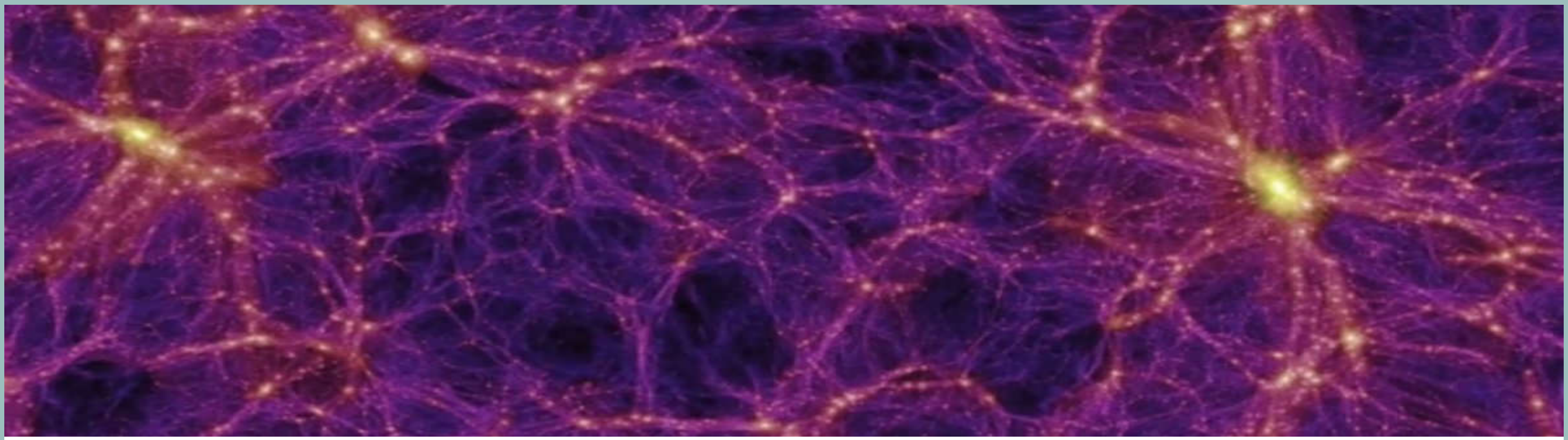


PRIMUS + DEEP2: THE DEPENDENCE OF GALAXY CLUSTERING ON STELLAR MASS AND SPECIFIC STAR FORMATION RATE AT 0.2<2<1.2

COIL ET AL. 2016

Callie Hood, ASTR 503

WHY STUDY THE CLUSTERING OF GALAXIES?

- Galaxies thought to form in centers of dark matter halos
- Observed galaxy clustering matches simulations of dark matter clustering
- Mapping from galaxy → halo is complicated
- Comparison with dark matter clustering can help clarify this relation and how galaxy evolution differs from dark matter

PAST STUDIES OF GALAXY CLUSTERING

- Older studies focused on luminosity and color:
  - brighter galaxies are more clustered than their fainter counterparts (e.g. Alimi et al. 1988)
  - red galaxies more clustered than blue (e.g. Norberg et al. 2002)
  - Complicated at low z with satellite population (Berlind et al. 2005)

PAST STUDIES OF GALAXY CLUSTERING (CON.)

- Many studies have found that galaxy clustering is a strong positive function of the stellar mass (although decreasingly so at lower stellar masses)
- However, the relation of this correlation to the star-forming main sequence is poorly explored. Thus, Coil et al set out to determine the clustering dependence on both stellar mass and sSFR.

