The clustering of star-forming galaxies across cosmic time with HiZELS

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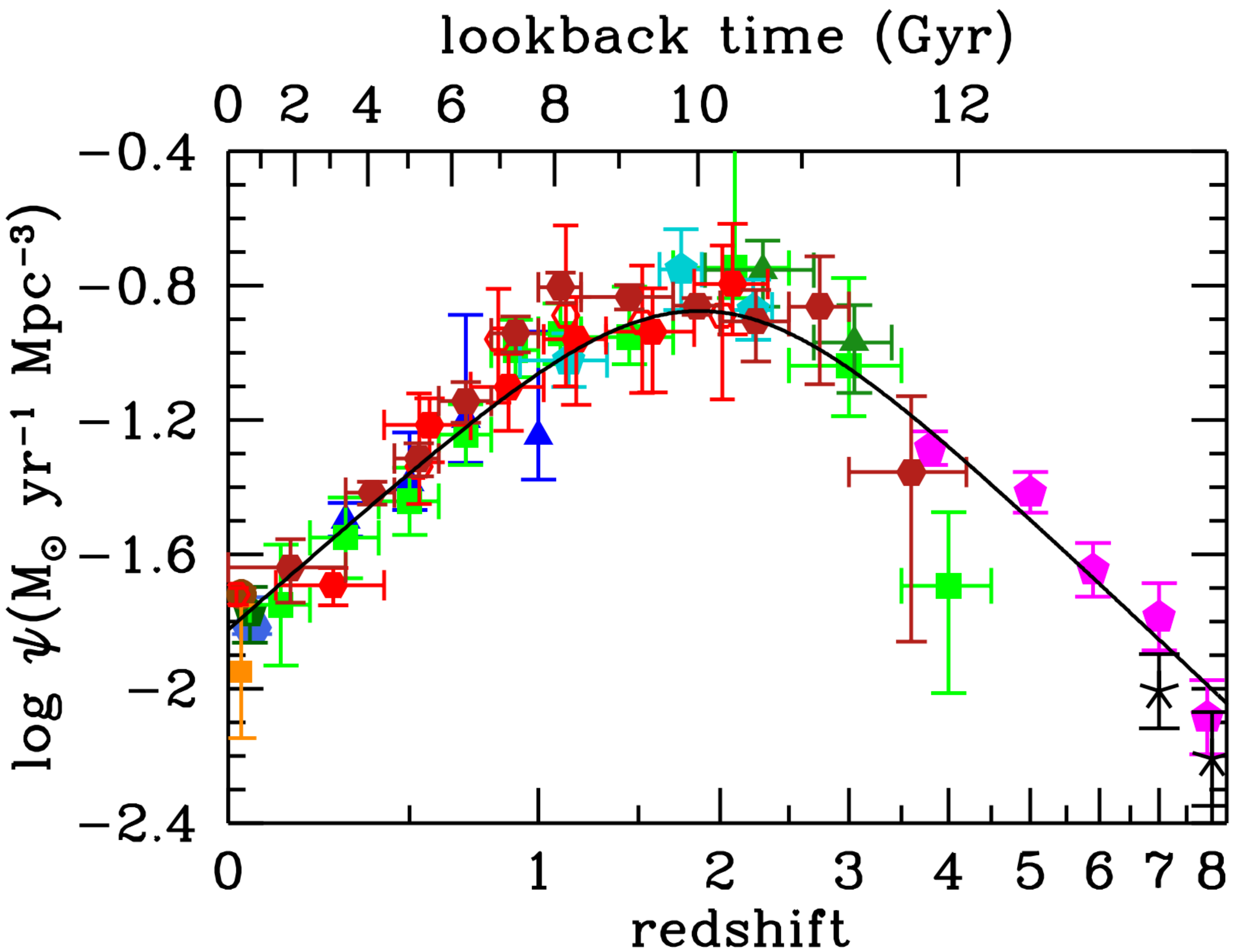
Use a single indicator, Hα, to observe star-forming galaxies across the peak and fall of the volume-averaged star formation rate density.



Madau & Dickinson 2014

HiZELS: the survey

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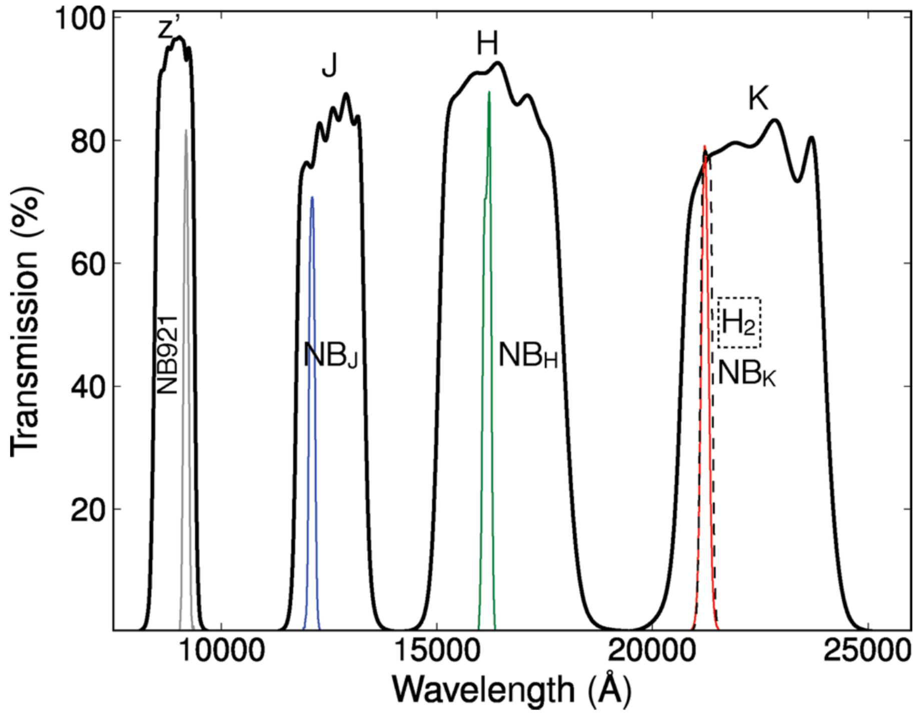
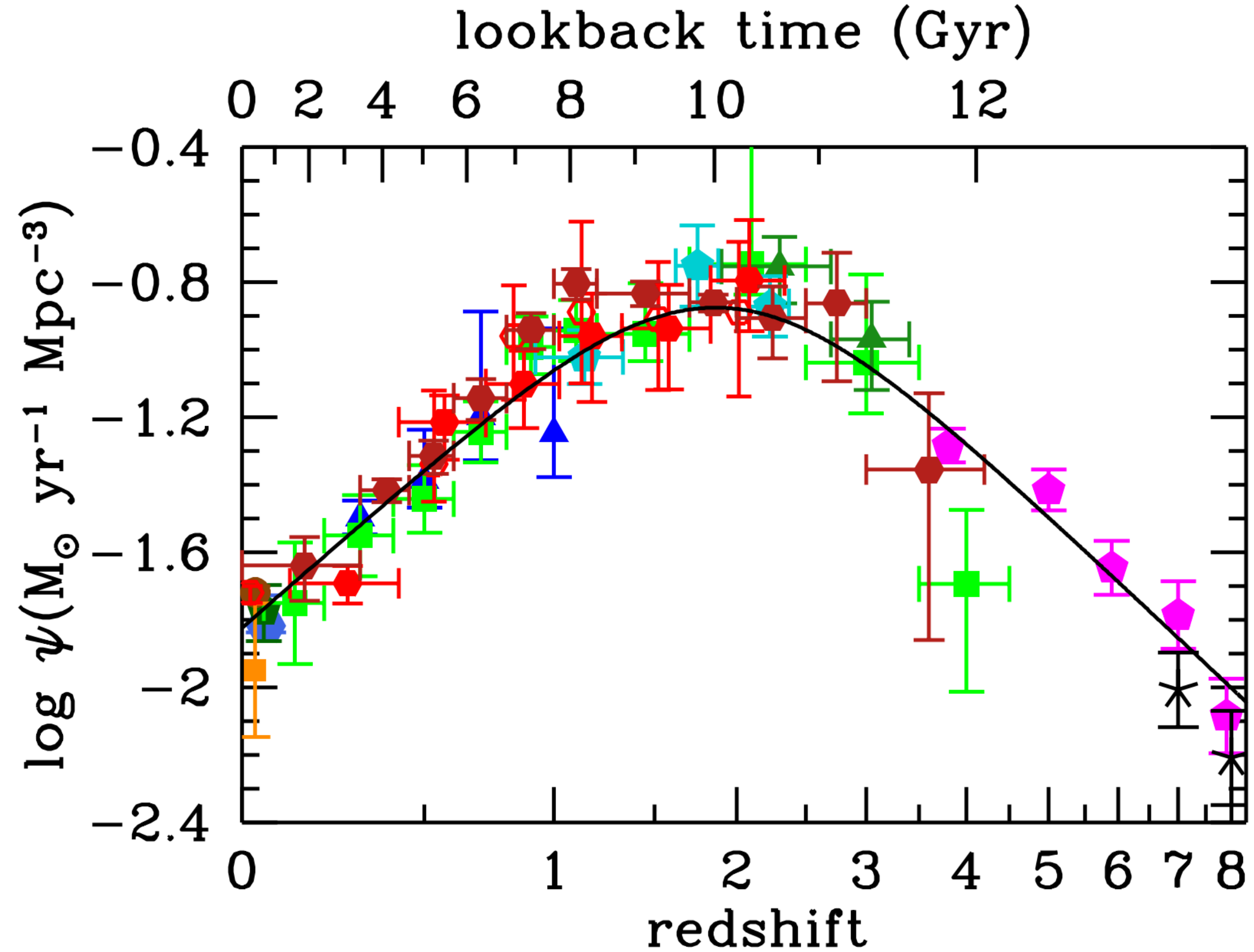
Sobral et al. 2013



