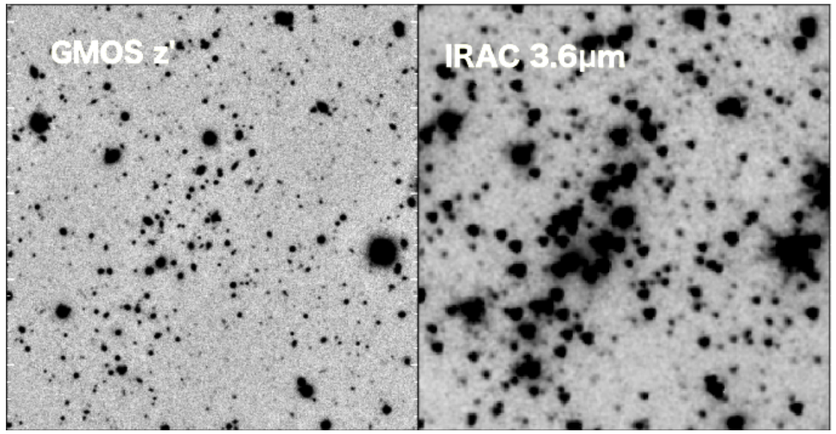
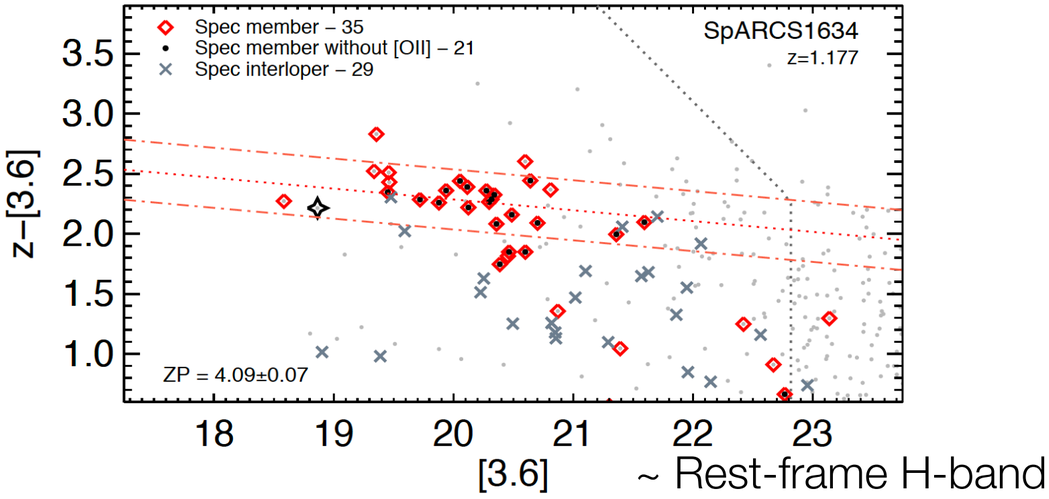
Survey description: Balogh+17
Public data release planned this year

http://gogreensurvey.ca/

Red sequence Luminosity Function of GOGREEN clusters

- Goal: Study the build up of the **faint end** of the red sequence galaxies in 7 (out of 21) GOGREEN clusters with the **RS luminosity functions (RS LF)** and compare to a low-z cluster sample (EDisCS):