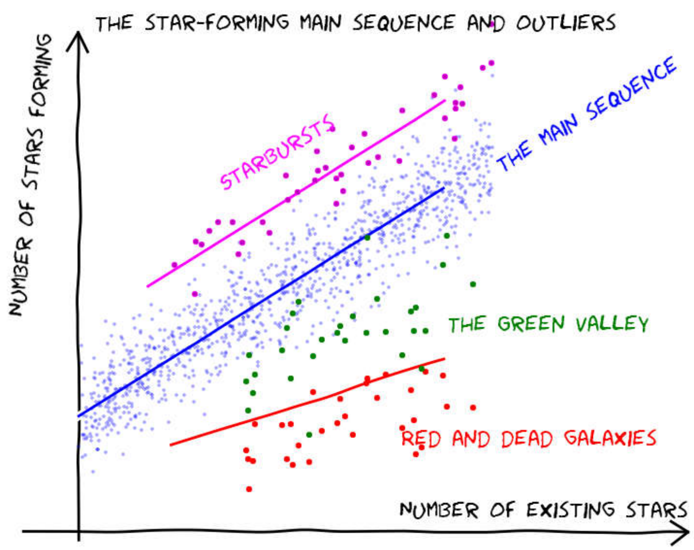


Image Credit: Harry Ferguson

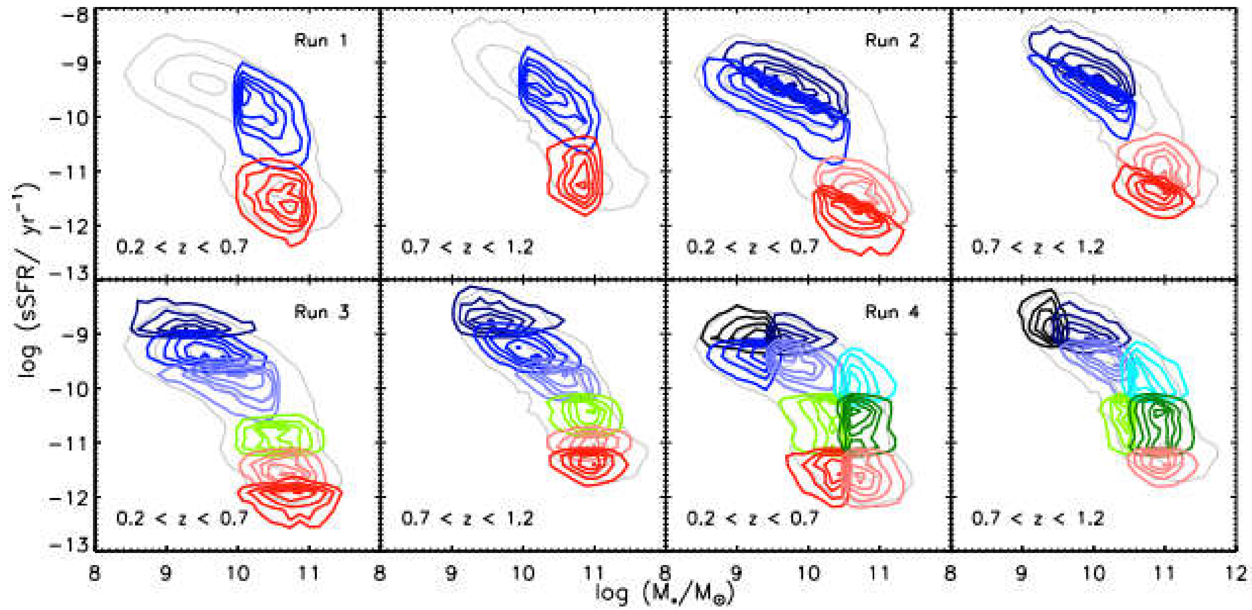
REDSHIFT SURVEYS

- PRIMUS: statistically complete sample of ~ 120, 000 robust spectroscopic redshifts to $i_{AB} \sim 23.5$.
  - obtained low-resolution ($\lambda/\ \lambda \sim 40$) spectra with the IMACS instruments
  - Redshifts are derived by fitting a large suite of galaxy, broad-line AGN, and stellar spectral templates to the low-resolution spectra and optical photometry
- DEEP2: measured ~ 17, 000 high confidence redshifts to $R_{AB} = 24.1$
  - Used DEIMOS spectrograph on Keck-II
- Overall, over 100,000 galaxies spanning $0.2 < z < 1.2$ covering an area of 7.2 deg^2 over five separate fields on the sky