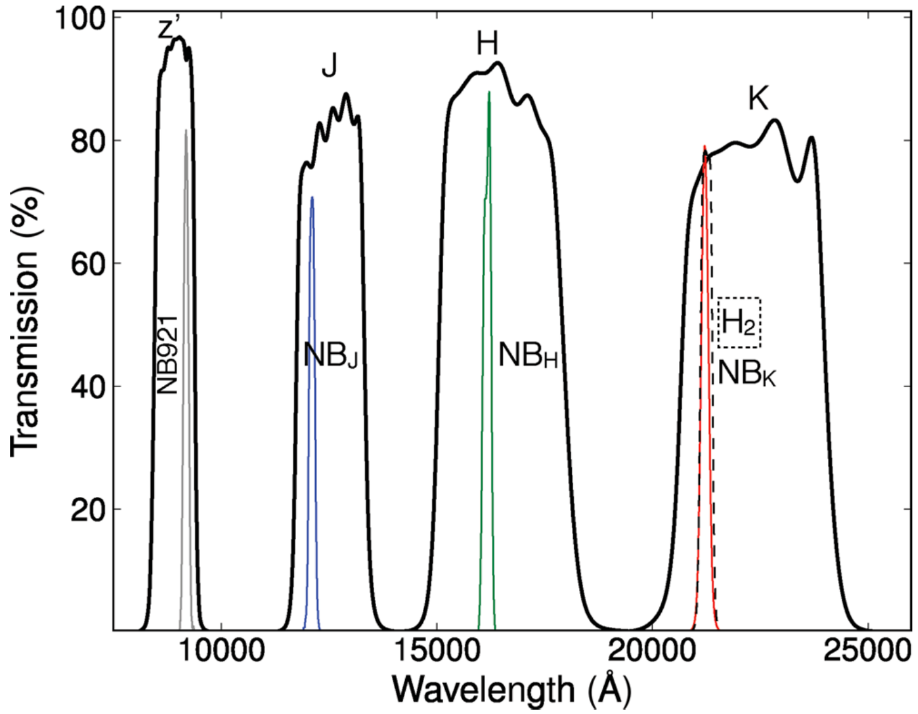


Madau & Dickinson 2014

- Narrow-band survey
- Known flux limits
- Probe fields with good multi-wavelength coverage: COSMOS, UDS, SA22. Total coverage is several square degrees.

Identically-selected SF galaxies at 3 redshifts

Sobral et al. 2013



z	Volume ($10^4 Mpc^{-3} deg^{-2}$)	Number of emitters
0.810 ± 0.011	~100	~3400
1.466 ± 0.016	~34	~500
2.231 ± 0.016	~38	~800

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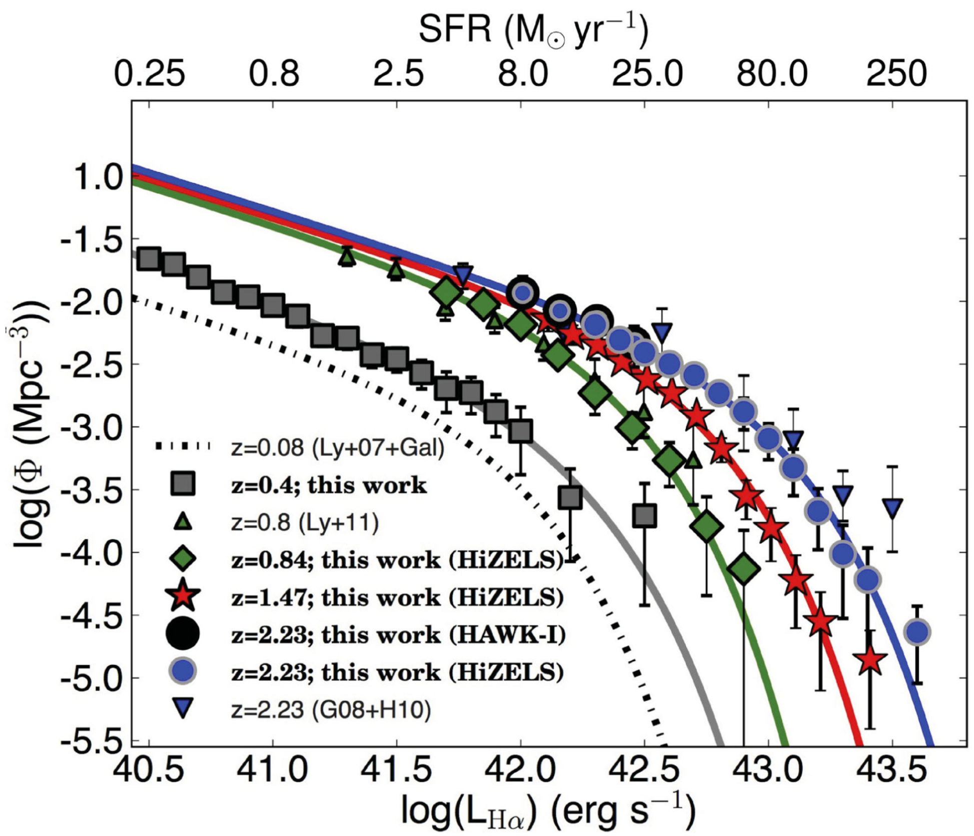
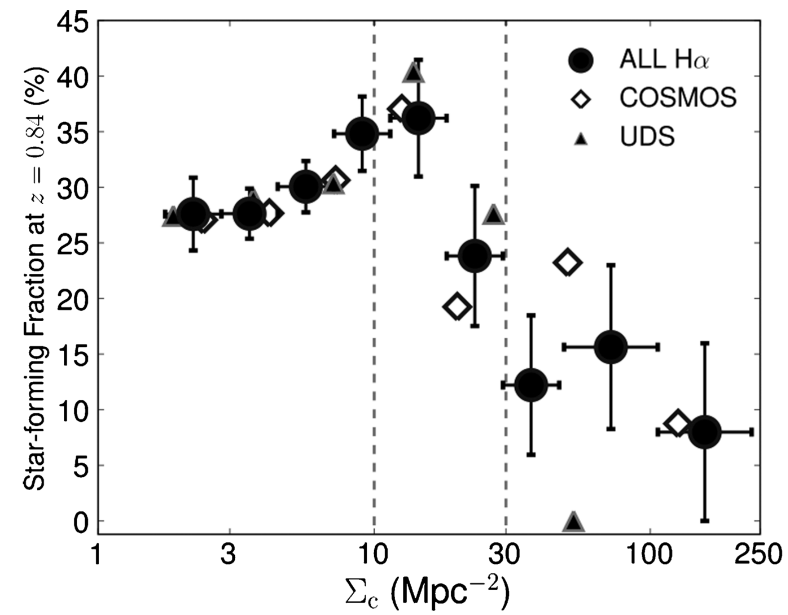
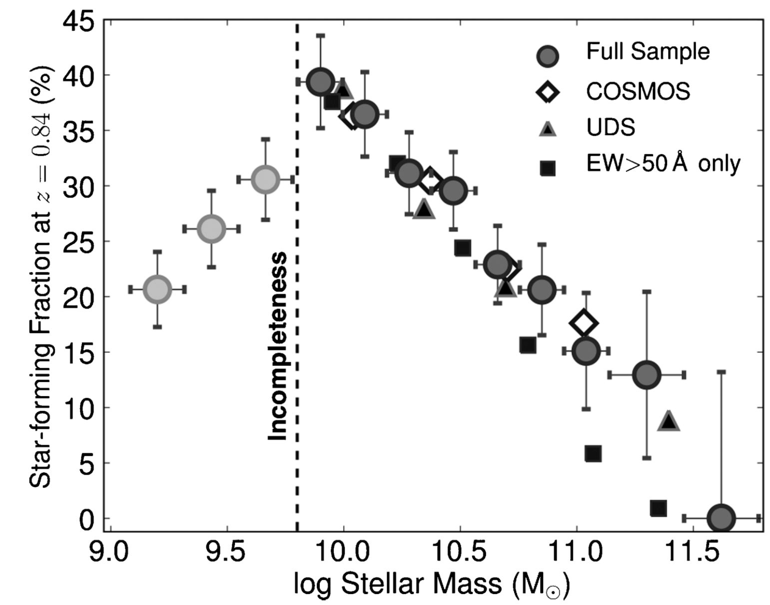
Identically-selected SF galaxies at 3 redshifts



Sobral et al. 2013

Sobral et al. 2011





- Luminosity functions reflect the decline in luminosities of typical star-forming galaxies towards low-z.
- Star-forming fractions at z ~ 0.8 - mass/environment quenching.
- Clustering