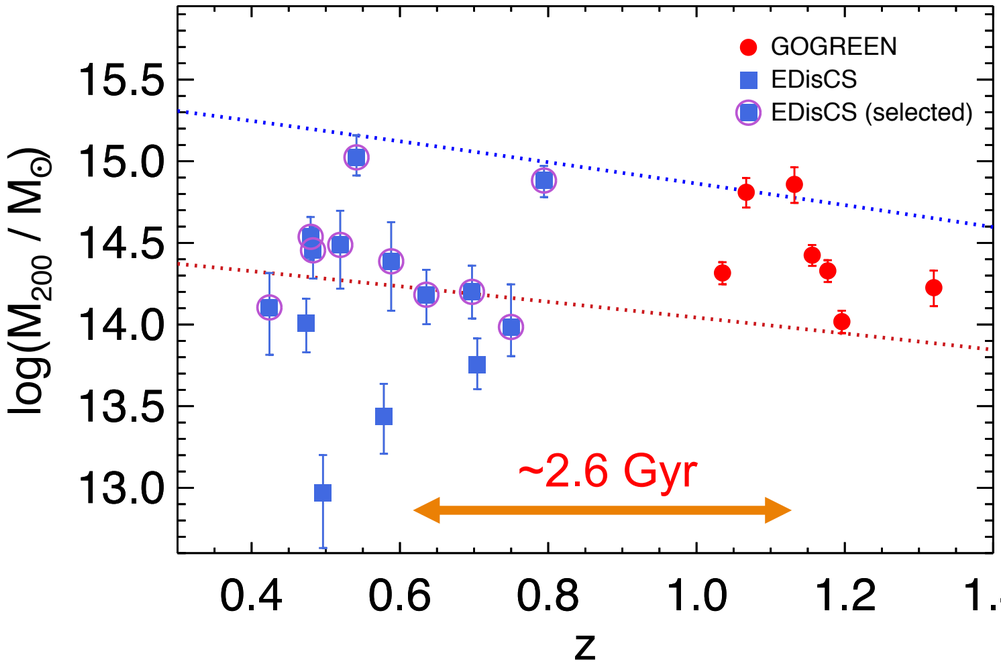




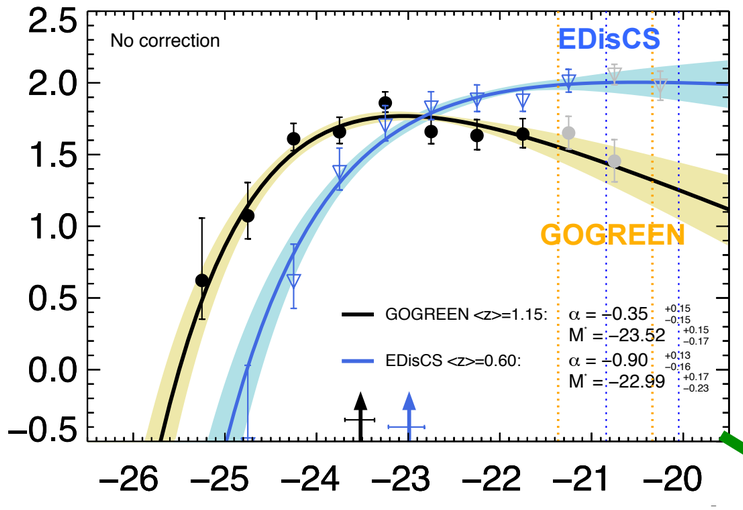
arxiv.org/abs/1906.10707
Chan+19, ApJ, 880,119

High-z sample:
- 7 GOGREEN clusters (1.0 <z <1.3)

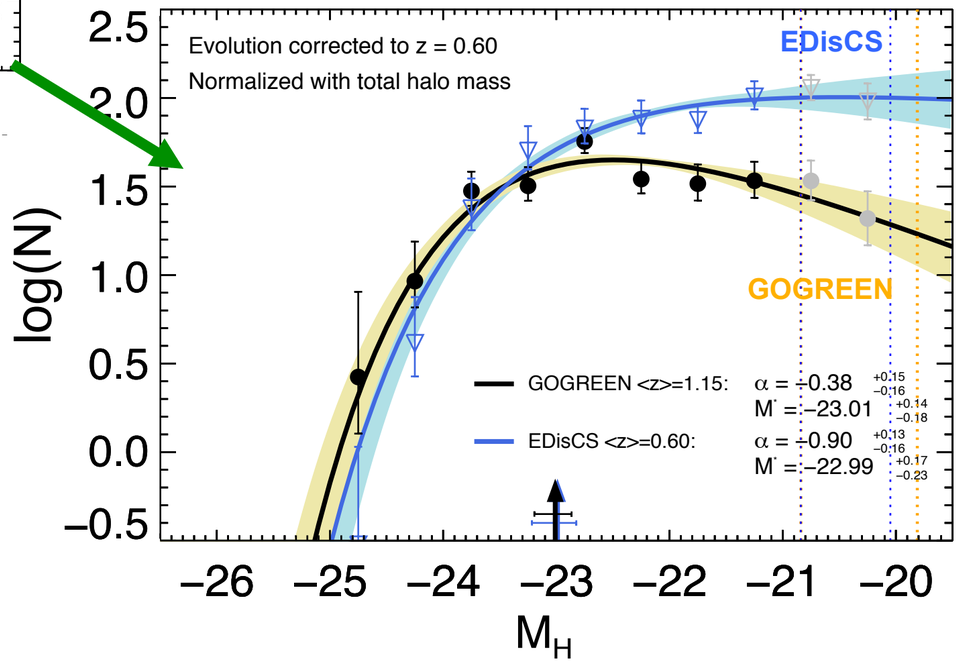
Low-z sample:
- 14 EDisCS clusters (0.42 < z < 0.79)