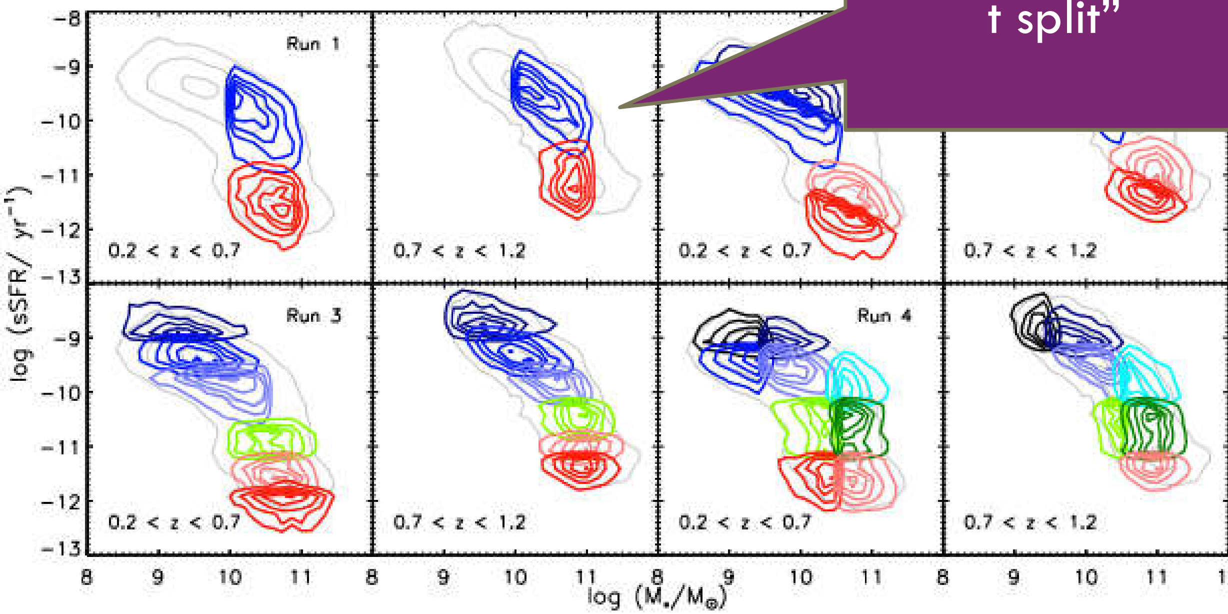
STELLAR MASS AND SFR ESTIMATES

- Fit spectral energy distributions (SEDs) of sources with stellar population synthesis models using iSEDfit (Bayesian fitting code)
  - Marginalizes full posterior probability distribution of stellar masses and SFRs over all other parameters
  - Uses results derived from photometry spanning UV to infrared
  - For each source, takes median stellar mass and star formation rate from full probability distribution as best estimates (then calculate specific star formation rate (sSFR) as SFR per unit stellar mass)