Results so far: probing galaxy evolution back 11Gyr

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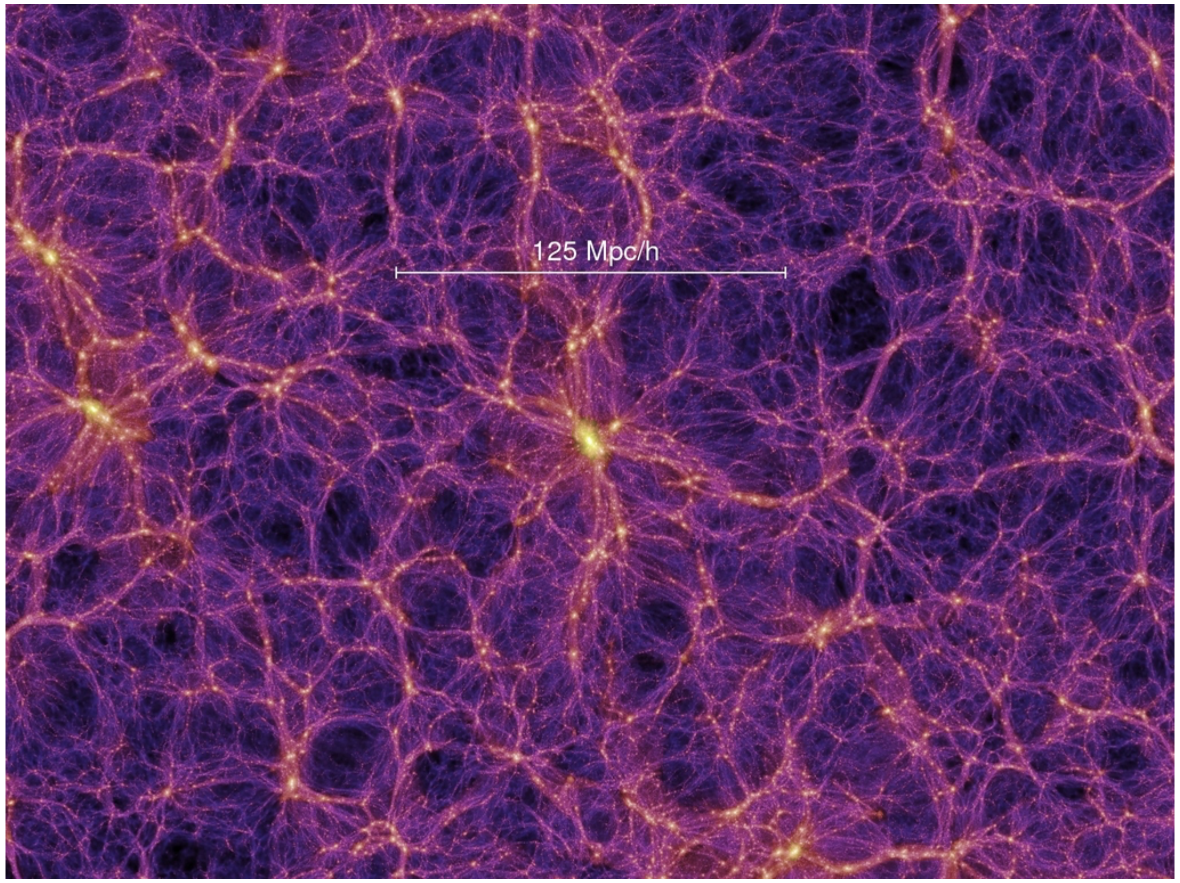
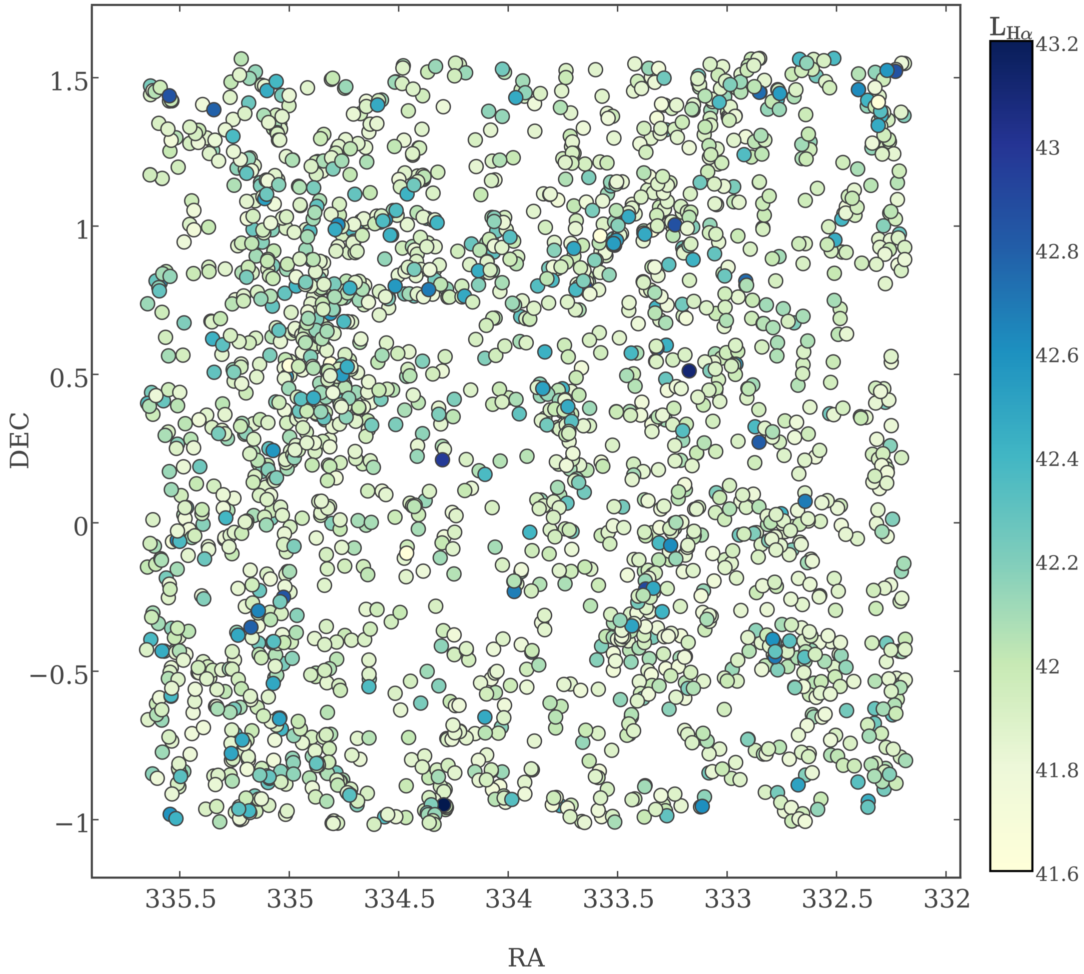
Quantifying galaxy environments



Springel et al. (2005)



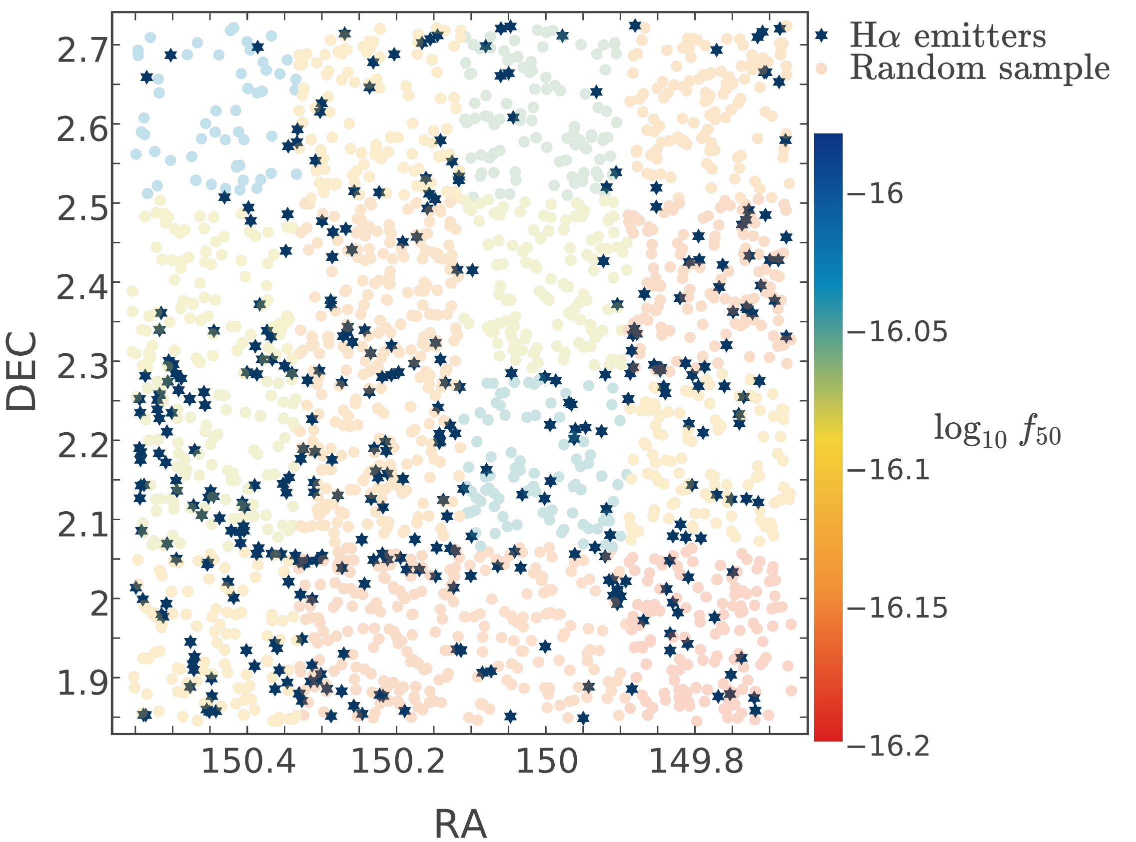
Example field - HiZELS z=0.8 galaxies in SA22, colour-coded by Hα luminosity.

$$dP(\theta) = N^2(1 + w(\theta))\, d\Omega_1 d\Omega_2$$

$$w(\theta) = 1 + \left(\frac{N_R}{N_D}\right)^2 \frac{DD(\theta)}{RR(\theta)} - 2\frac{N_R}{N_D}\frac{DR(\theta)}{RR(\theta)} = A\theta^{-\beta}$$

Landy & Szalay, 1993

- Require uniform distribution of random emitters.
- Masks applied to real and random emitters.
- Luminosities of random sources generated on a frame-by-frame basis - frames have difference depths due to survey strategy.



