Clustering of Passive vs. Star-forming galaxies

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Papers

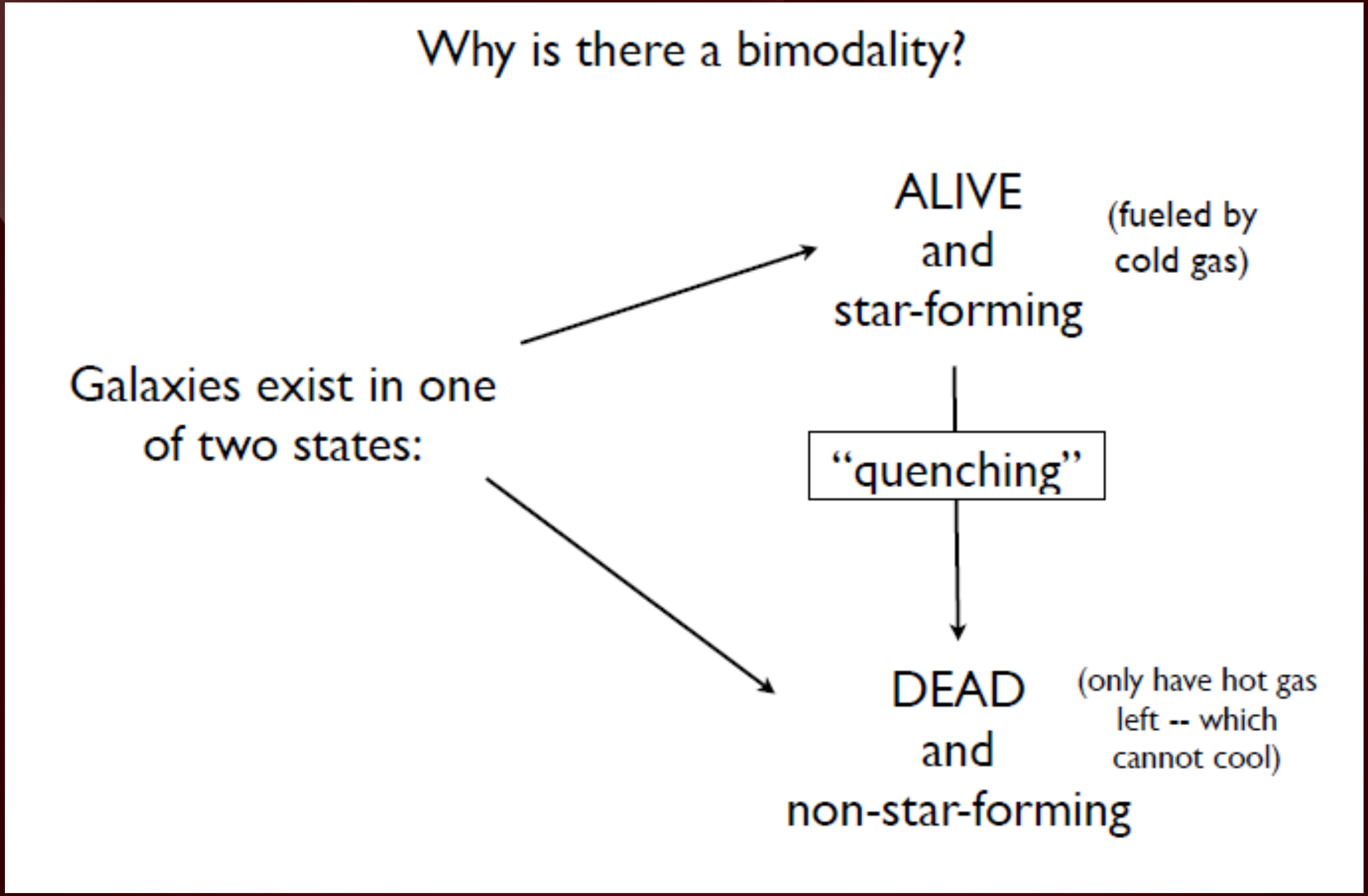
Hartley et al. 2013

Studying the emergence of the red sequence through galaxy clustering:
host halo masses at $z > 2$

Bielby et al. 2014

The WIRCam Deep Survey
II. Mass selected clustering

Bimodality



Why is there a bimodality?

Galaxies exist in one of two states:

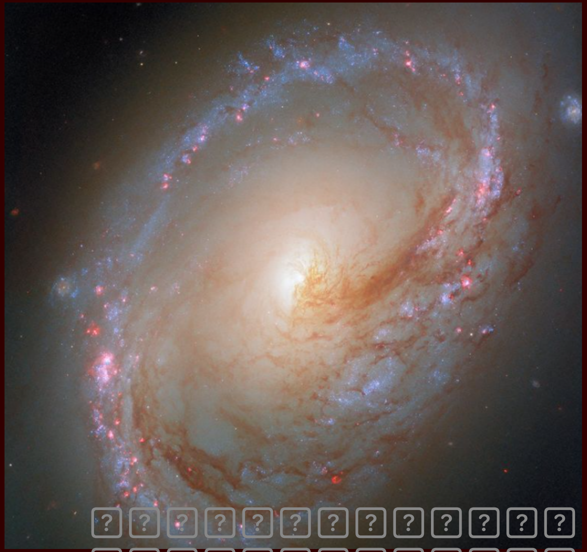
ALIVE
and
star-forming

(fueled by cold gas)