GALAXY SAMPLES

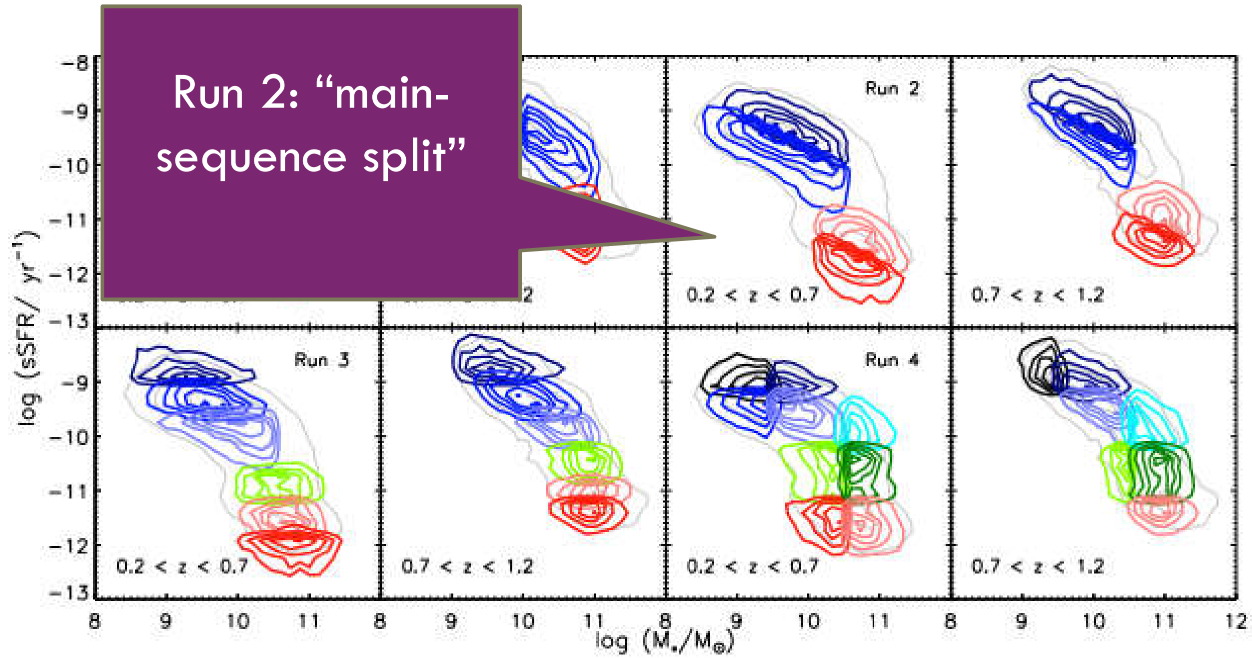


GALAXY SAMPLES

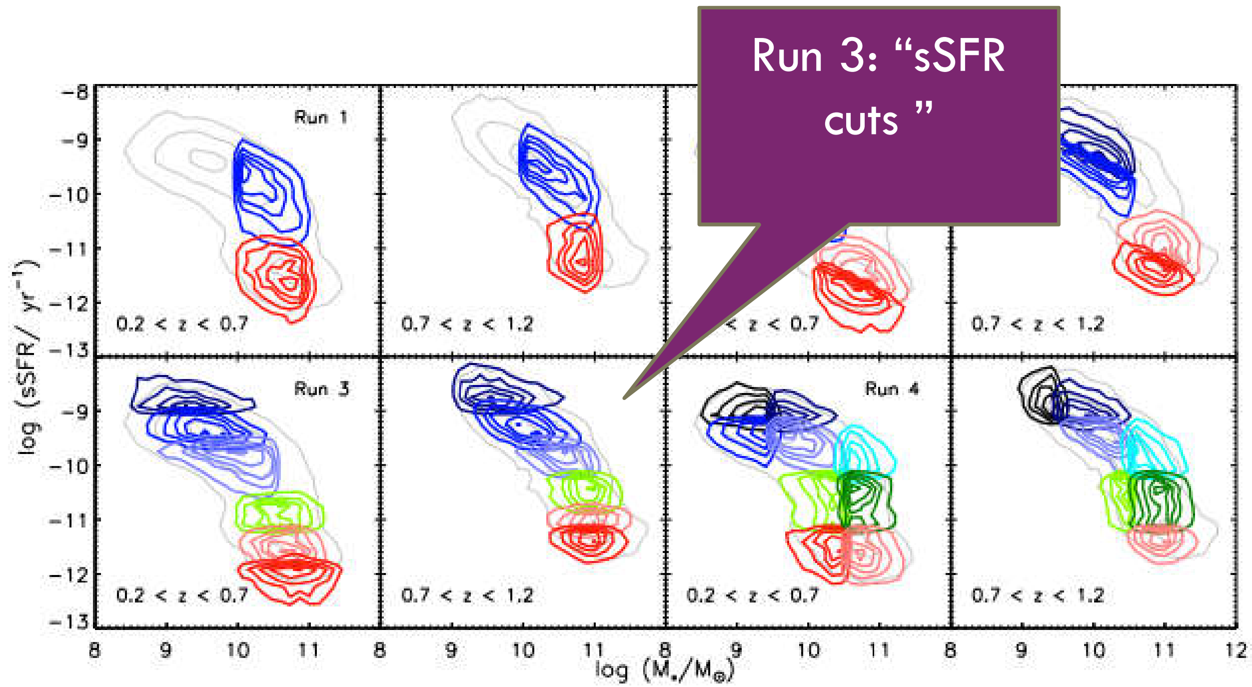


Run 1: "star-forming/quiescent split"