2-point angular correlation functions

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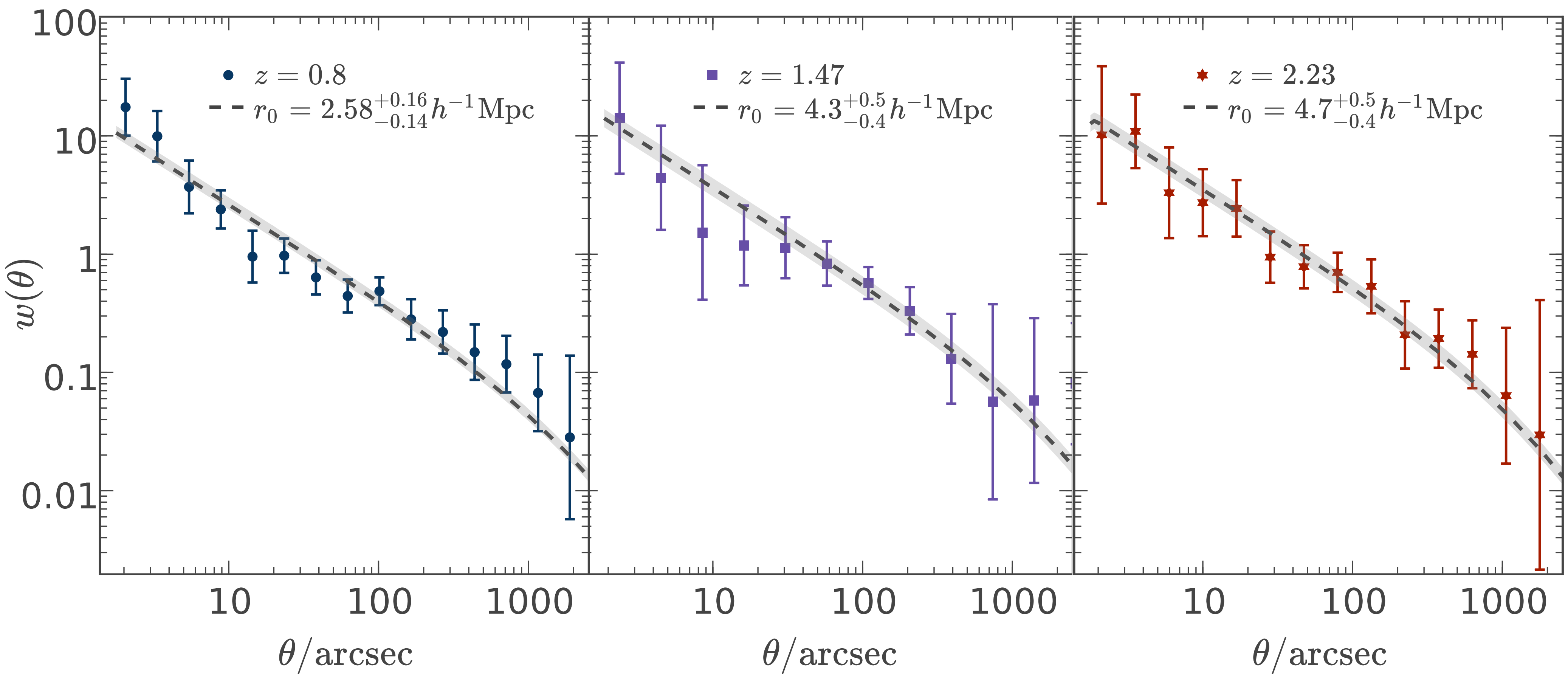
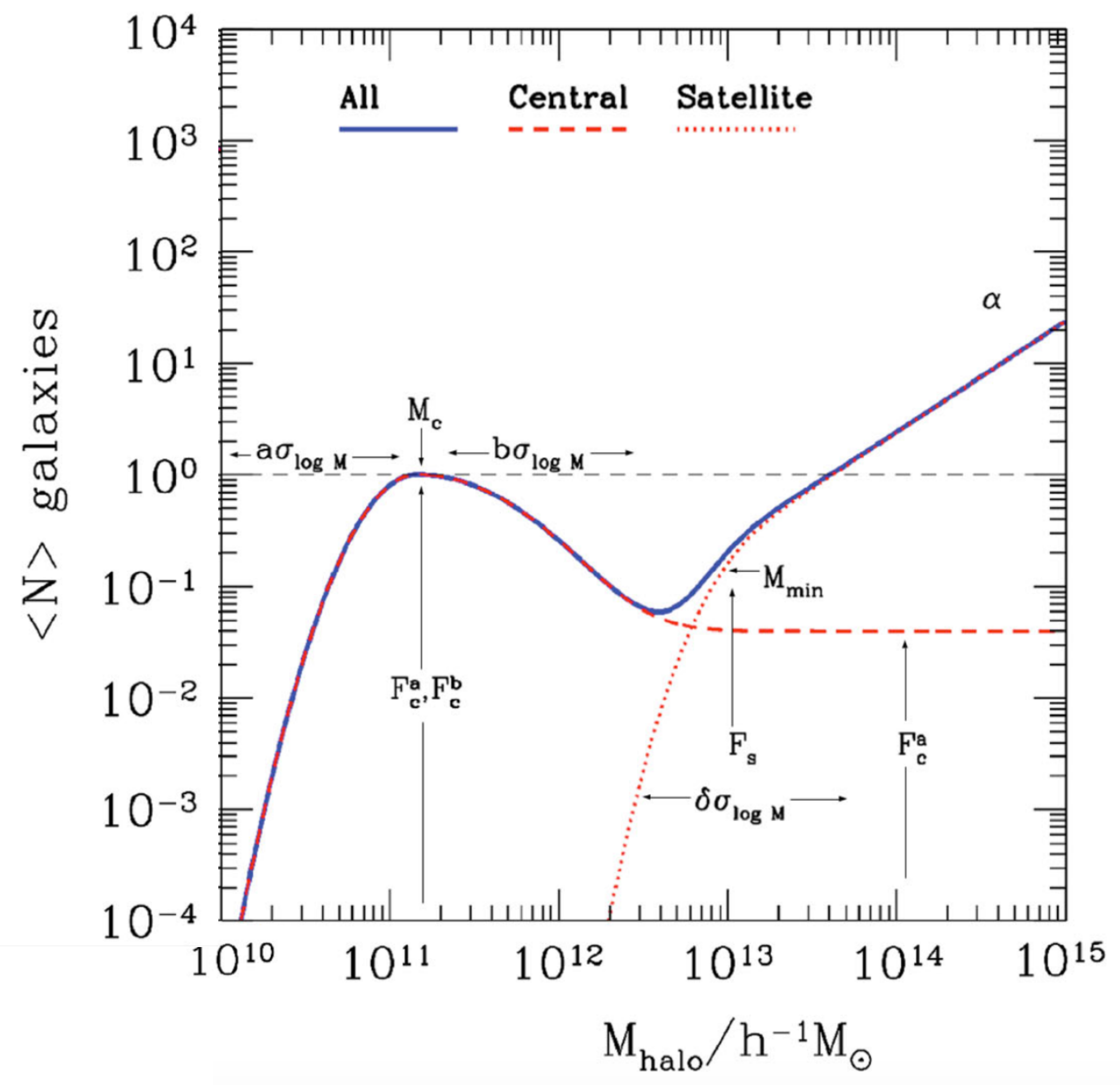


- We construct the 2-point angular correlation function for HiZELS samples.
- Power law fits (with large-scale correction to simple Limber approximation due to very narrow filter profiles) fit the data fairly well.
- The angular clustering amplitude for each sample is easily converted to a spatial one because the redshift distribution of emitters is very well determined.