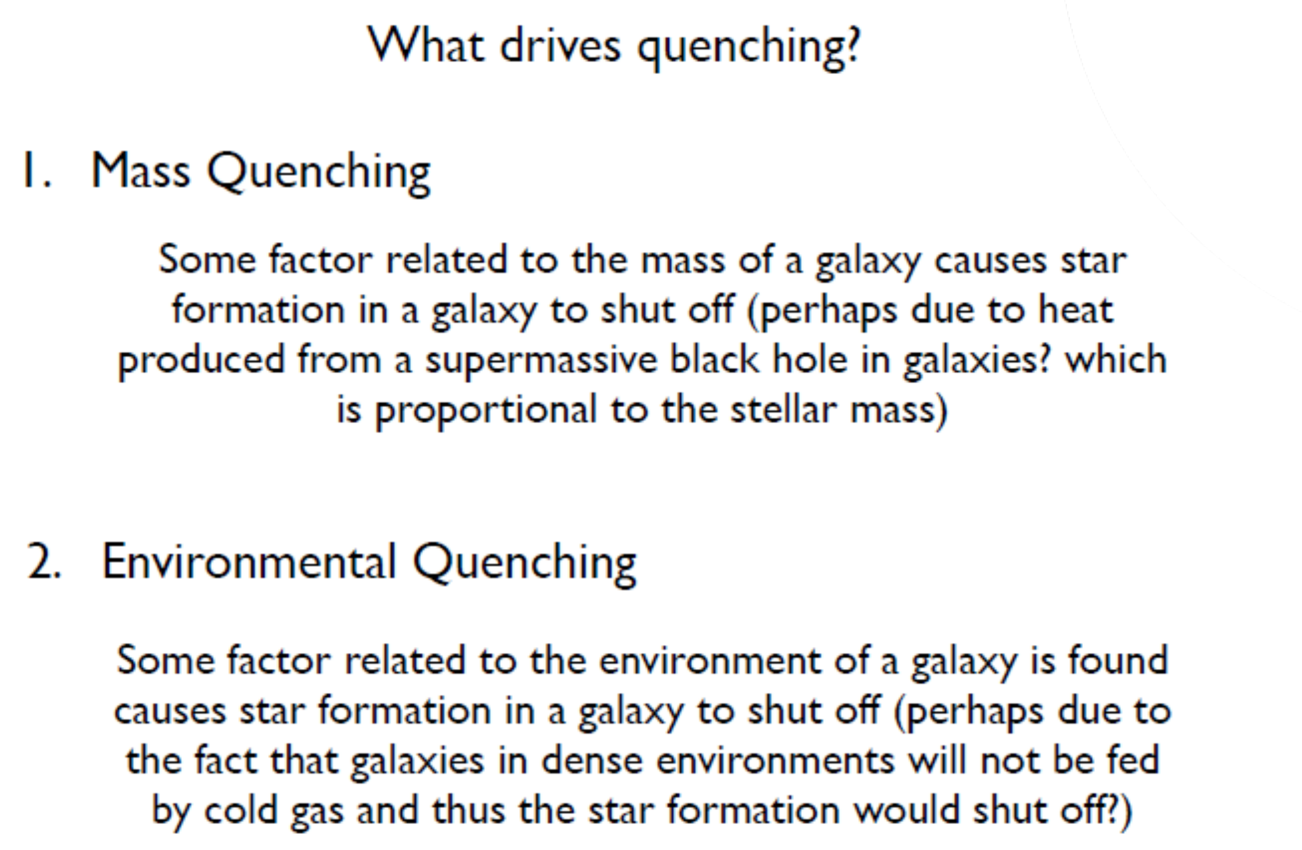
"quenching"

DEAD
and
non-star-forming

(only have hot gas left -- which cannot cool)



Quenching



What drives quenching?

1. Mass Quenching

   Some factor related to the mass of a galaxy causes star formation in a galaxy to shut off (perhaps due to heat produced from a supermassive black hole in galaxies? which is proportional to the stellar mass)

2. Environmental Quenching

   Some factor related to the environment of a galaxy is found causes star formation in a galaxy to shut off (perhaps due to the fact that galaxies in dense environments will not be fed by cold gas and thus the star formation would shut off?)

Hartley et al. 2013

“Hot halo” model

When dark matter grows in mass, the incoming gas gets shock heated and can not cool fast enough to form stars.

Hartley et al. 2013

Before the paper:

Passive galaxies consistently cluster in more massive dark matter haloes than star-forming galaxies, up to $z=2$. (Williams et al. 2009 and Hartley et al. 2010)

In the paper:

- First halo mass measurements for passive galaxies at $z > 2$.
- First estimates for low-mass passive galaxies out to $z \sim 1.5$.
- Consistent measurements across $0.3 < z < 3.36$.
- Goal: test whether a universal halo mass threshold for quenching exists.