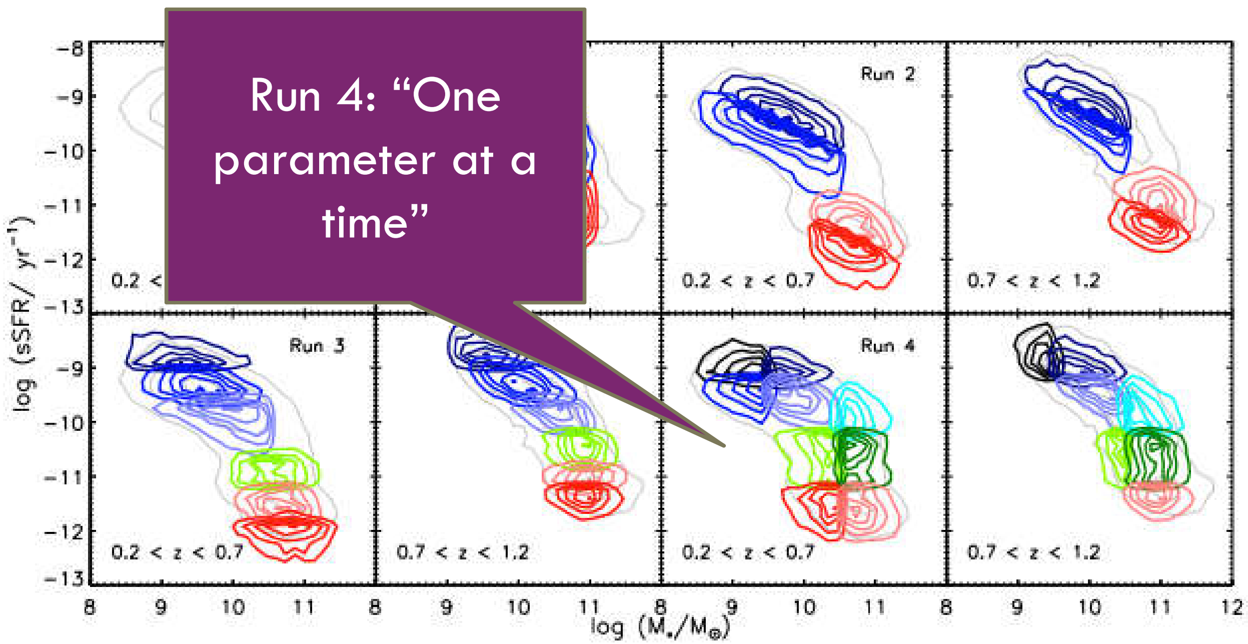
GALAXY SAMPLES



GALAXY SAMPLES



GALAXY SAMPLES



MEASURING THE TWO-POINT CORRELATION FUNCTION

- Quantify clustering: $\xi(r)$ is the excess probability above Poisson of finding two sources with a given physical separation

- ACF: clustering of a single sample, where the two sources are from the same sample

- CCF: clustering of one type of source, taken from one sample, around that of another type of source, taken from a second sample. Here, measured with a second total sample which is all galaxies with robust redshifts in the region of interest

- Estimators used for evaluating both functions (Landy & Szalay 1993, Davis & Peebles 1983)

PROJECTED CORRELATION FUNCTION

- Peculiar velocities distort $\xi(r)$ measurements along the line of sight
- measure $\xi(r)$ in two dimensions, $\xi(r_p, \pi)$
  - r_p is the separation perpendicular to the line of sight (unaffected by peculiar velocities)
  - π is the separation along the line of sight

PROJECTED CORRELATION FUNCTION (CON.)

- Integrating $\xi(r_p, \pi)$ along the π dimension leads to the projected correlation function

$$\begin{aligned} w_p(r_p) &= 2\int_0^{\infty} d\pi\, \xi(r_p, \pi) \\ &\approx 2\int_0^{\pi_{max}} d\pi\, \xi(r_p, \pi) \end{aligned}$$

- Estimate uncertainties using jackknife resampling of data
  - Use 11 jackknife samples across their five fields to calculate the variance in the projected correlation function, estimating the uncertainty due to cosmic variance

ABSOLUTE AND RELATIVE BIAS MEASUREMENTS

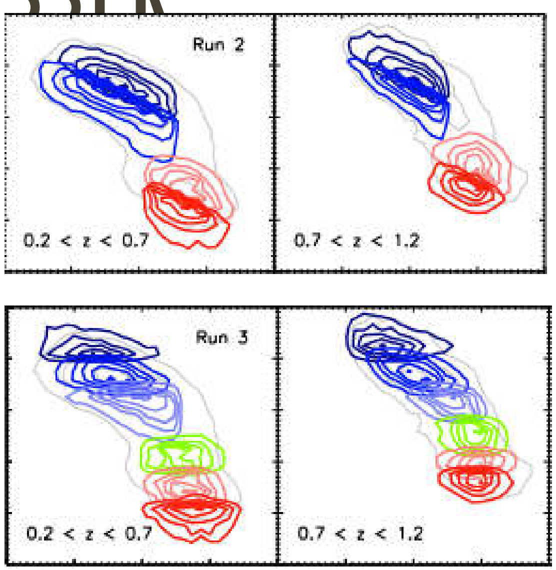
- Use measured projected correlation function to estimate the absolute bias, or dark matter bias, of various galaxy subsamples.
  - Absolute bias b measures relative clustering strength of the galaxy subsample to that of dark matter particles