Power-law fits to correlation functions

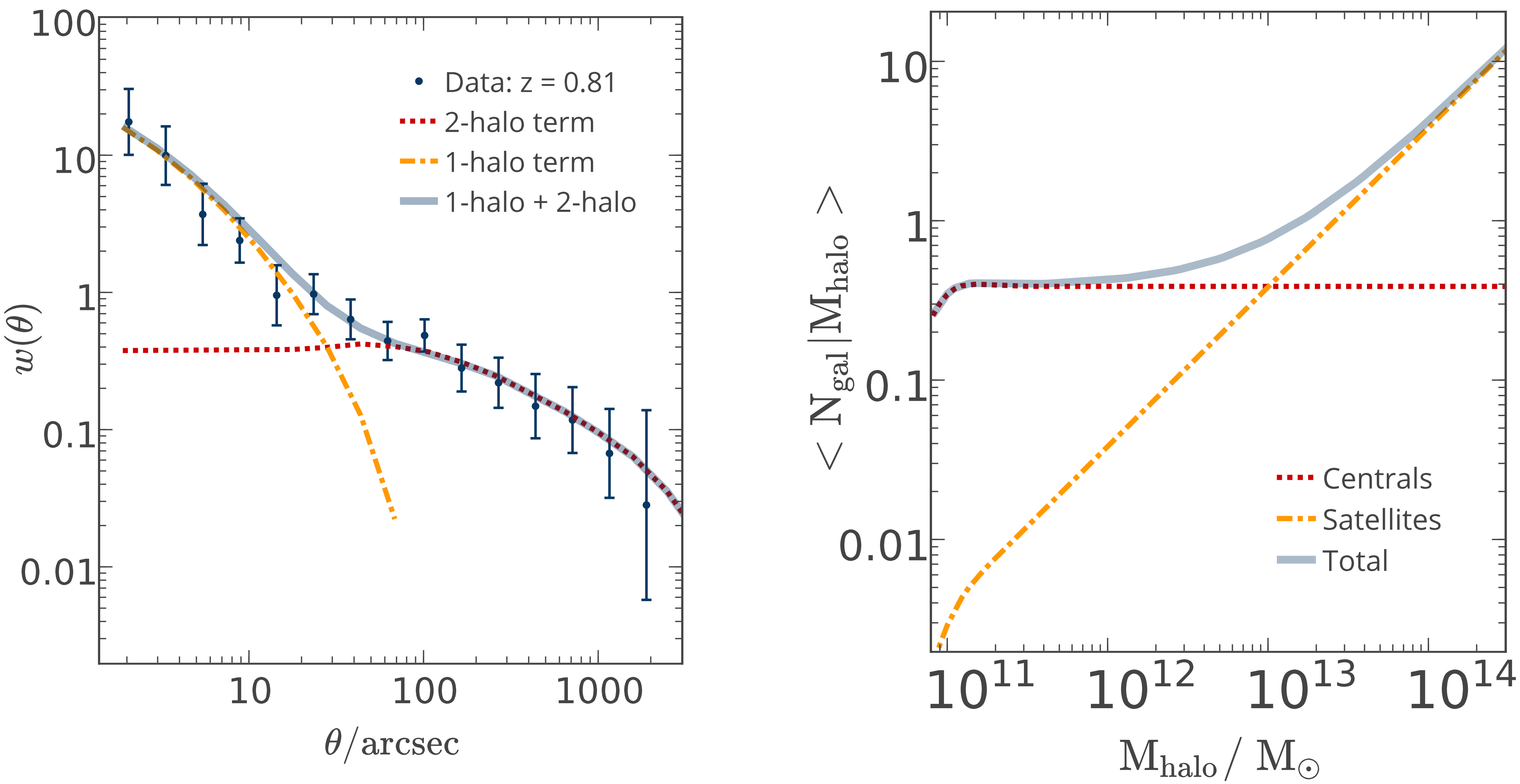
Contreras et al. 2013



We parameterise the number of central/satellite galaxies as a function of halo mass. We constrain these parameters by constructing model correlation functions and comparing these to data.

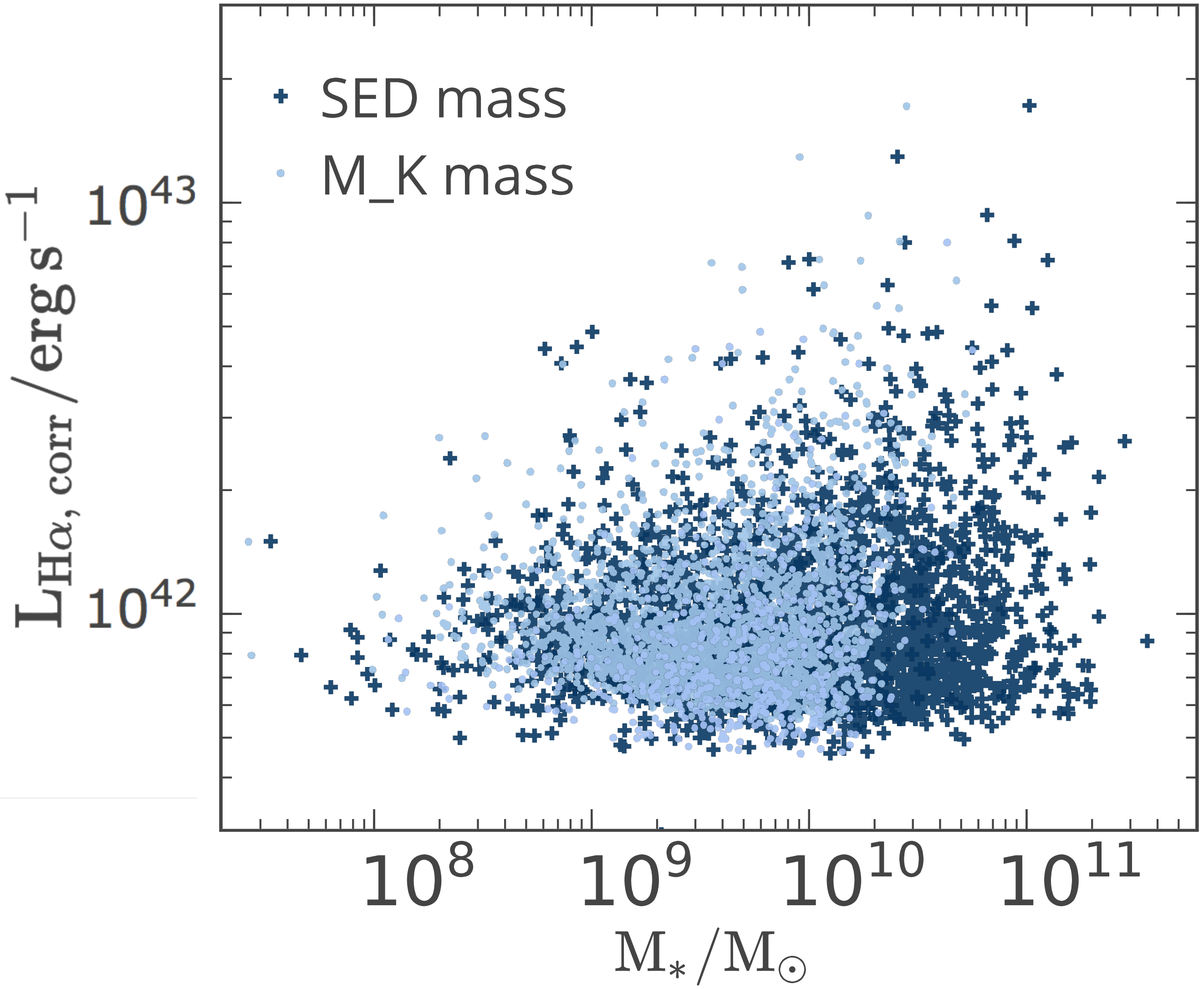
We use HALOMOD (Murray et al. in prep; https://github.com/steven-murray/halomod) to fit HOD models.

Halo occupation distribution (HOD) modelling



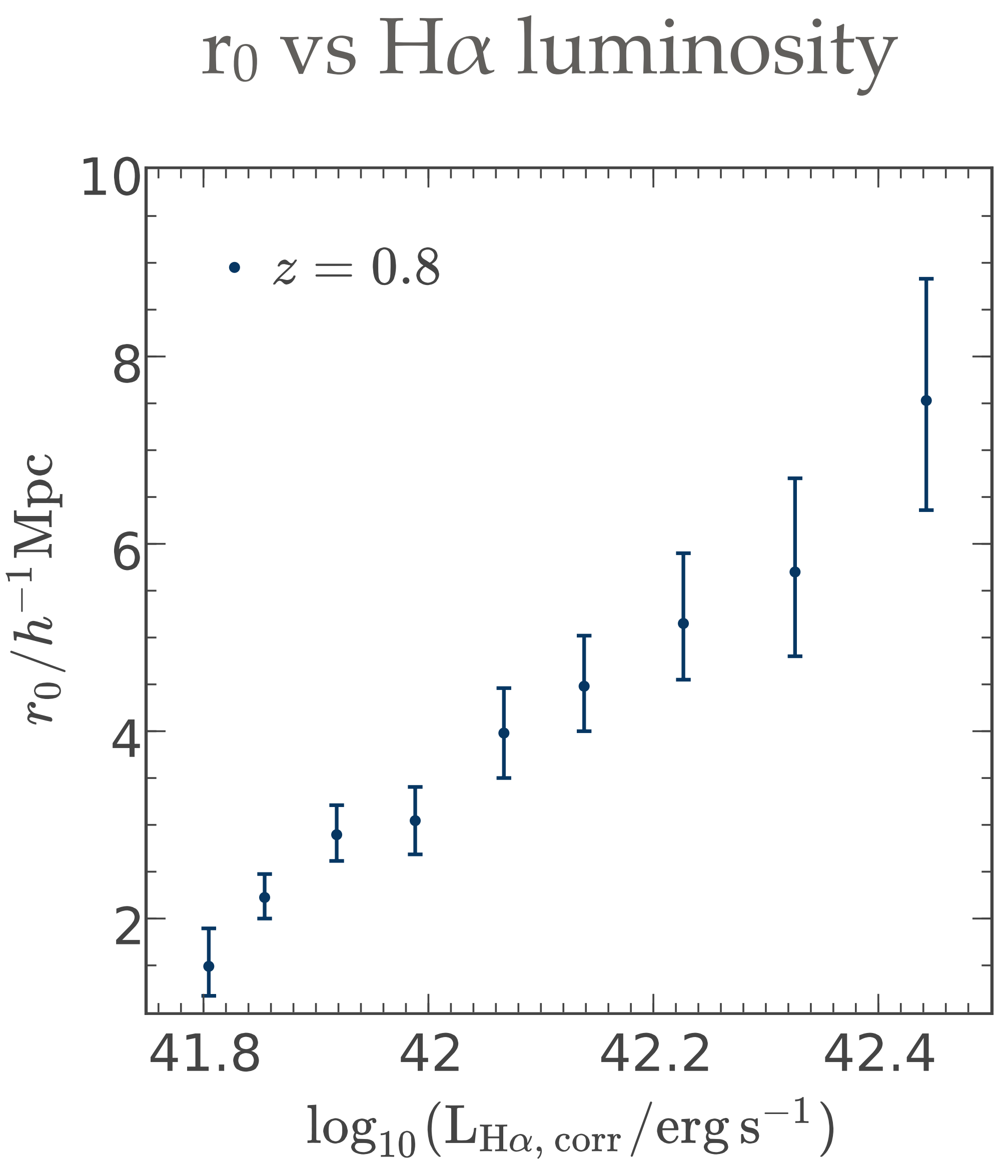
We can clearly see the separate contributions of the 1-halo and 2-halo terms to the measured correlation function.