Data

➔ **UKIDSS Ultra Deep Survey (UDS) DR8**

Deepest near-infrared survey at the time → enables $z > 2$ measurements

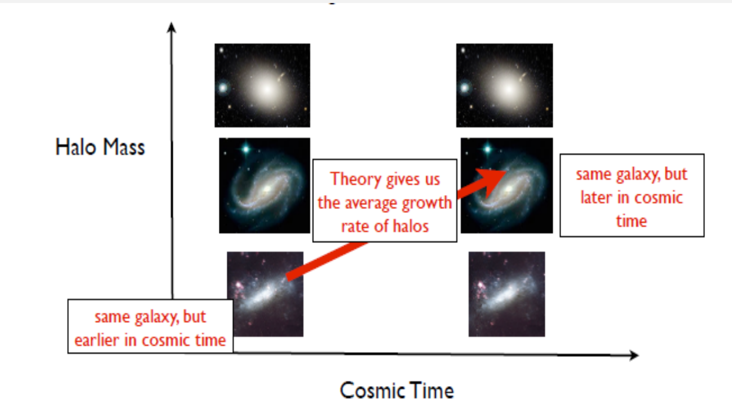
0.62 deg^2 — multiwavelength coverage: u-band to Spitzer/IRAC

➔ **Stellar masses** measured via SED fitting

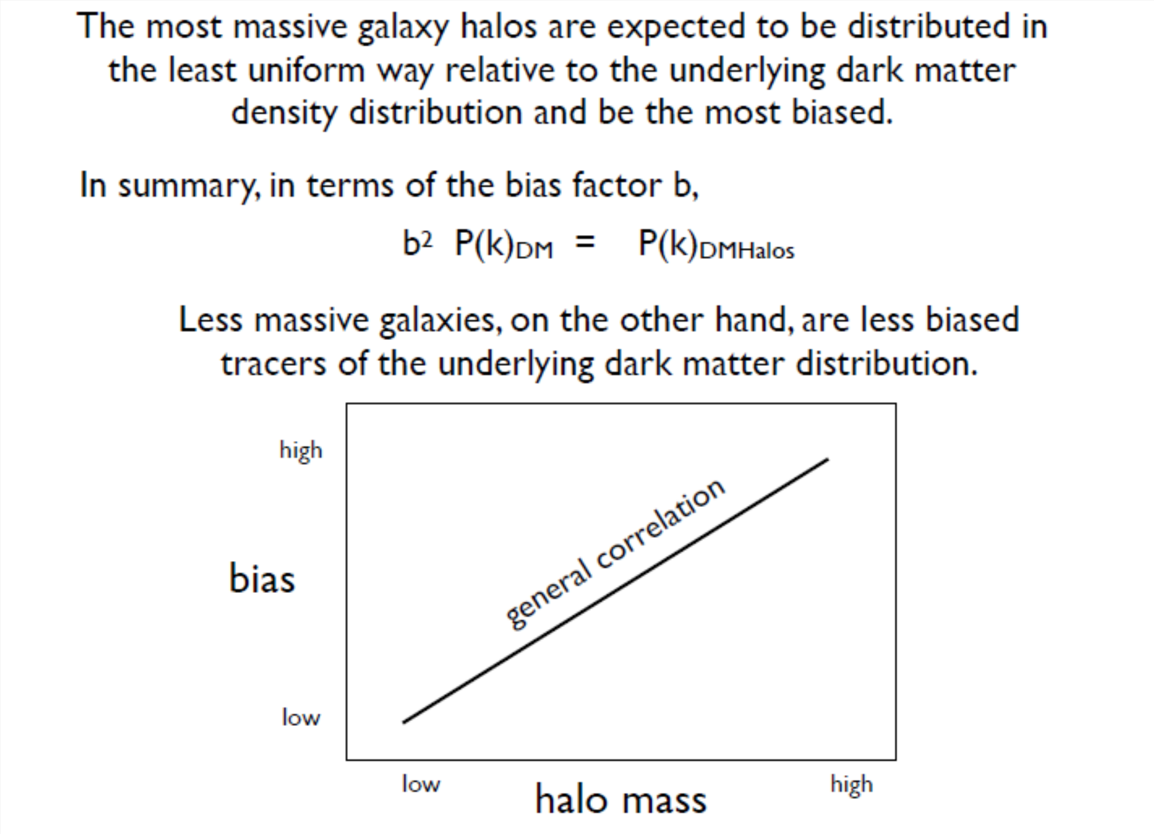
➔ **Photometric redshifts** validated against ~5500 spectra

➔ AGN removed using X-ray and radio data

➔ Passive/star-forming split via **UVJ colour selection.**



Clustering as DM halos tracers



The most massive galaxy halos are expected to be distributed in the least uniform way relative to the underlying dark matter density distribution and be the most biased.

In summary, in terms of the bias factor b,

$$b^2 \; P(k)_{DM} = P(k)_{DMHalos}$$

Less massive galaxies, on the other hand, are less biased tracers of the underlying dark matter distribution.

Bias:

How much more clustered galaxies are compared to the underlying dark matter.

Halo masses estimated from galaxy **clustering** via the **bias** parameter.

