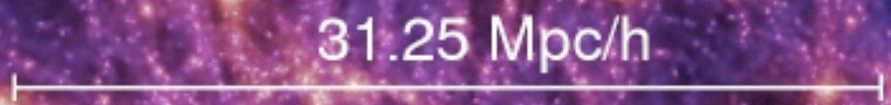
How galaxies form in protoclusters



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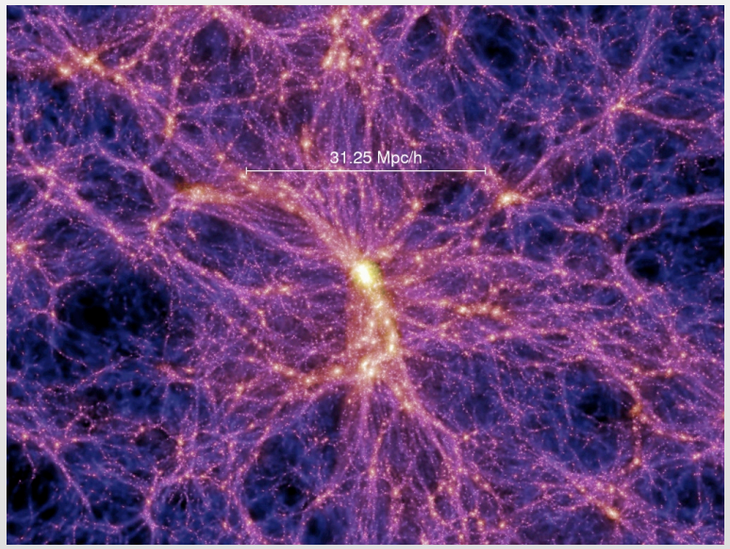
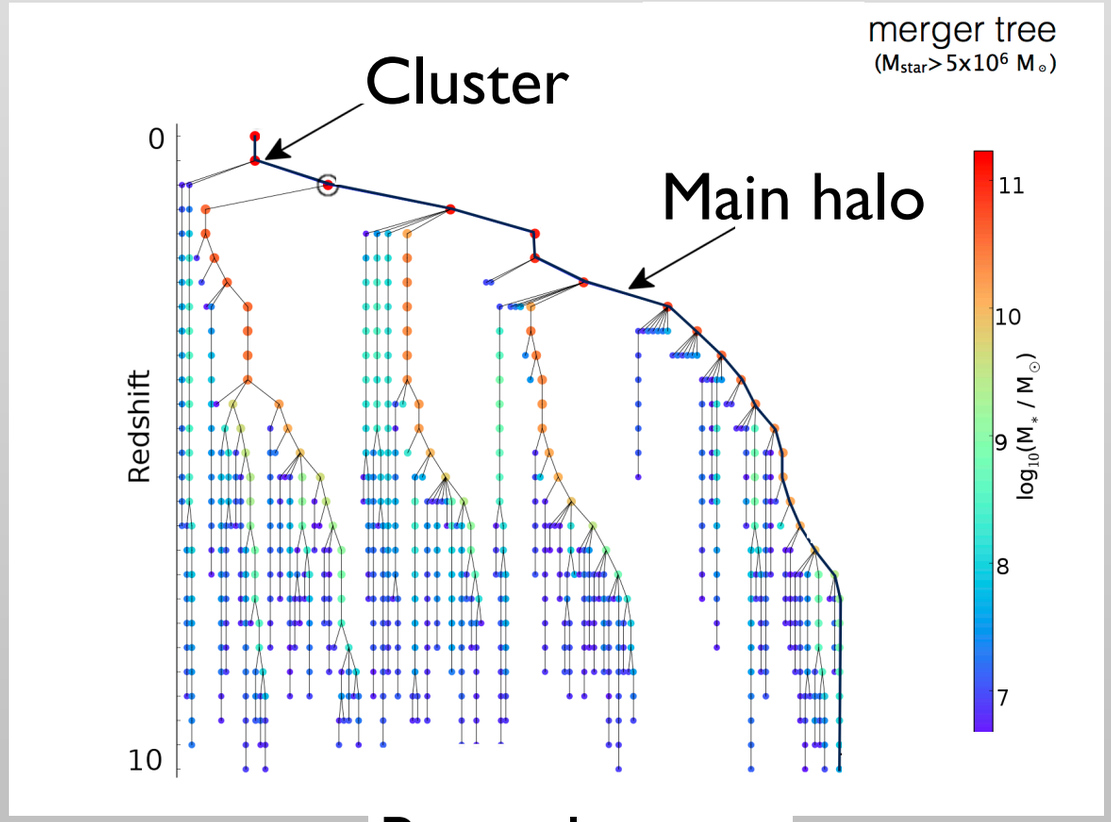
Exploring protocluster galaxy formation with SAMs