RSLF - Comparison with EDisCS



Evolution correction applied +
Normalized with total halo mass

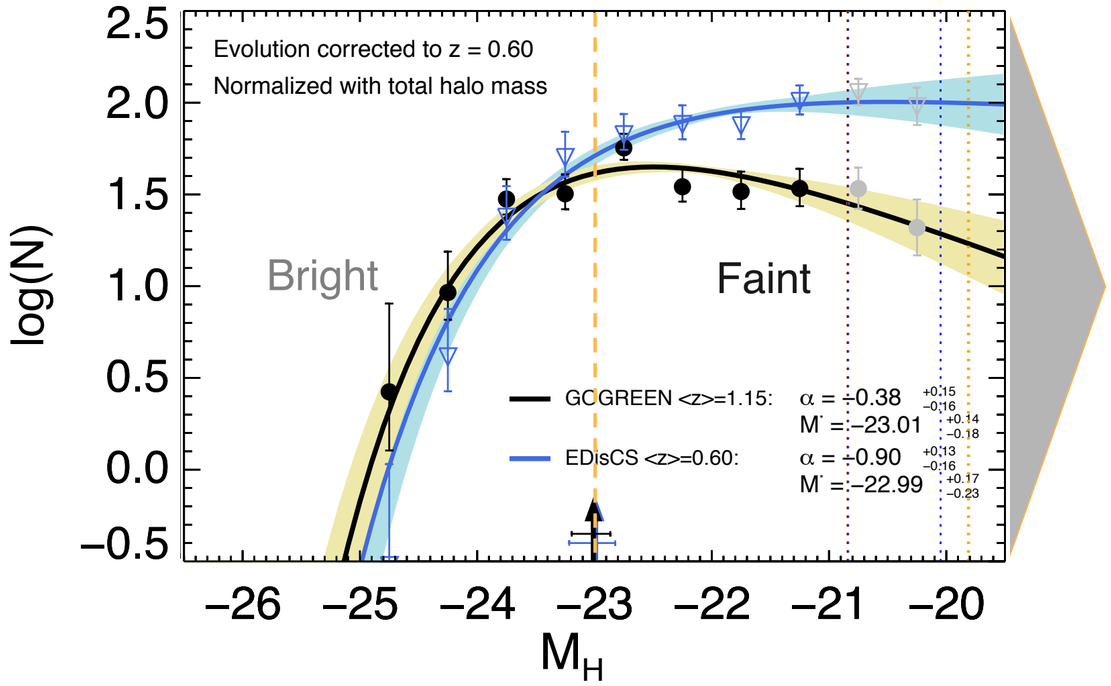


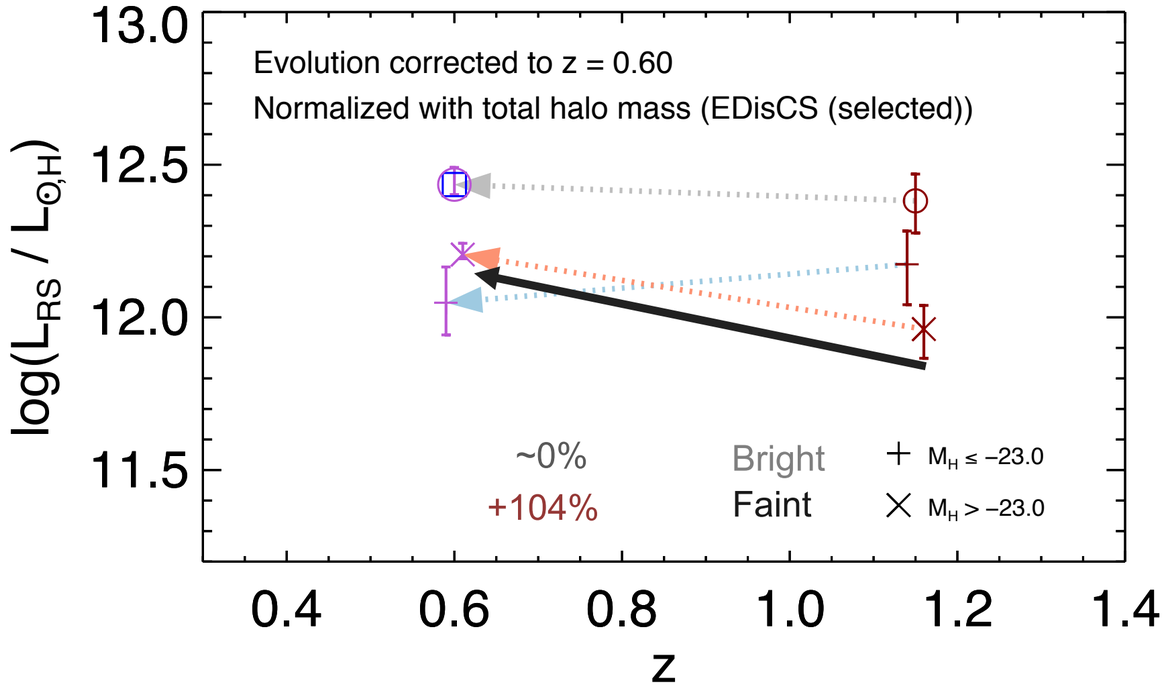
- Goal: Study the build up of the faint end of the red sequence galaxies in 7 GOGREEN clusters with the RS luminosity functions (RS LF) and compare to a low-z cluster sample (EDisCS)

- High-z sample:
- 7 GOGREEN clusters (1.0 <z <1.3)
- Low-z sample:
- 14 EDisCS clusters (0.42 < z < 0.79)

- Shallow faint end slope of α ~ -0.4 from the GOGREEN stack compared to the EDisCS stack of α ~ -0.9