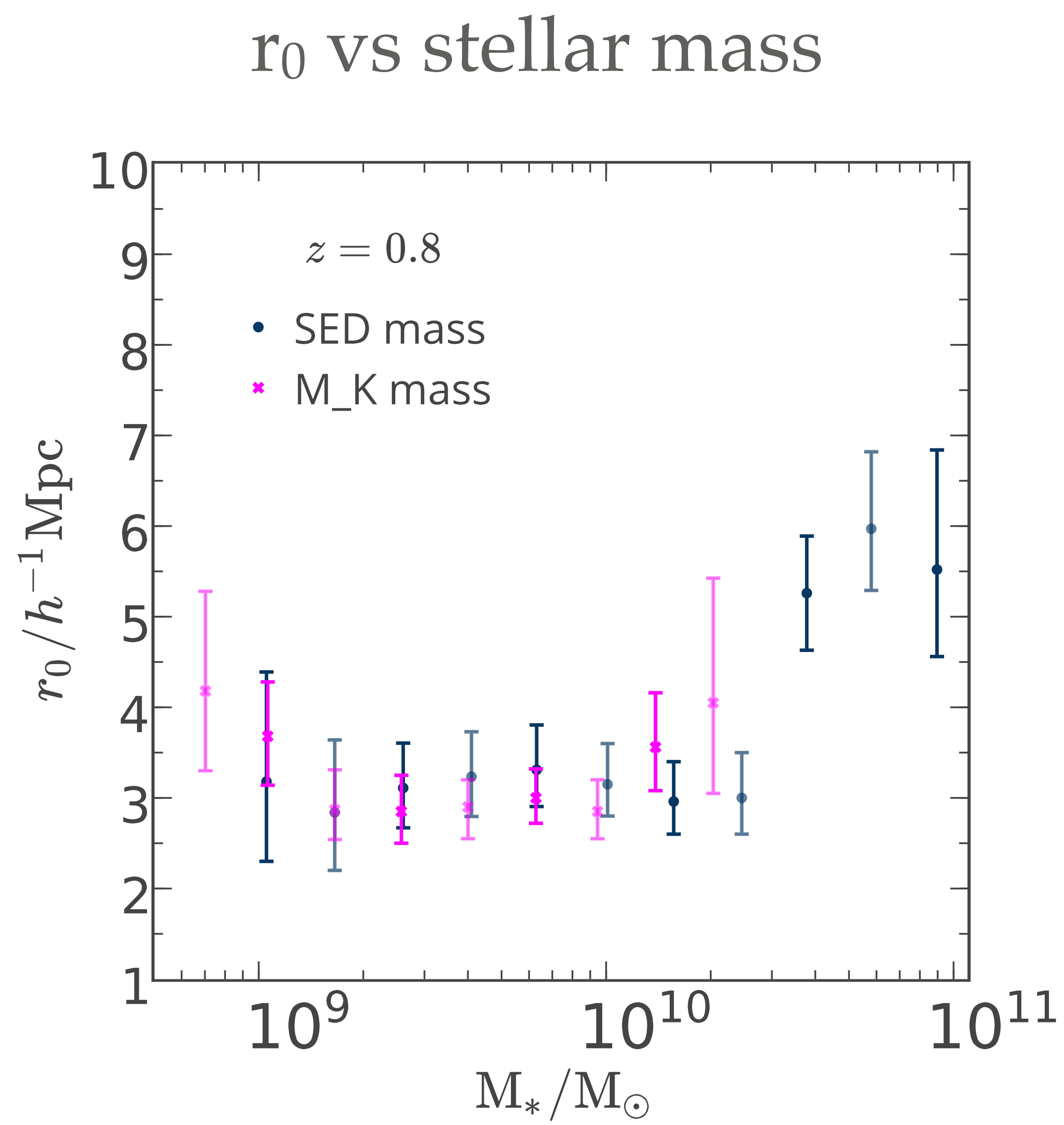
Fitting HOD models to data



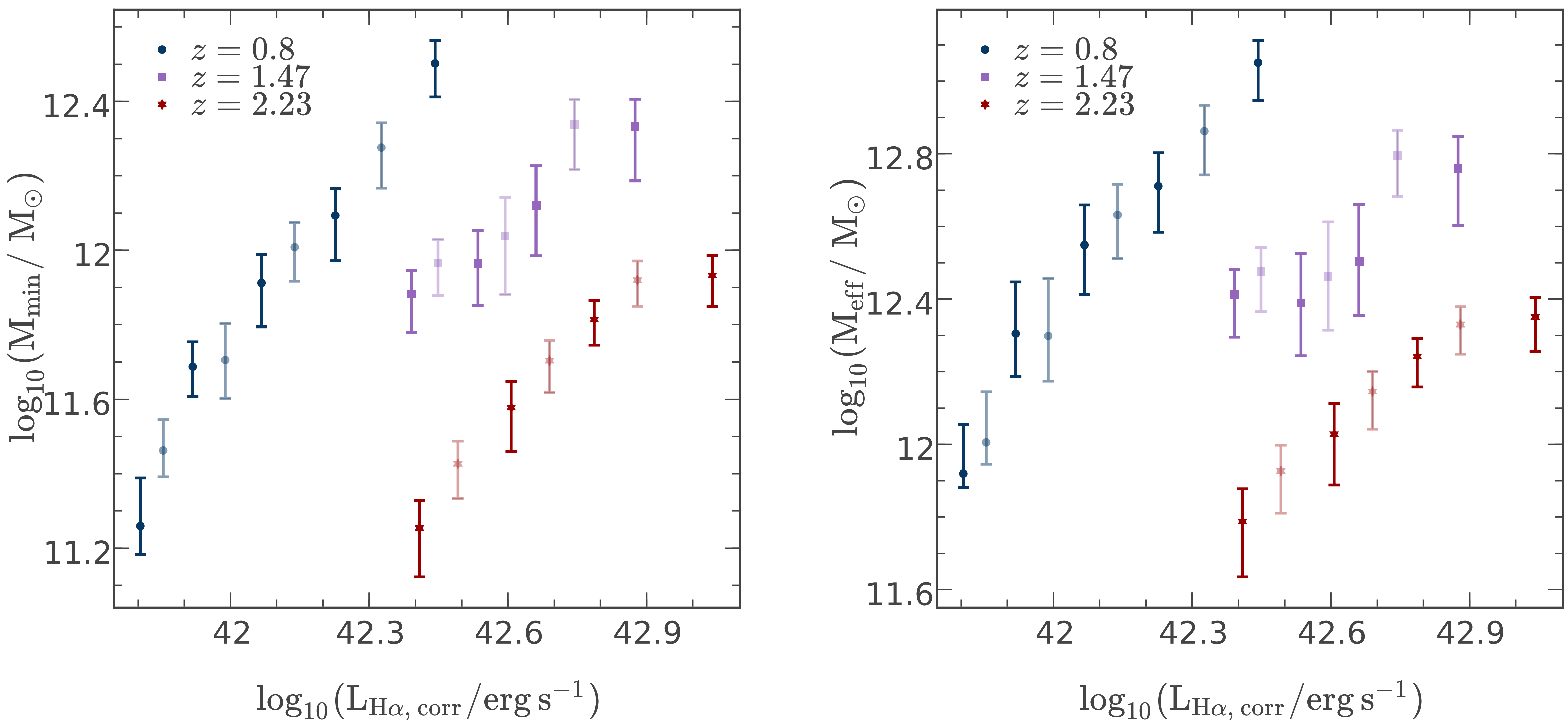
z~0.8 data spans large ranges in both stellar mass and Hα luminosity

Binning samples by Hα luminosity and stellar mass





Strong trends in clustering strength with Hα luminosity (though not with stellar mass)