More massive halos

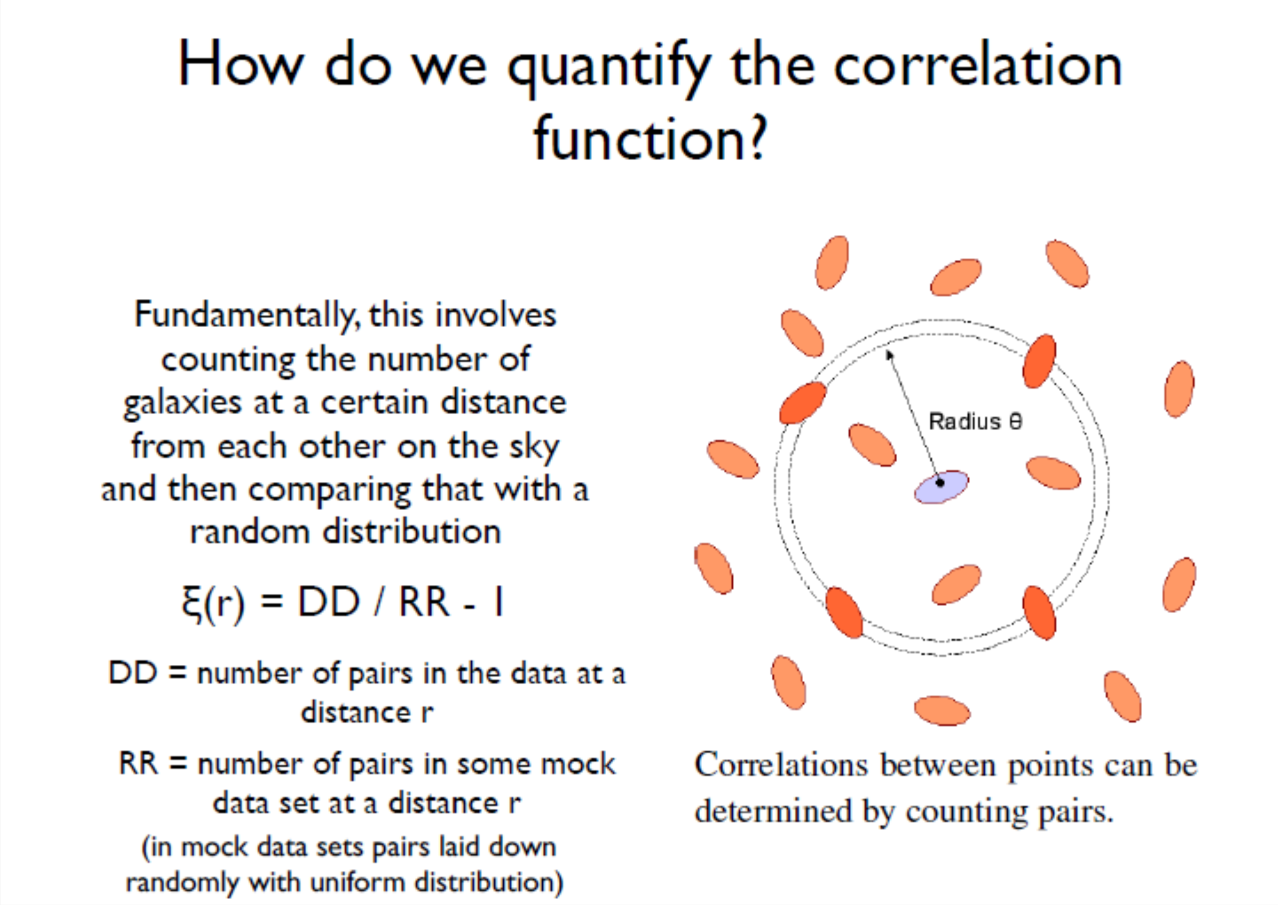
⬇

Stronger clustering

⬇

Higher bias

Methodology



How do we quantify the correlation function?

Fundamentally, this involves counting the number of galaxies at a certain distance from each other on the sky and then comparing that with a random distribution

$$\xi(r) = DD / RR - 1$$

DD = number of pairs in the data at a distance r

RR = number of pairs in some mock data set at a distance r

(in mock data sets pairs laid down randomly with uniform distribution)

Correlations between points can be determined by counting pairs.

Cross-correlation technique

Problem:

At $z > 2$: too few passive galaxies for a direct measurement → noisy results

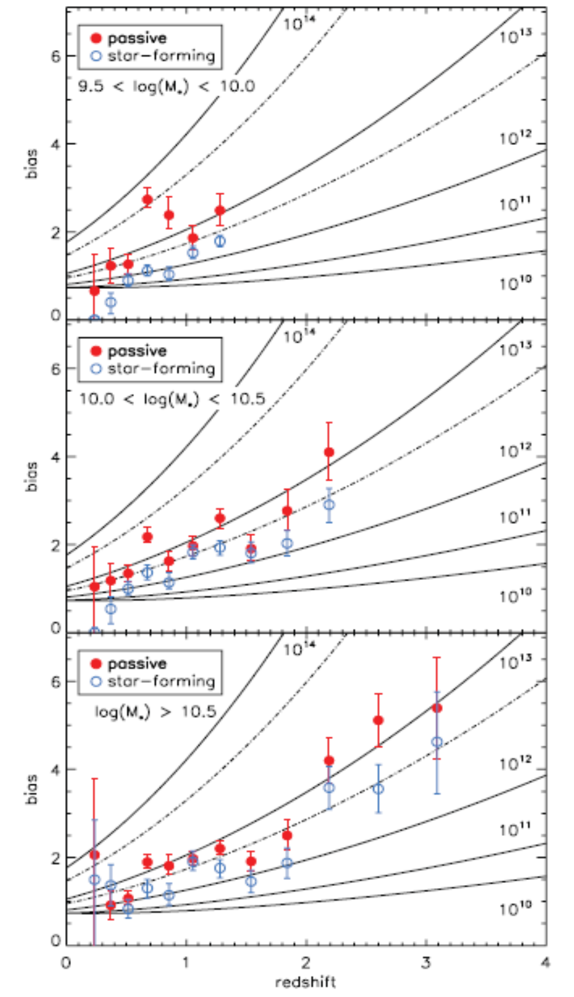
Solution:

Cross-correlate the small passive sample against a larger tracer population of all galaxies at the same redshift