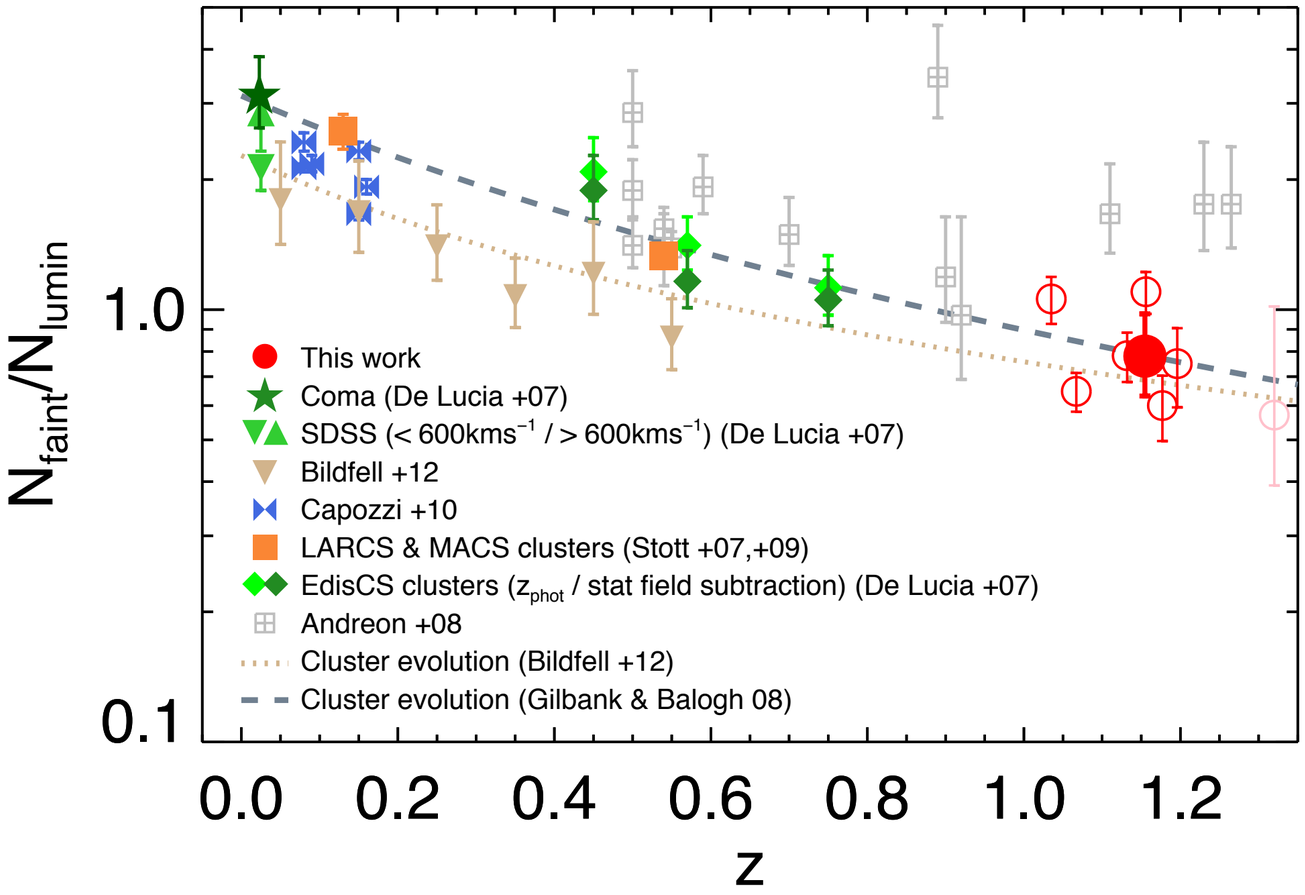
RSLF – Total RS luminosities





- The mean RS luminosity of the faint end grows by 2X from z~1.15 to z~0.6, while the bright end is already in place

Red sequence Luminosity Function of GOGREEN clusters



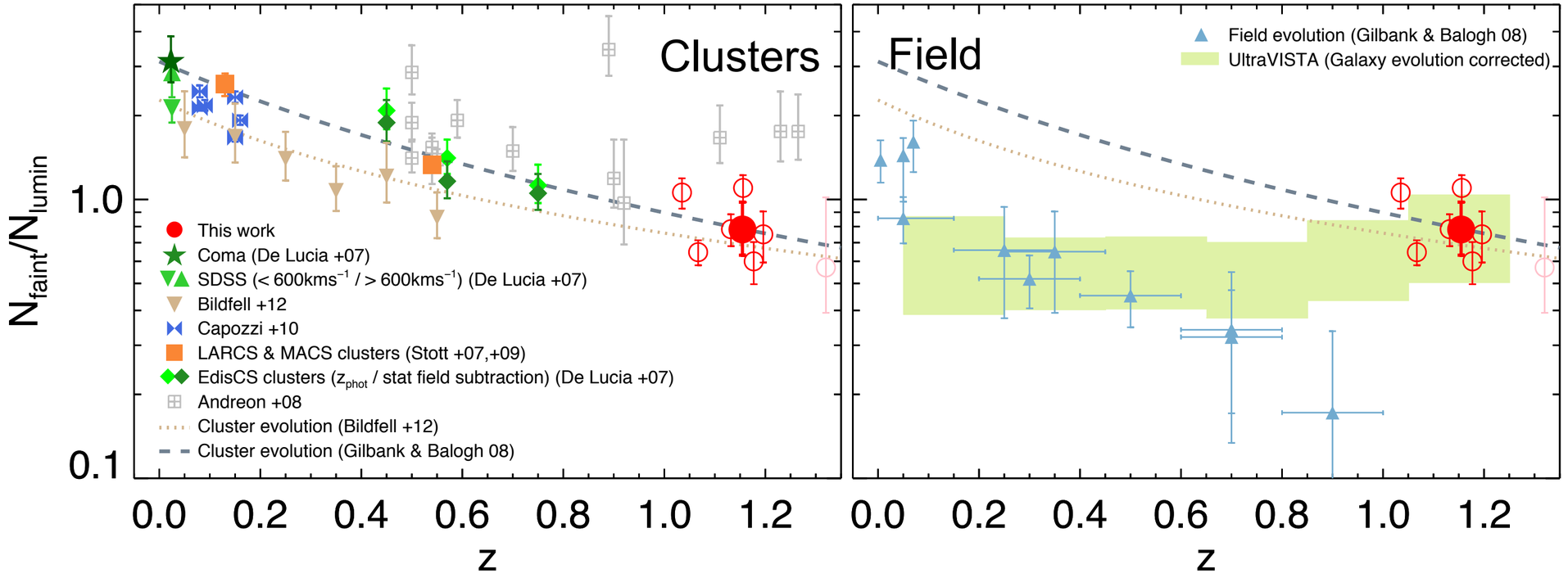
arxiv.org/abs/1906.10707
Chan+19, ApJ, 880,119

- To trace the evolution over time, we derive the red sequence faint-to-luminous ratio (N_{faint} / N_{bright}) in rest-frame V-band (instead of H) (De Lucia+04,07):

- Faint RS galaxies N_{faint}: $-20 < M_V <= -18.2$ at z=0
- Bright RS galaxies N_{bright}: $M_V > -20$ at z=0

- Cluster faint-to-luminous ratios show a strong redshift dependence
- Suggest a gradual build up of the faint end of the RS over time
- … since the bright end is mostly in place