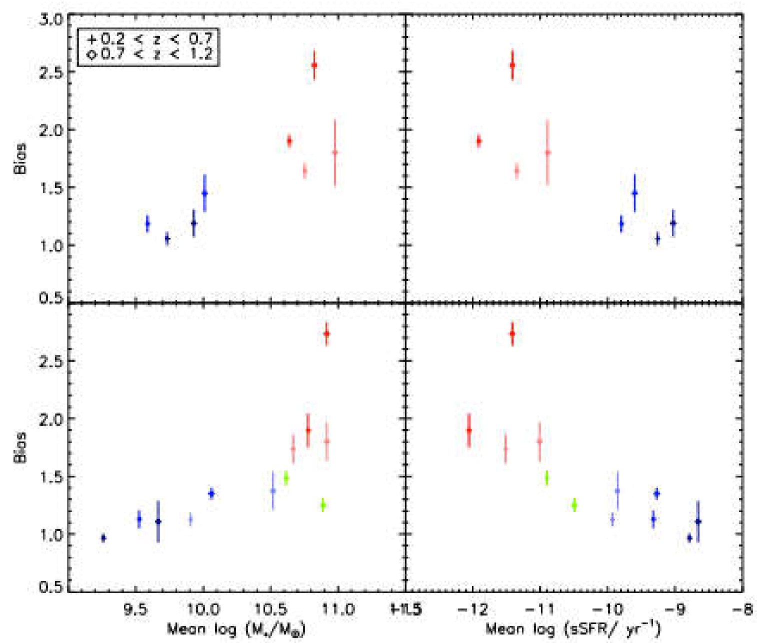
$$b = \sqrt{\frac{w_G}{w_{DM}}}$$

  - relative bias between two galaxy subsamples is defined as the square root of the ratio of their respective projected correlation functions
    - Allows for simple comparison of the clustering strength of two samples
    - two scales: $0.1 < r_p < 1\ h^{-1}$ Mpc ("one-halo" or "small-scale" relative bias) and $1 < r_p < 10\ h^{-1}$ Mpc ("two-halo" or "large-scale" relative bias)