Results: relationship between Hα luminosity and dark matter halo mass

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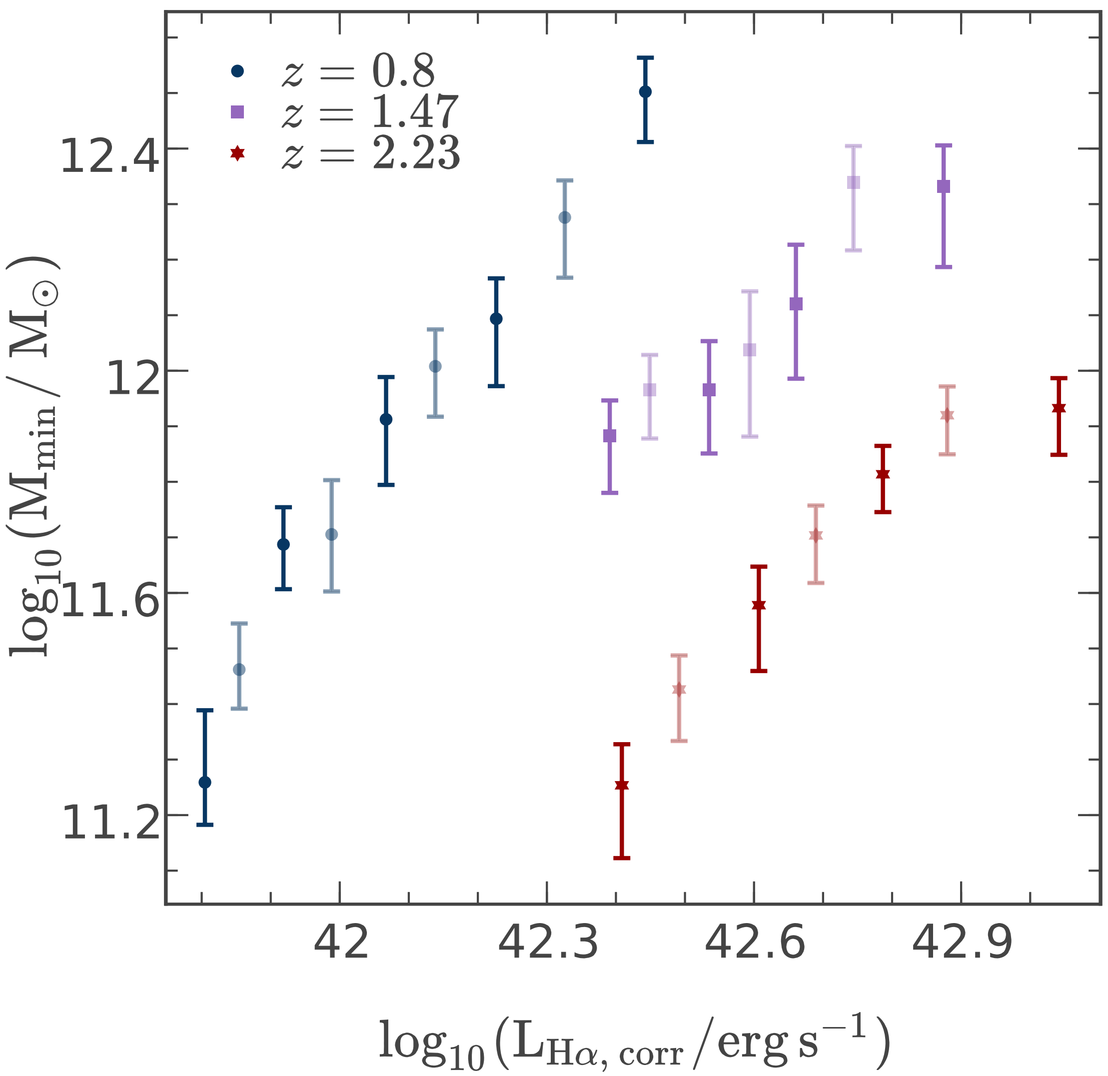
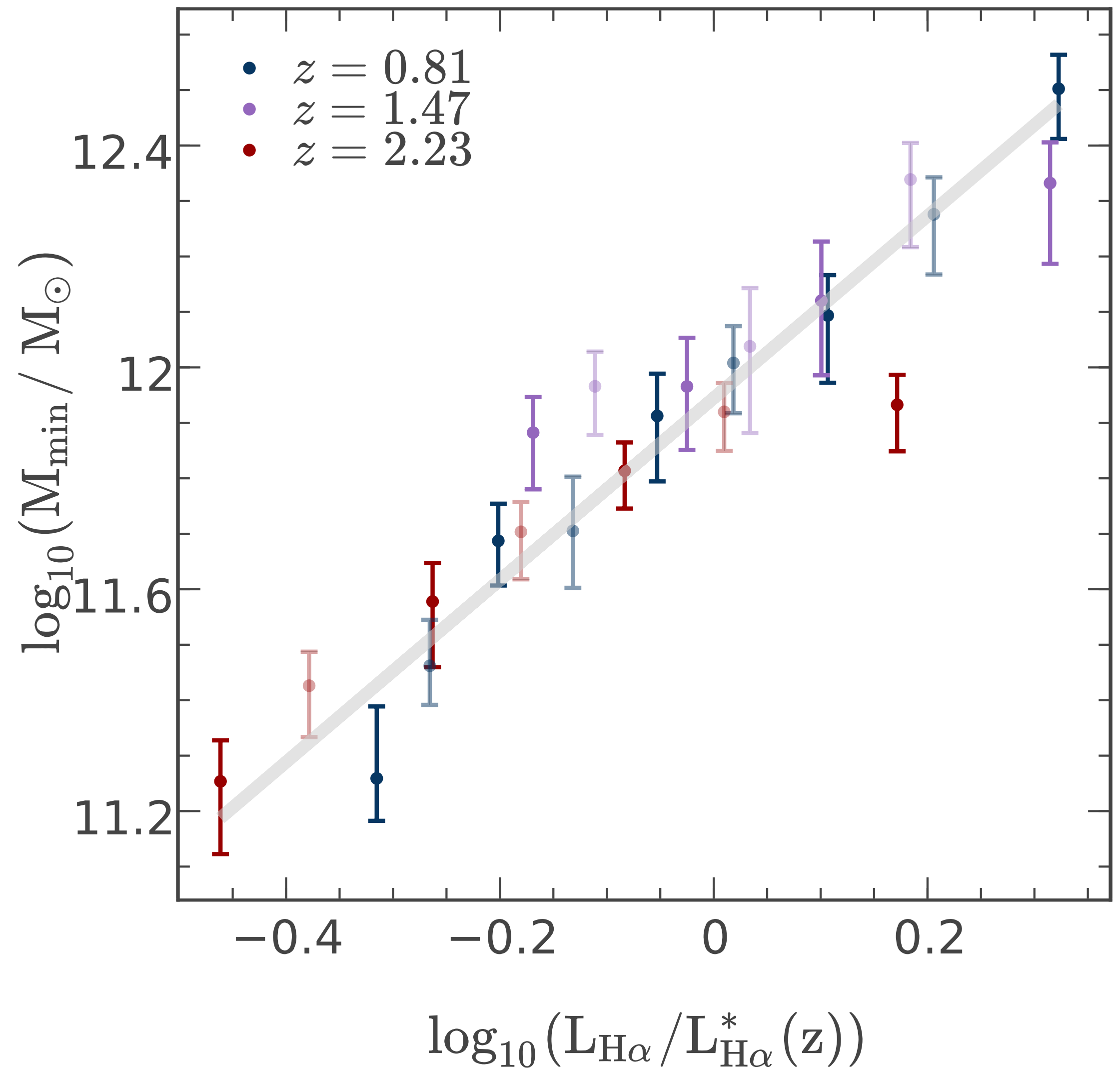
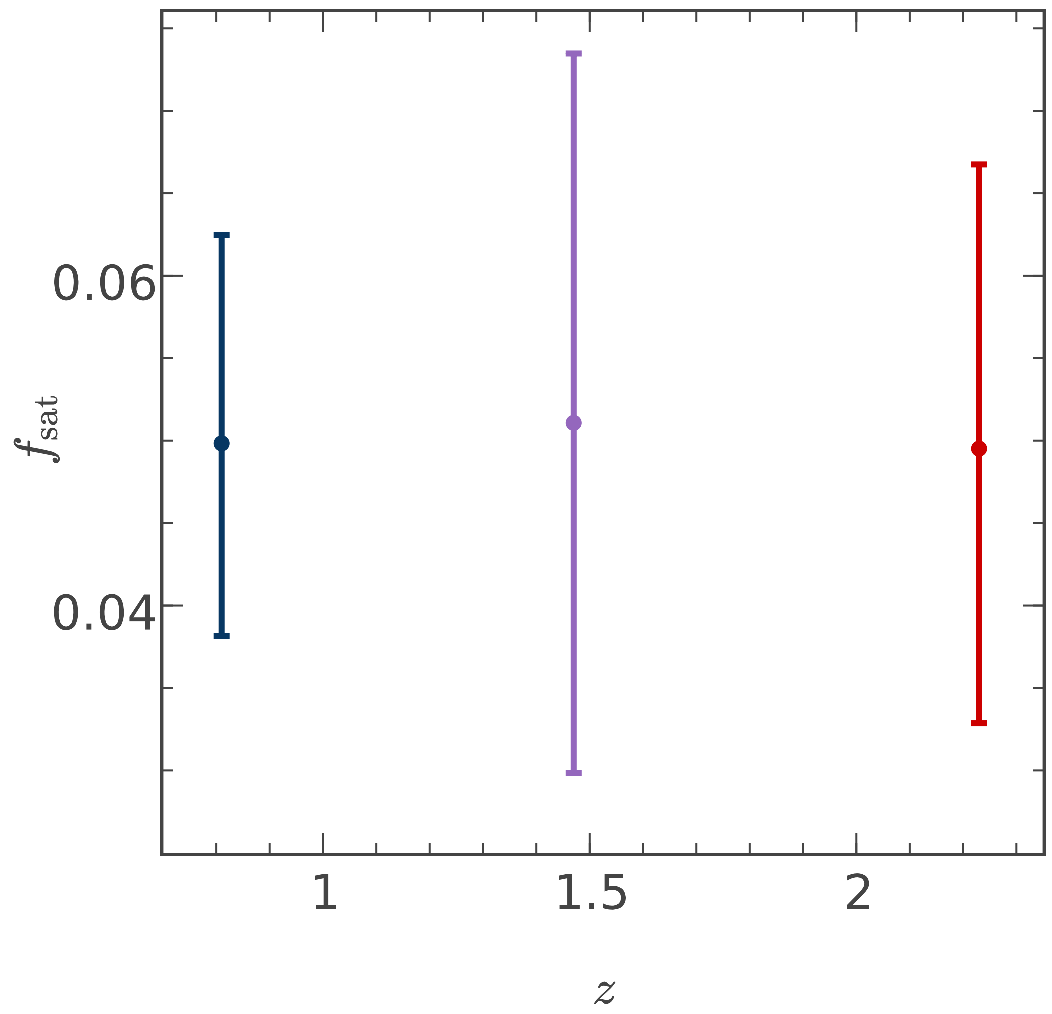
Scaling by $L_{H\alpha}$* brings the halo mass relation into agreement across 3 redshift slices, revealing a tight relationship between galaxy star formation rate and host halo mass.