Red sequence Luminosity Function of GOGREEN clusters

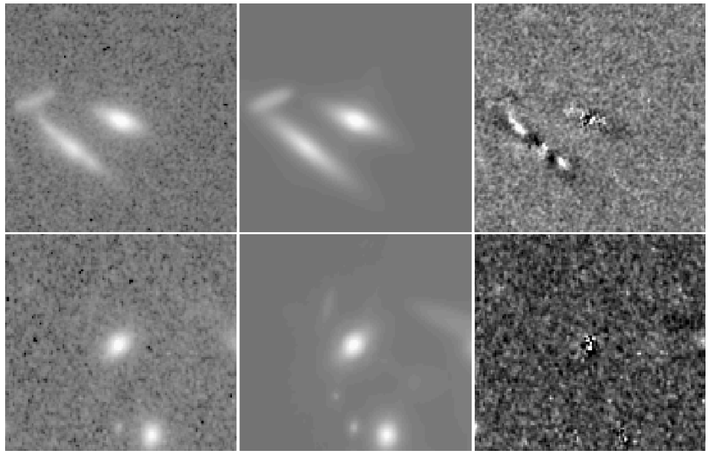


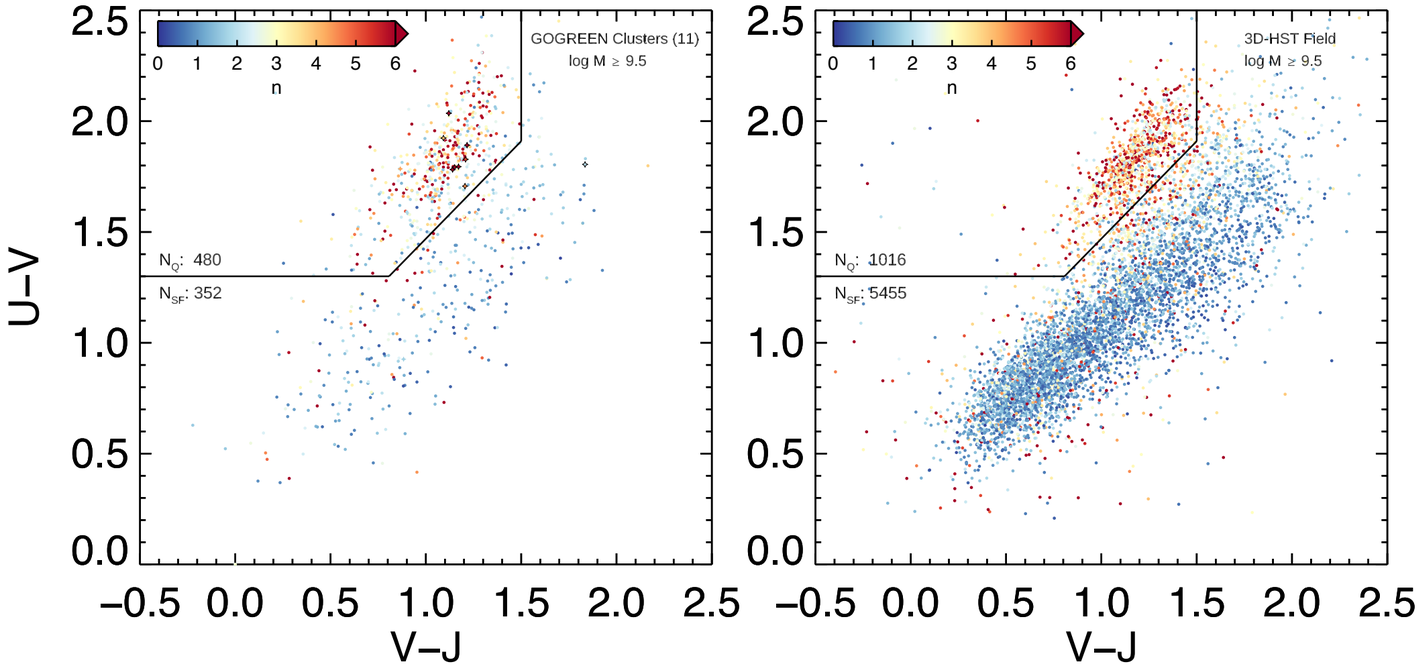
- Field ratios show a much milder redshift dependence -> Environmental effects at work
- Clusters at z~1.15 show consistent faint-to-luminous ratios as the field (See also, SMF results from van der Burg+20)
- Faint galaxies already experience environmental effects at this redshift

Morphologies of GOGREEN galaxies

- Goal: Compare the morphologies and structural properties between cluster and field galaxies to study the effect of environment on galaxy morphology at z>1

Structural parameters derived from HST/WFC3 F160W imaging using Sersic fitting with GALAPAGOS





- Mass-size relations
- **Axis ratio distributions (Most accurate!)**
- Visual morphologies
- etc …

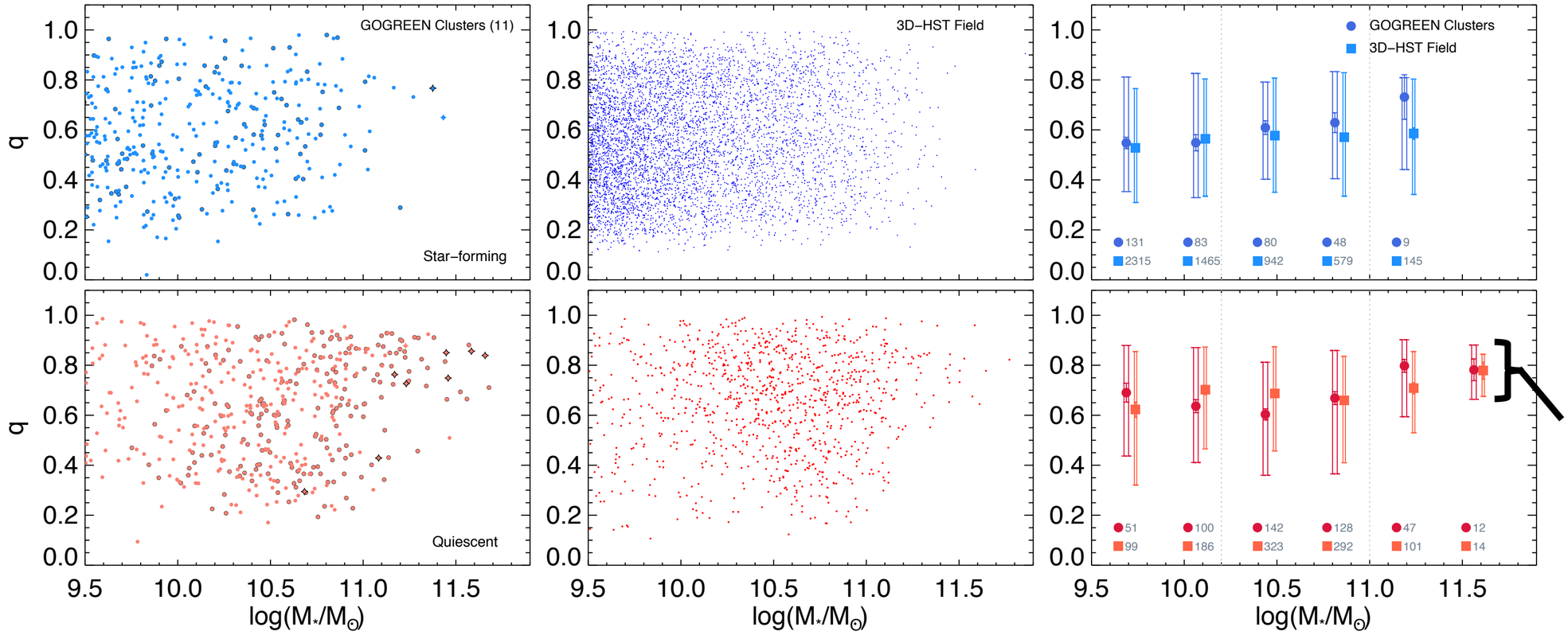
Cluster sample:

- 11 GOGREEN clusters (1.0 <z <1.4) (**$N_{cluster}$: 832)**

Field sample:

- CANDELS/3D-HST (**$N_{CANDELS/3DHST}$: 6471)**

Cluster vs. Field – Axis ratio distributions

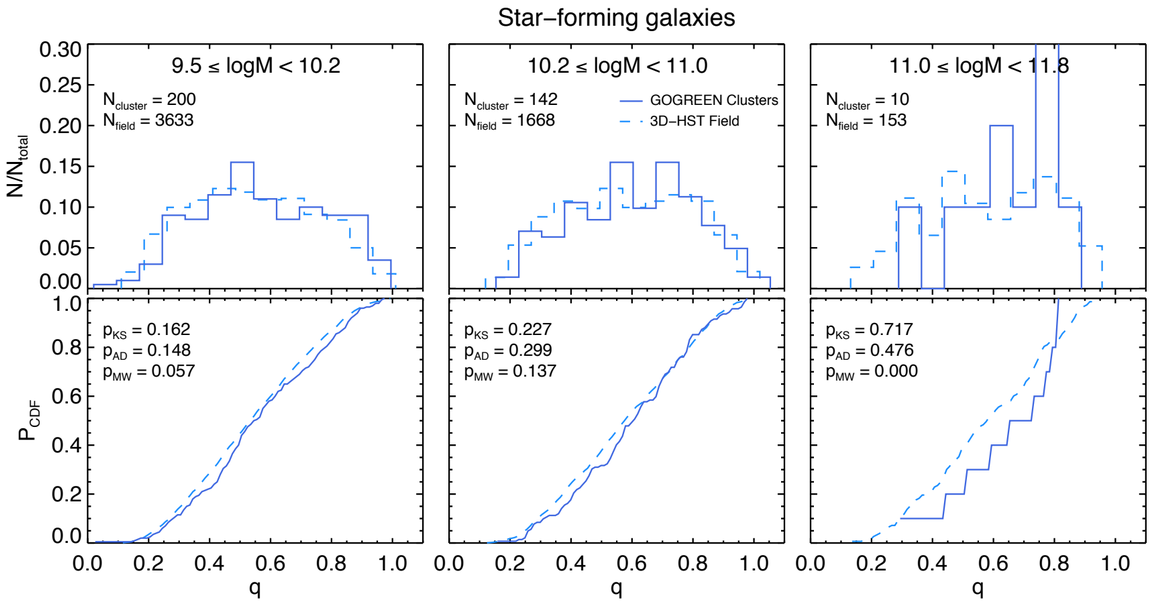


16th and 84th percentiles

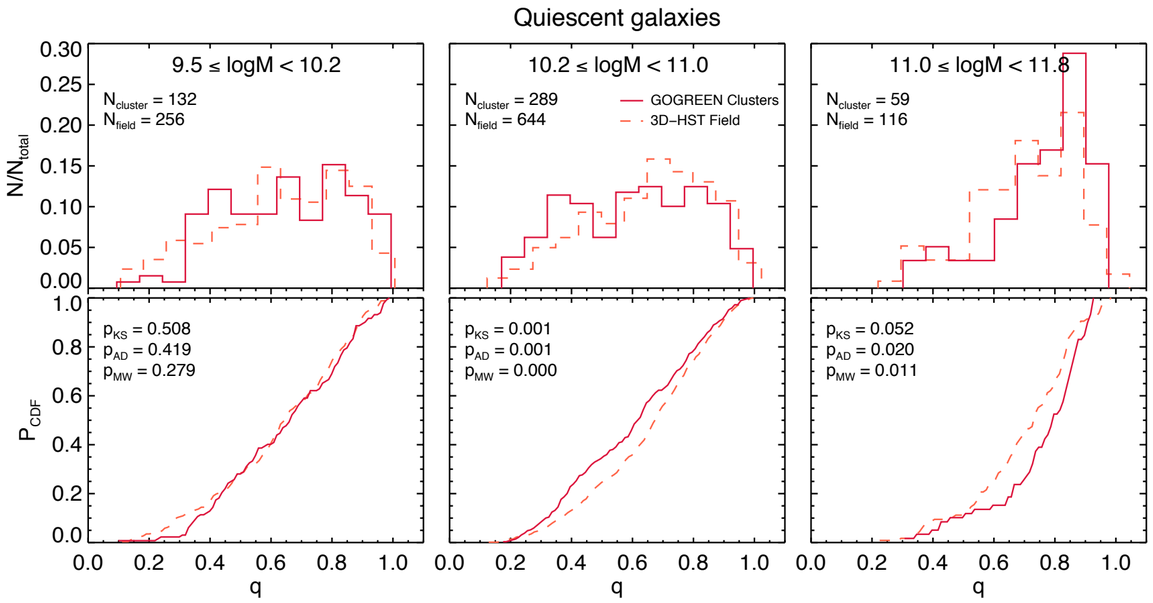
- Median *q* increases with mass for both SF and Q
- log(*M*) ≥ 11 Q galaxies are round and have narrower *q* distribution, similar to low-z
- Cluster vs. field differences: logM ~ 10.5 and logM ~ 11.0

Chan+20, in prep.