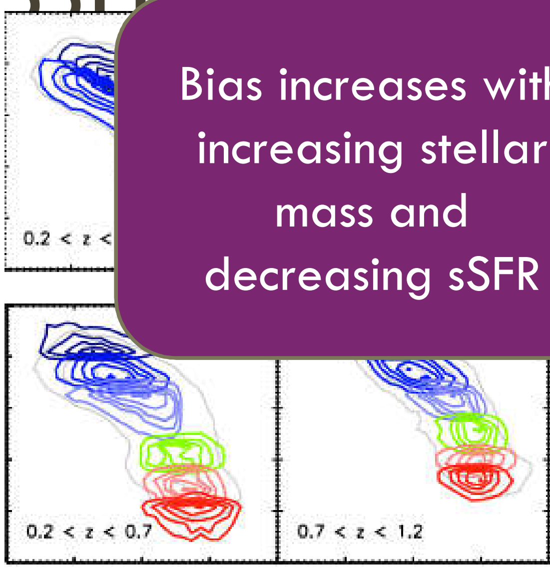
RESULTS

GALAXY CLUSTERING DEPENDS ON BOTH STELLAR MASS AND SSFR

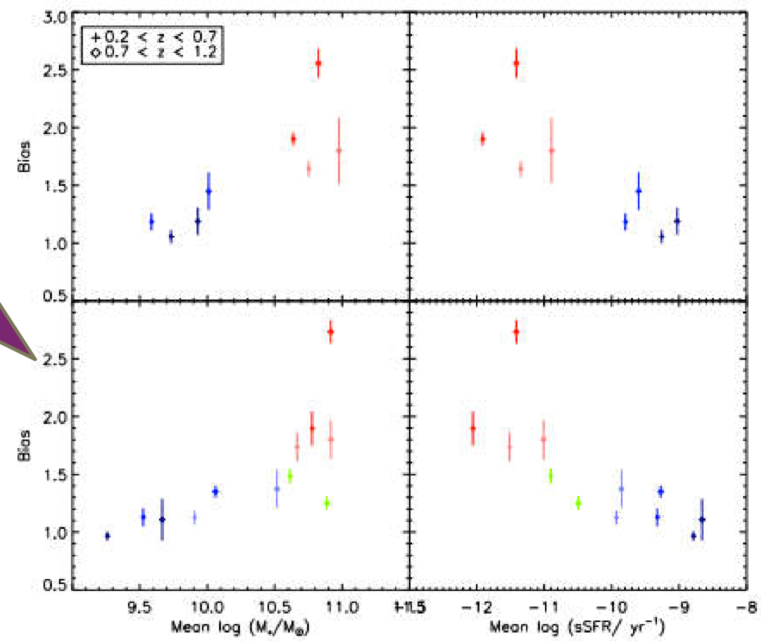




GALAXY CLUSTERING DEPENDS ON BOTH STELLAR MASS AND SSFR

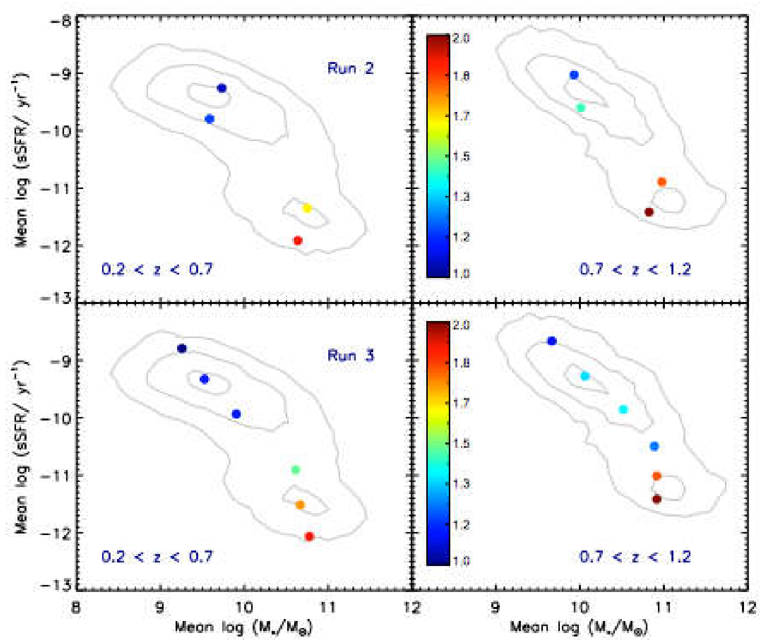


Bias increases with increasing stellar mass and decreasing sSFR

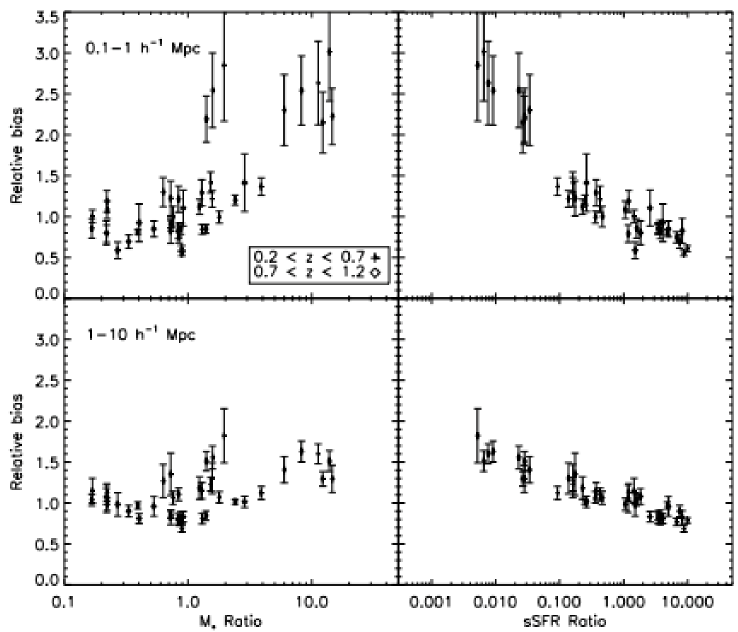


STAR-FORMING GALAXIES CLUSTER MORE BELOW THE MAIN SEQUENCE

- Color bar reflects the absolute bias
- Galaxies with a high sSFR that lie above the main sequence are less clustered than galaxies below
- Constrains evolutionary path of galaxies in sSFR-stellar mass plane= must evolve across the main sequence, not just along it