More galaxy pairs → smaller uncertainties

Full redshift range $0.3 < z < 3.36$

Results


passive
star−forming
9.5 < log(M*) < 10.0
10.0 < log(M*) < 10.5
log(M*) > 10.5
bias
redshift
0
1
2
3
4
6
10^{14}
10^{13}
10^{12}
10^{11}
10^{10}

[illegible]

[illegible]

Results

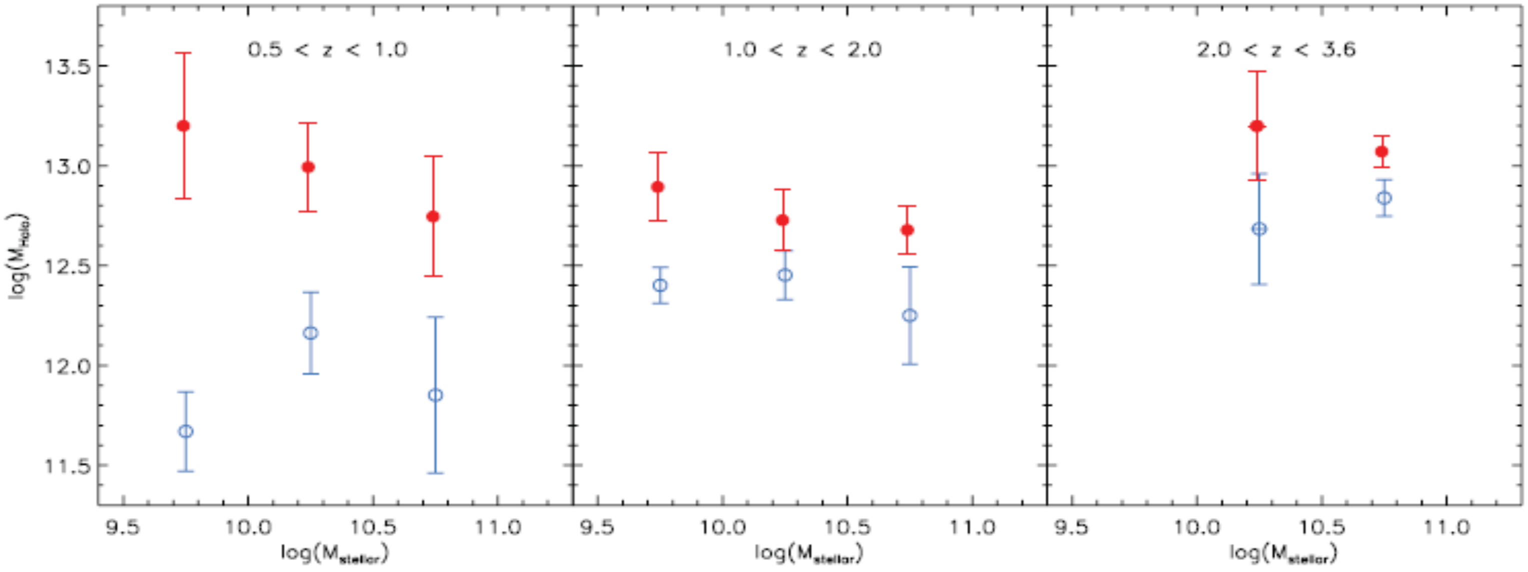


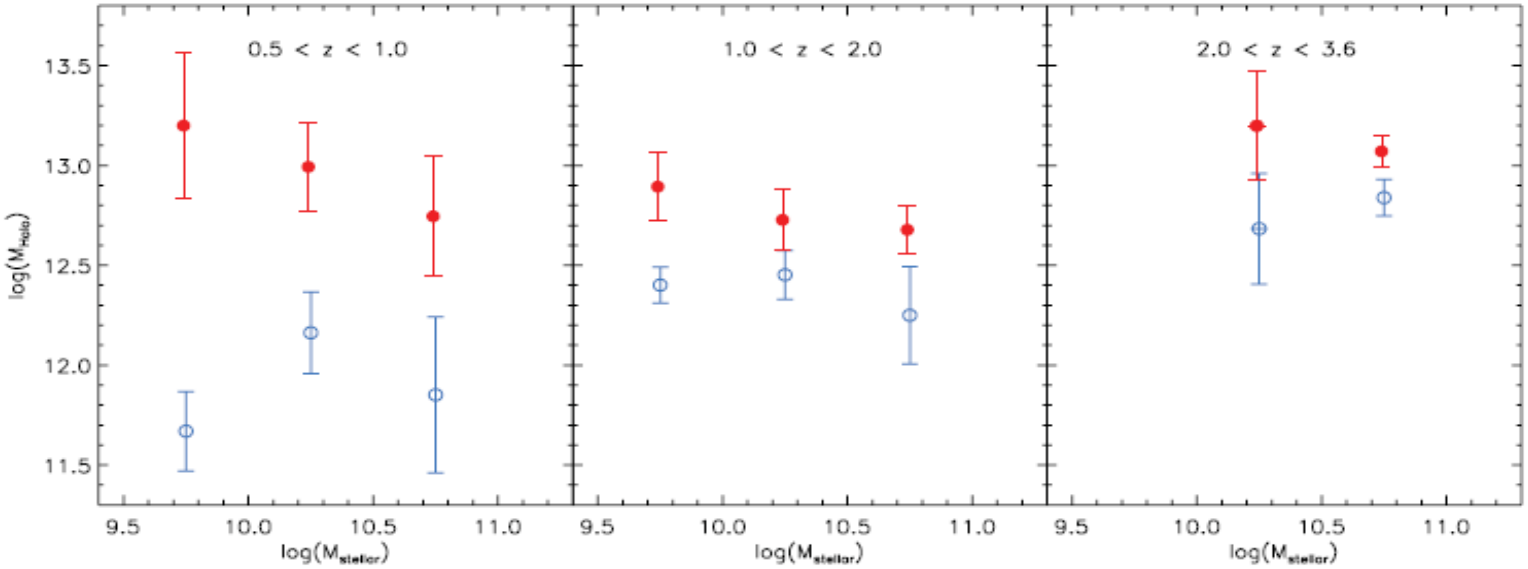
Figure 8. Average halo masses implied by our bias measurements in three redshift intervals (as labelled). The data are mean halo masses for samples of fixed stellar mass, while the uncertainties are the standard error on the mean. As in previous figures, the filled red points represent passive galaxy samples and open blue points are for star-forming objects.