Halo environment is a strong driver of galaxy star formation rate and therefore the evolution of the luminosity function.

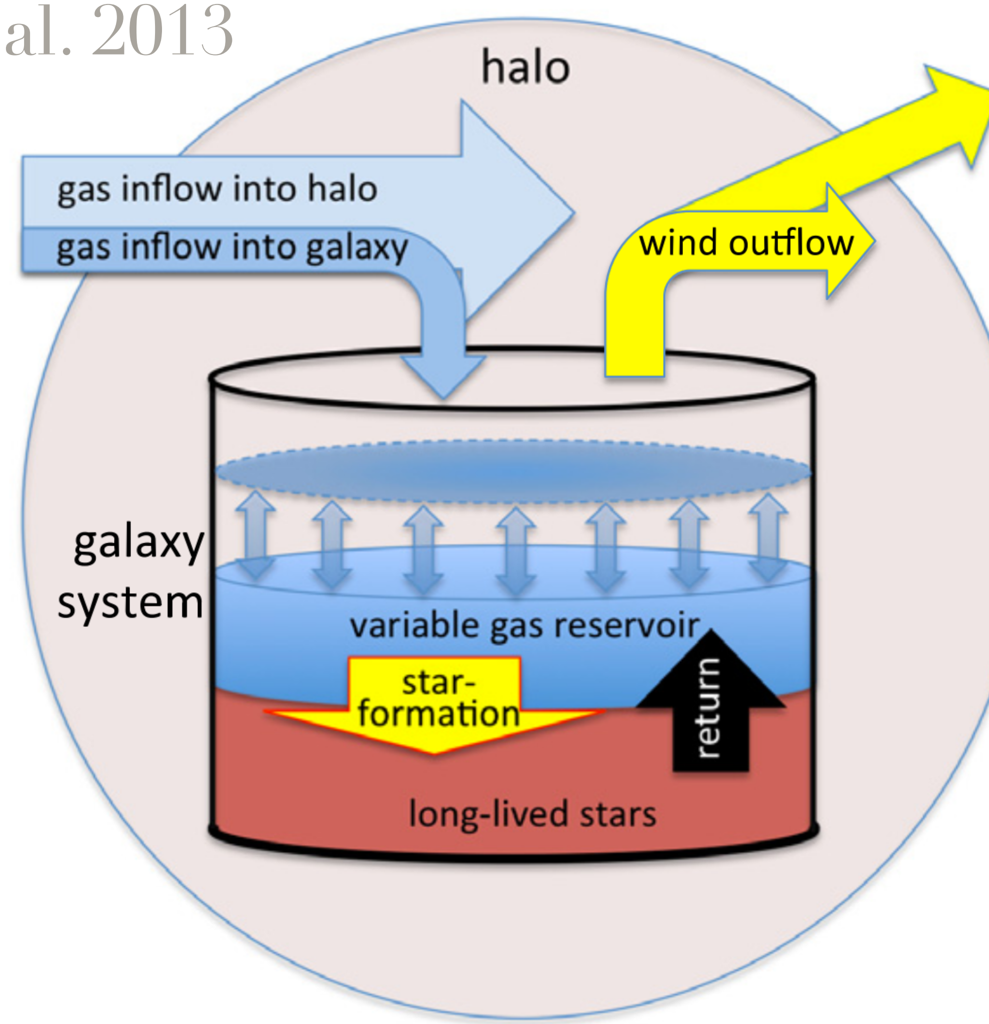


Most HiZELS galaxies are centrals.

The satellite fractions of mass-limited samples are higher => satellite quenching, particularly in the lowest redshift slice.

Satellite fractions for these Hα emitters are low at all redshifts

Lilly et al. 2013



Specific mass accretion rate of the dark matter halo:

$$sMIR_{\rm DM} = \frac{1}{m_{\rm halo}} \frac{dm_{\rm halo}}{dt}$$

Specific star formation rate of the galaxy:

$$sSFR = \frac{1}{(1-\eta)(1-R)} sMIR_{\rm DM}$$

$= f(z)$

$$\left\langle \frac{dm_{\rm halo}}{dt} \right\rangle = 46.1 \left(\frac{m_{\rm halo}}{10^{12}} \right)^{1.1} (1 + 1.11z) \sqrt{\Omega_M (1+z)^3 + \Omega_\Lambda}$$

Fakhouri et al. 2010

The gas regulator model

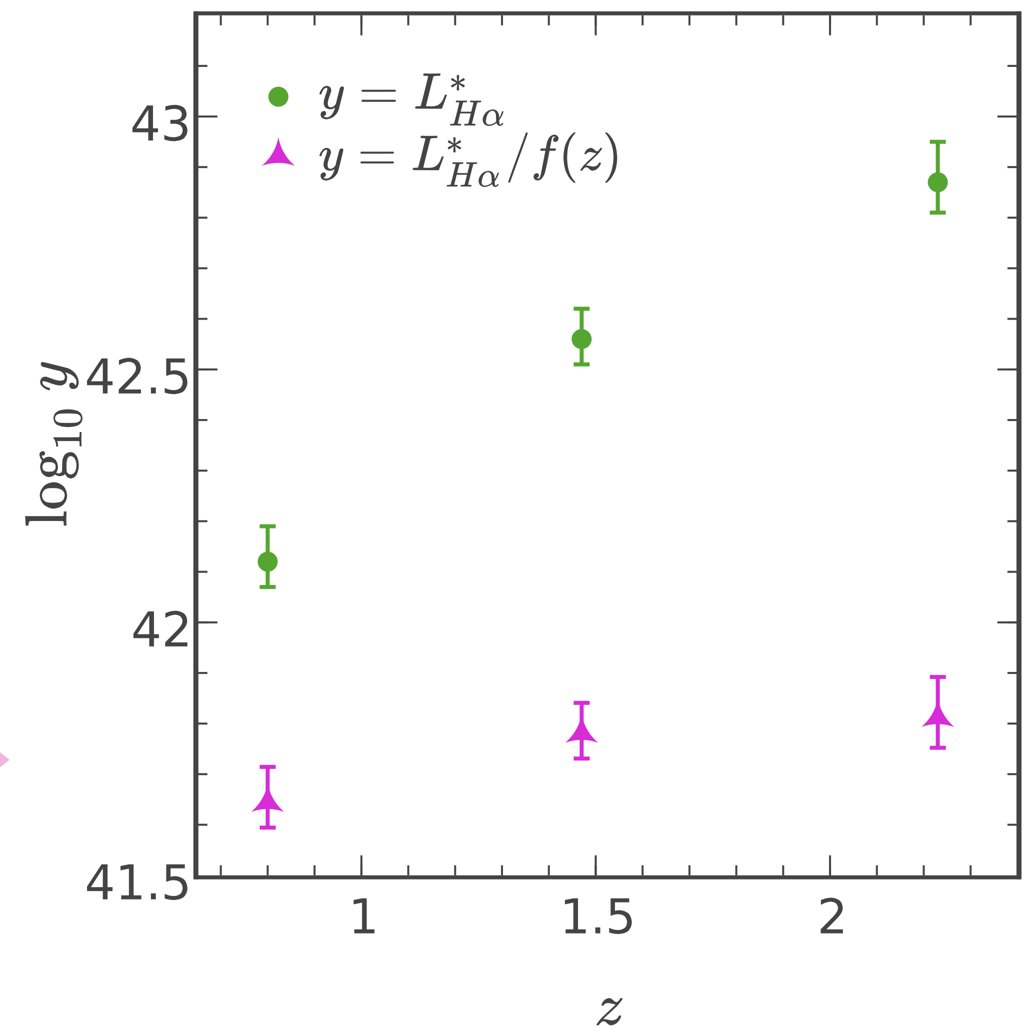
For our observed redshift-independent relation:

$$\frac{L_{\mathrm{H}\alpha}}{L^*_{\mathrm{H}\alpha}(z)} = \left(\frac{m_{\mathrm{halo}}}{10^{12}}\right)^{1/1.6}$$

to hold, we require:

$$\frac{f(z)}{L^*_{\mathrm{H}\alpha}(z)} = const.$$

And that's what we find.



This supports a model in which the evolution of galaxy luminosities is driven by the halo mass growth, in line with the gas regulator model. The HiZELS samples are dominated by typical SF galaxies in equilibrium.

The gas regulator model

Summary

- We have quantified the clustering of star-forming galaxies at $0.8 < z < 2.2$ from HiZELS.
- The clustering strength increases steeply with Hα luminosity. HOD modelling shows that galaxies with the highest Hα luminosities reside in the most massive dark matter halos, with a tight, redshift-independent relationship between scaled galaxy luminosity ($L_{H\alpha}/L_{H\alpha}^*$) and halo mass.
- Interpreting our results using the framework of the gas regulator model, we find that HiZELS galaxy luminosities evolve in equilibrium with their dark matter halos.