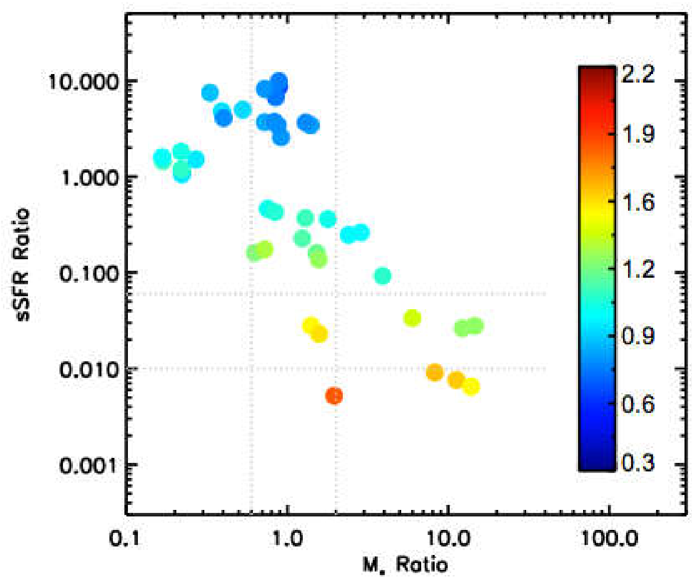


GALAXY CLUSTERING DEPENDS **MORE** ON SSFR THAN STELLAR



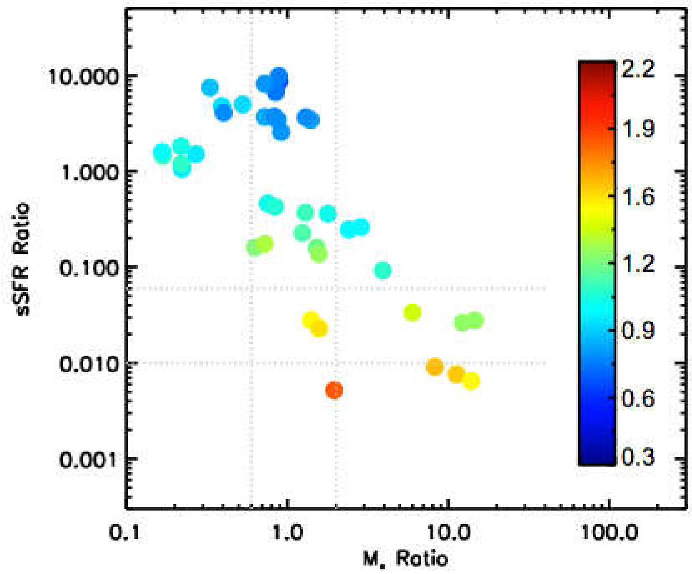
- One-halo (top) and two-halo(bottom) relative biases between various galaxy samples
- Additional galaxy samples are used here beyond the runs shown earlier to help fill in space.
- relative bias is more monotonically dependent on the sSFR ratio than the stellar mass ratio.

GALAXY CLUSTERING DEPENDS **MORE** ON SSFR THAN STELLAR MASS



- Color bar: two-halo relative bias between various galaxy samples
- dotted lines highlight regions of fixed stellar mass or sSFR ratio where galaxy samples probe at least an order of magnitude in the ratio of the other parameter (stellar mass or sSFR)

GALAXY CLUSTERING DEPENDS **MORE** ON SSFR THAN STELLAR MASS



- at a fixed stellar mass ratio, variations with sSFR lead to strong differences in the relative bias, while at a fixed sSFR ratio, variations with stellar mass do not result in substantially different clustering amplitudes.

SUMMARY AND CONCLUSIONS

- Used over 100,000 spectroscopic redshifts to determine dependence of clustering (calculated using **ACFs** and **CCFs** and **jackknife sampling** for errors) on stellar mass and sSFR (determined using **SED fitting**)
- Galaxy clustering is a stronger function of sSFR than stellar mass, within the range probed
- Results imply the stellar mass to halo mass relation, which connects galaxies to dark matter halos, likely depends on sSFR as well

REFERENCES

1. arXiv:1609.09090

2. http://candels-collaboration.blogspot.com/2013/02/star-formation-in-mountains.html