Downsizing in **star-forming galaxies**:

At high z → star formation in massive haloes

At low z → star formation shifts to lower-mass haloes

Results



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At z > 2: star-forming galaxies also found above the 5 × 10^{12} M⊙ threshold

➔ Hot halo mechanism may be less efficient at high redshift.

Biebly et al. 2014

Before:

- Kong et al. 2006
    - By redshift z>=1.4, passive galaxies show stronger clustering than star forming. Also seen by Blanc et al. 2008, Hartley et al. 2008 and McCracken et al. 2010
- Hartley et al. 2010
    - clustering strength of star-forming galaxies grows with redshift and is comparable to that of passive galaxies at $z > 2$.
- Foucaud et al. 2010
    - clustering depends on stellar mass, and that galaxies of a fixed stellar mass tend to be more strongly clustered at higher redshift
- Wake et al. 2011
    - clustering depends on stellar mass and no stellar mass to halo mass relation that depends on redshift for 1<z<2, but might be some for z<1

Biebly et al. 2014

This paper:

- Goal
  - Investigate how galaxy clustering varies across 0<z<2, and how it is influenced by stellar mass, galaxy type, and cosmic time
- Data
  - Combination of WIRCam Deep Survey (Near-infrared) and Canda-France-Hawai’i Telescope Legacy Survey (Optical)
  - Effective 2.4 deg^2 field of view
  - Used GALFORM to predict the clustering of the galaxies
- Key results
  - “The key results that the passive and star-forming populations remain relatively constant in terms of clustering strength as a function of redshift up to $z \approx 2$ (given a constant mass selection) fits in well with complimentary observations showing little evolution in the stellar mass function over a similar range (Ilbert et al. 2010).”(Biebly et al. 2014)

Results (Redshift)

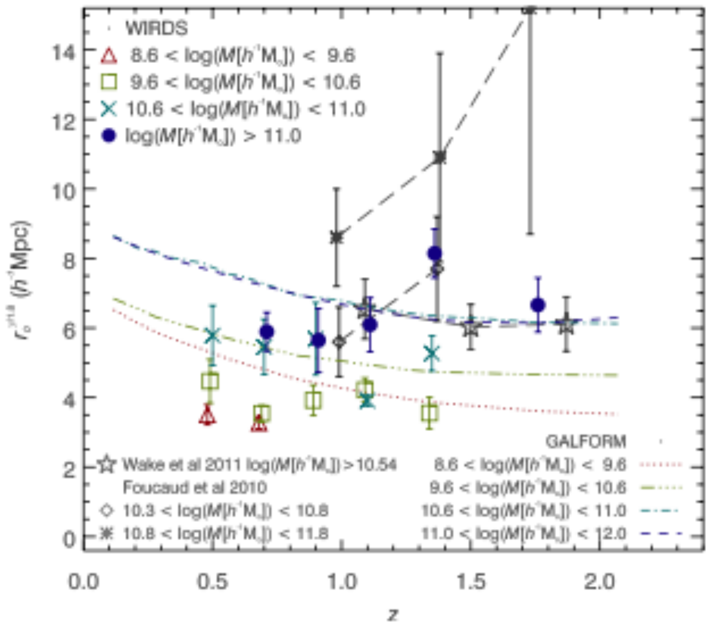


Fig. 3. Clustering strength, $r_0^{\gamma/1.8}$ as a function of redshift for all galaxies with errors based on a bootstrap estimate. The populations are split by mass, with triangles showing the $10^{8.6} < M[h^{-1}M_\odot] \leq 10^{9.6}$ samples, squares $10^{9.6} < M[h^{-1}M_\odot] \leq 10^{10.6}$, x's $10^{10.6} < M[h^{-1}M_\odot] \leq 10^{11}$ and circles $M[h^{-1}M_\odot] > 10^{11}$. The curves give the results of the GALFORM model for the observed mass ranges, as indicated in the legend. Results from Foucaud et al. (2010, grey asterisks and crosses connected by dashed lines) and Wake et al. (2011, grey stars connected by dashed lines) are also plotted.