Cluster vs. Field – Axis ratio distributions



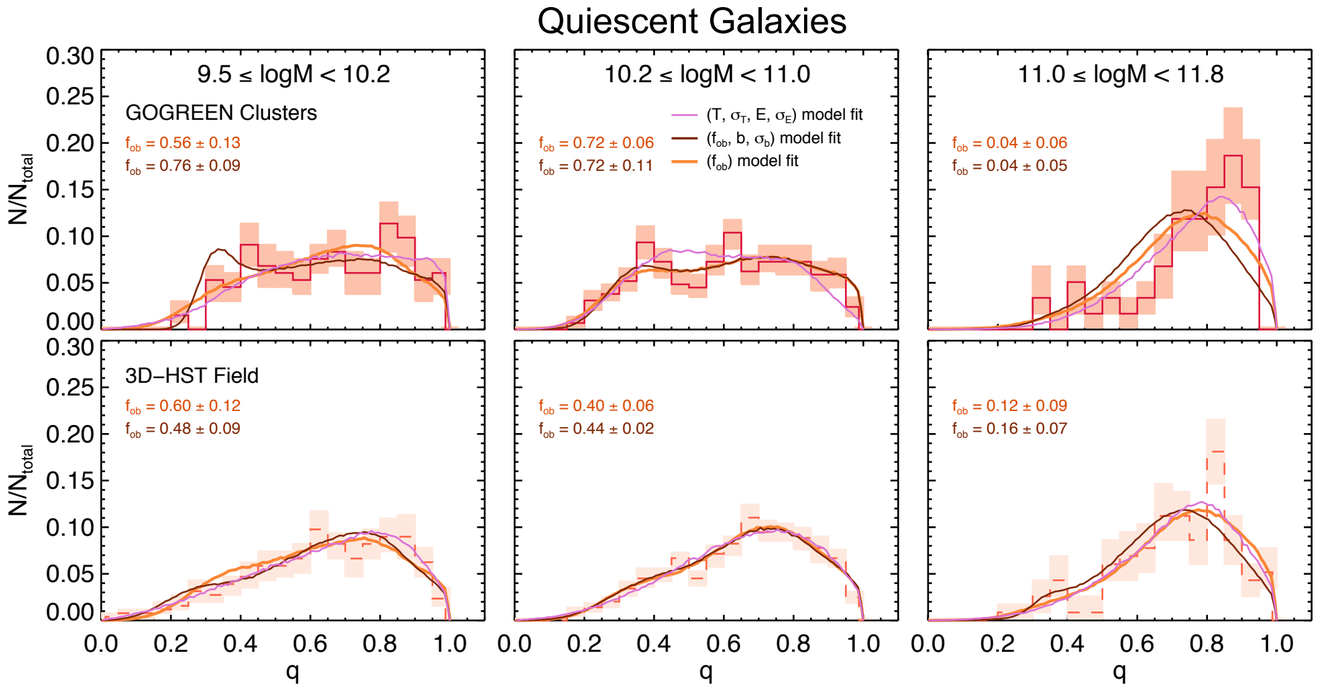
- Distribution of SF galaxies in cluster and the field are consistent with each other



- No obvious differences in the low-mass bin
- Cluster distribution in the middle mass bin shows broader q and “double-peak” feature
- Cluster distribution at high mass show larger median q

Constraining the fraction of oblate ("disky") quiescent galaxies in cluster and field

- Projected axis ratio distributions can be used to reconstruct the intrinsic shapes of a galaxy population (Holden+12, Chang+13, van der Wel+14)
- Assuming a **triaxial** set + an **oblate** set of galaxies with Gaussian distribution of intrinsic parameters
- f_{ob}: the fraction of oblate galaxies in the population

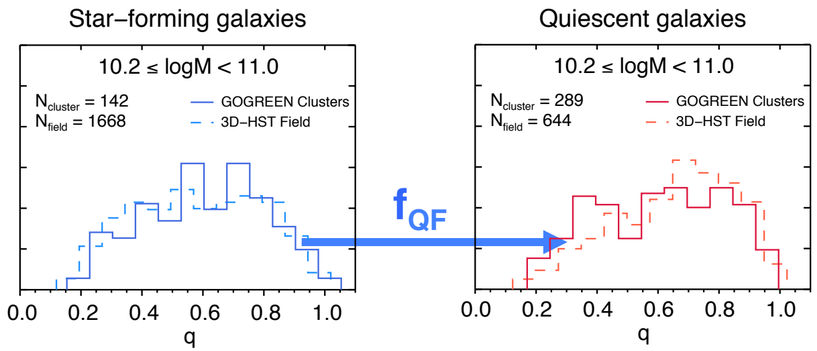


- **Middle mass bin** – Cluster have more disky galaxies than the field (f_{ob} = 0.72 vs 0.40)
- No evidence for a difference between the intrinsic shape of the oblate component (consistent *b*=0.29) in clusters and the field
- The single-component model cannot match the broad feature present in the cluster sample
- **High mass bin** – Massive galaxies in clusters intrinsically rounder (E=0.39 vs. 0.46)