Figure from Biebly et al. 2014

- No redshift dependence
- Dependence on stellar mass

Results (Passive vs Star-forming)

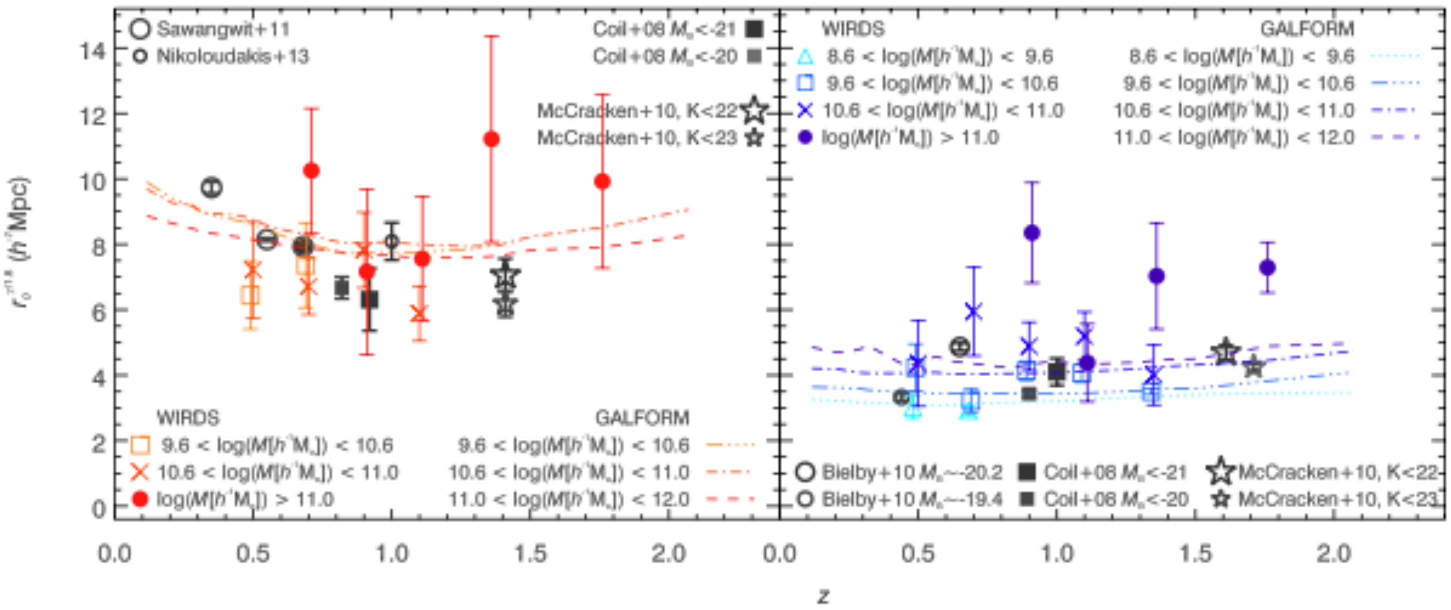


Fig. 7. Clustering strength, $r_0^{\gamma/1.8}$ as a function of redshift for passive galaxies (*left panel*) and star-forming galaxies (*right panel*). In each case, the populations are split by mass, with triangles showing the $10^{8.6} < M[h^{-1}M_\odot] \le 10^{9.6}$ range, squares $10^{9.6} < M[h^{-1}M_\odot] \le 10^{10.6}$, ×'s $10^{10.6} < M[h^{-1}M_\odot] \le 10^{11}$ and circles $M[h^{-1}M_\odot] > 10^{11}$. The curves give the predictions of the GALFORM model for the different mass bins as indicated in the legend.

Figure from Biebly et al. 2014

- Still no redshift dependence for both star forming and passive
- Little stellar mass dependence for passive below 10^11 *h*^–1 *M*⊙
- Largest star forming comparable to passive clustering

Results (Halo mass vs stellar mass)

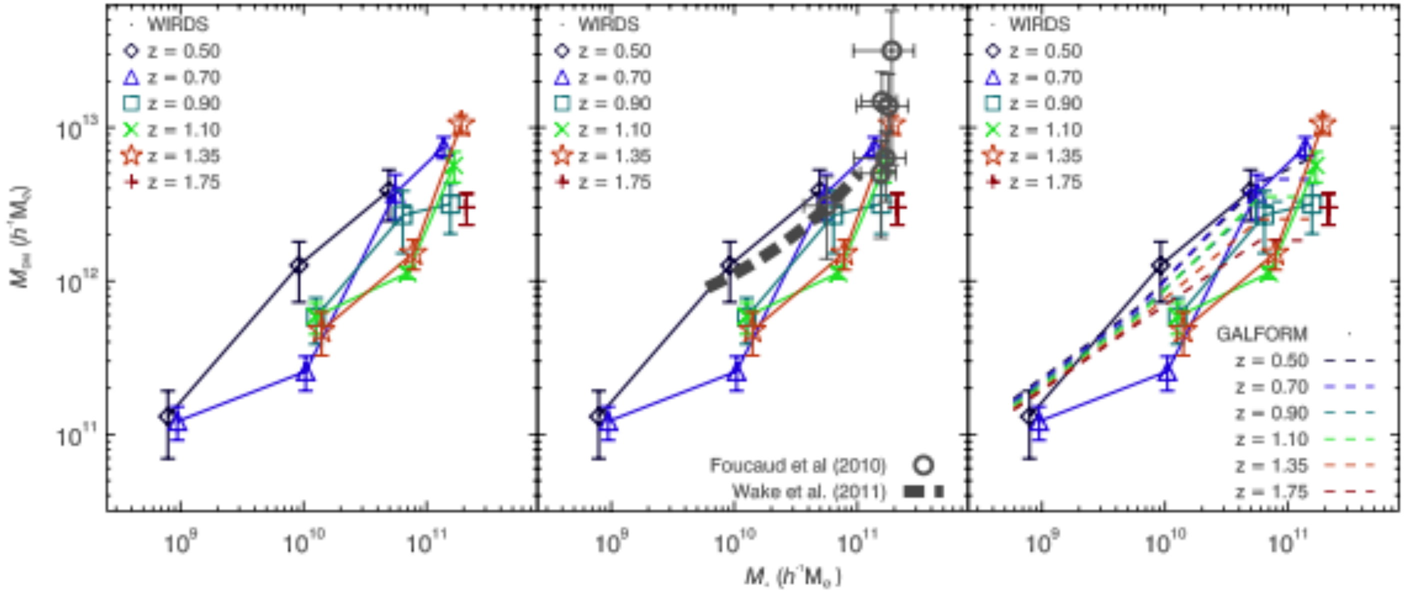


Fig. 9. Host dark matter halo mass, M_{DM}, as a function of galaxy stellar mass, M_* for the full galaxy sample split by mass and redshift. The WIRDS results are reproduced in *all three panels*, whilst literature results are added in the *centre panel* and the GALFORM predictions are added in the *right hand panel*. In terms of the WIRDS data, the triangles, squares, ×, stars and crosses show the results from the WIRDS data for redshift ranges centred on $z = 0.50$, $z = 0.70$, $z = 0.90$, $z = 1.10$, $z = 1.35$ and $z = 1.75$ respectively. In the *centre panel*, the thick dashed curve shows the fit to M_{DM} versus M_* given by Wake et al. (2011) for galaxies at $1 < z < 2$ in the NEWFIRM survey, whilst the open circles show the results from Foucaud et al. (2010) at $z \gtrsim 1$. In the *right hand panel*, the predictions from the GALFORM model are given for the same central redshifts.

Figure from Biebly et al. 2014

- Clear relationship between stellar mass and halo mass
- Possibly an evolution with redshift?

Summary

Hartley et al. 2013

1) 0.62 deg^2 small field but extends to higher z up to 3.5
2) Separates passive vs star forming so they find that low-mass passive galaxies are in the most massive haloes.
3) Passive galaxies above $5 \times 10^{12}\ M_\odot$
4) Low-mass passive galaxies in most massive halos , likely satellite quenching
5) At $z > 2$ star-forming galaxies also above threshold

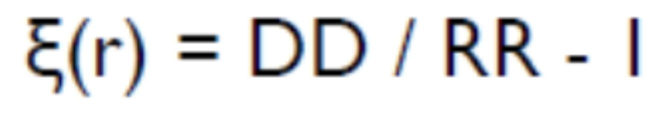
Bielby et al. 2014

1) 2.4 deg^2 larger field but up to $z = 2$
2) Redshift doesn't affect clustering strength up to $z=2$
3) Mean halo mass increases with galaxy stellar mass in the full population
4) Clustering of passive galaxies doesn't depend on stellar mass
5) Largest star forming galaxies have similar clustering to passive galaxies

Thank you

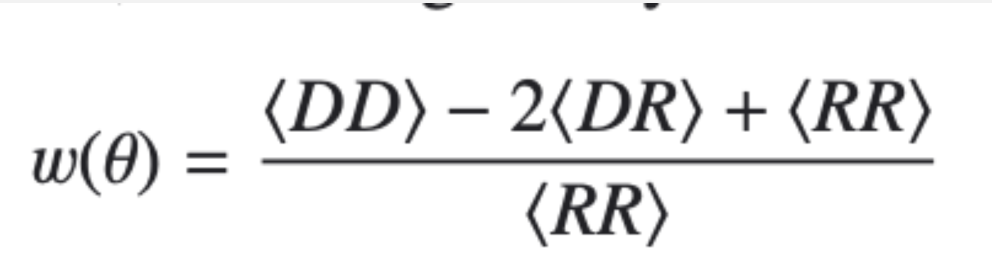
Landy-Szalay estimator

In class:



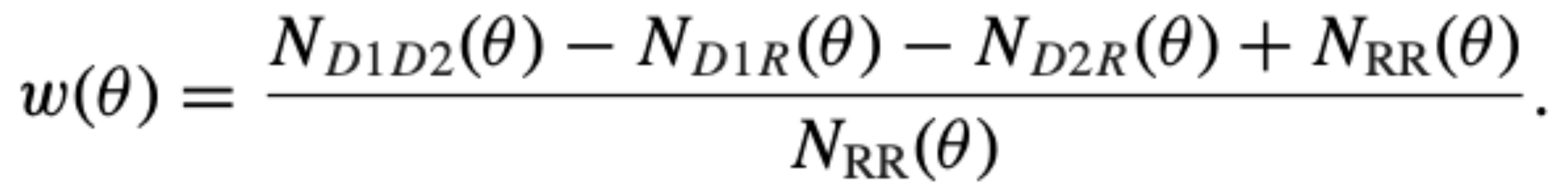
$$\xi(r) = DD / RR - 1$$

Bielby et al. 2014 (Auto-correlation):



$$w(\theta) = \frac{\langle DD \rangle - 2\langle DR \rangle + \langle RR \rangle}{\langle RR \rangle}$$

Hartley et al. 2013 (Cross-correlation):



$$w(\theta) = \frac{N_{D1D2}(\theta) - N_{D1R}(\theta) - N_{D2R}(\theta) + N_{\mathrm{RR}}(\theta)}{N_{\mathrm{RR}}(\theta)}.$$