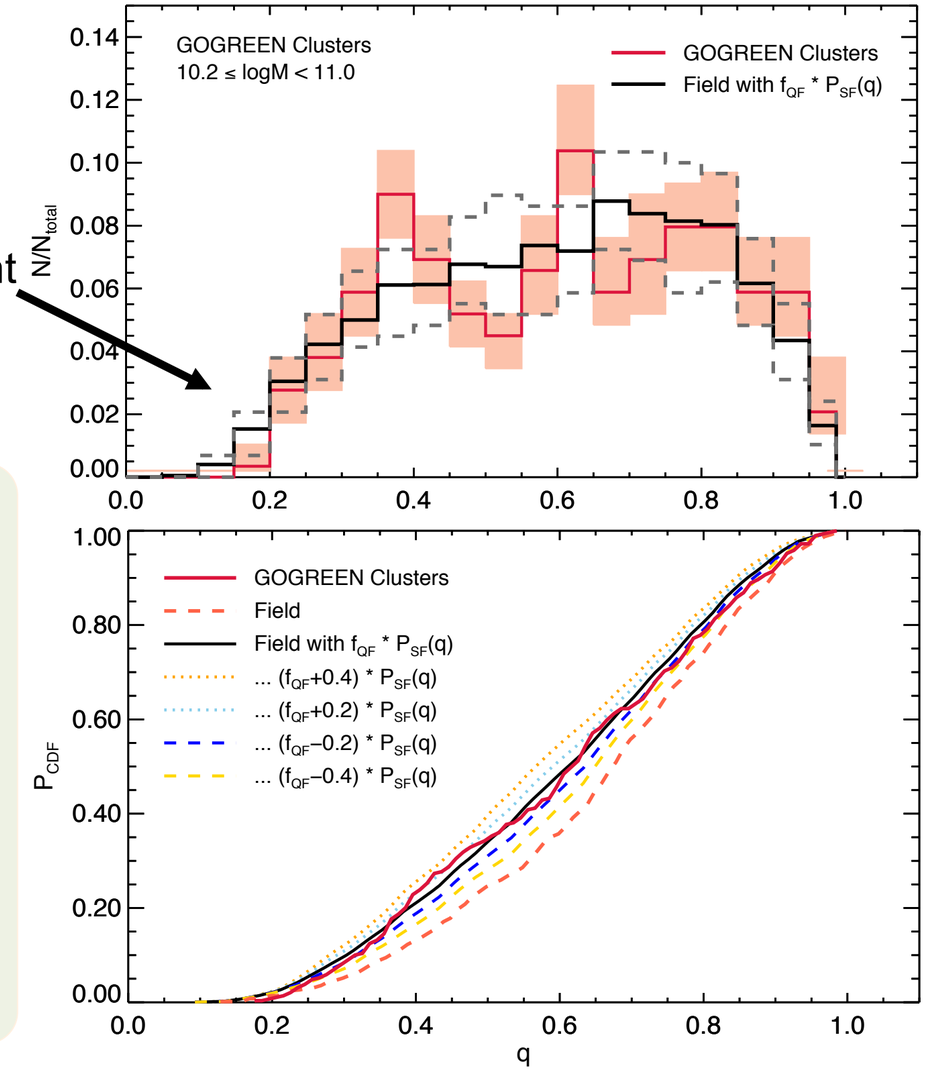
Relation between environmental quenching and morphological transformation

- Combine the axis ratio results with the quenched fractions to study the excess quenching in the cluster sample to test the extent of morphological transformation:
- Cluster QF: **0.67**, Field QF: **0.28**
- Define $f_{QF} = (QF_{cluster} - QF_{field}) / QF_{cluster} \sim 0.6$, i.e. 60%

- Inject random SF galaxies from the field distribution into the Quiescent q field distribution until the resultant distribution has $f_{QF} * P_{SF}(q)$ (q from SF ~60%)



The resultant model (black)



- The resultant toy model distribution is consistent with the observed distribution ($p_{KS} \sim 0.8$)
- ~60% of SF galaxies is, interestingly, the best match
- Consistent with no morphological transformation after being quenched

Summary

- We derived red-sequence LFs and faint-to-luminous ratios for 7 GOGREEN clusters at $1.0 < z < 1.3$
- The stacked red sequence LF of 7 GOGREEN clusters at $1.0 < z < 1.3$ shows a gradual decrease towards the faint end with $\alpha \sim -0.4$ and $M_H \sim -23.5$
- Comparing with EDisCS at z~0.6 shows that :
  - Most of bright galaxies already exist at z ~1.15
  - Build-up of the faint end from α~-0.4 to α~-0.9
  - The faint end grow by ~ a factor of 2 in L_{RS} while the bright end show ~no growth
- There is a general trend of decreasing faint-to-luminous ratio with increasing z
- Suggests a gradual build up of the faint red sequence population since z~1.2
- Cluster ratios are consistent to the field at z~1 -> Faint galaxies experience environmental effects already

Chan+19, ApJ, 880,119

- We compare the axis ratio distributions for 11 GOGREEN clusters at $1.0 < z < 1.4$ to a field sample to investigate the effect of the environment on galaxy structural properties.
- The median *q* of both star-forming galaxies and quiescent galaxies in clusters and the field increases with mass. Massive quiescent galaxies with $\log(M/M_{\odot}) \geq 11$ in both clusters and the field are on average rounder and and have a narrower *q* distribution than their low mass counterparts
- The *q* distribution of star-forming galaxies in clusters and field are consistent with each other
- The *q* distribution of quiescent galaxies in clusters and the field are distinct
- The difference between the cluster and the field sample is consistent with the existence of an excess population of flattened, disk-like galaxies in clusters

Chan+20, in prep.