- Millenium + L-galaxies SAM Springel (2005), Henriques et al. (2015)

- Data from the literature (Finn et al. 2005; Tadaki et al. 2011; Calvi et al. 2013; van der Burg et al. 2013; Clements et al. 2014; Dannerbauer et al. 2014; Stroe et al. 2015; Casey 2016; Hatch et al. 2017)

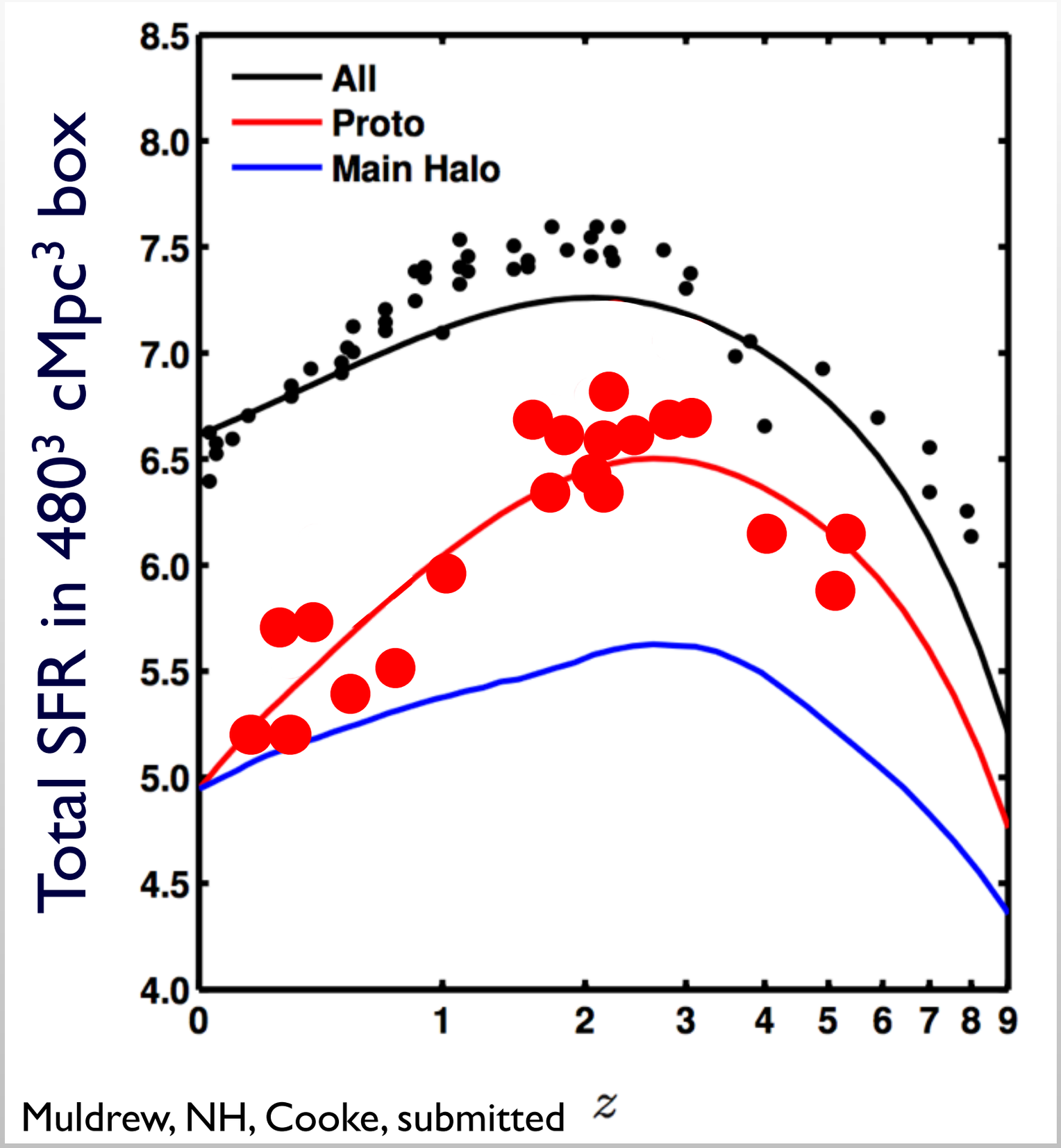
- Examine **star formation history**, **stellar mass growth** and **stellar mass assembly**





Protocluster

Star formation history



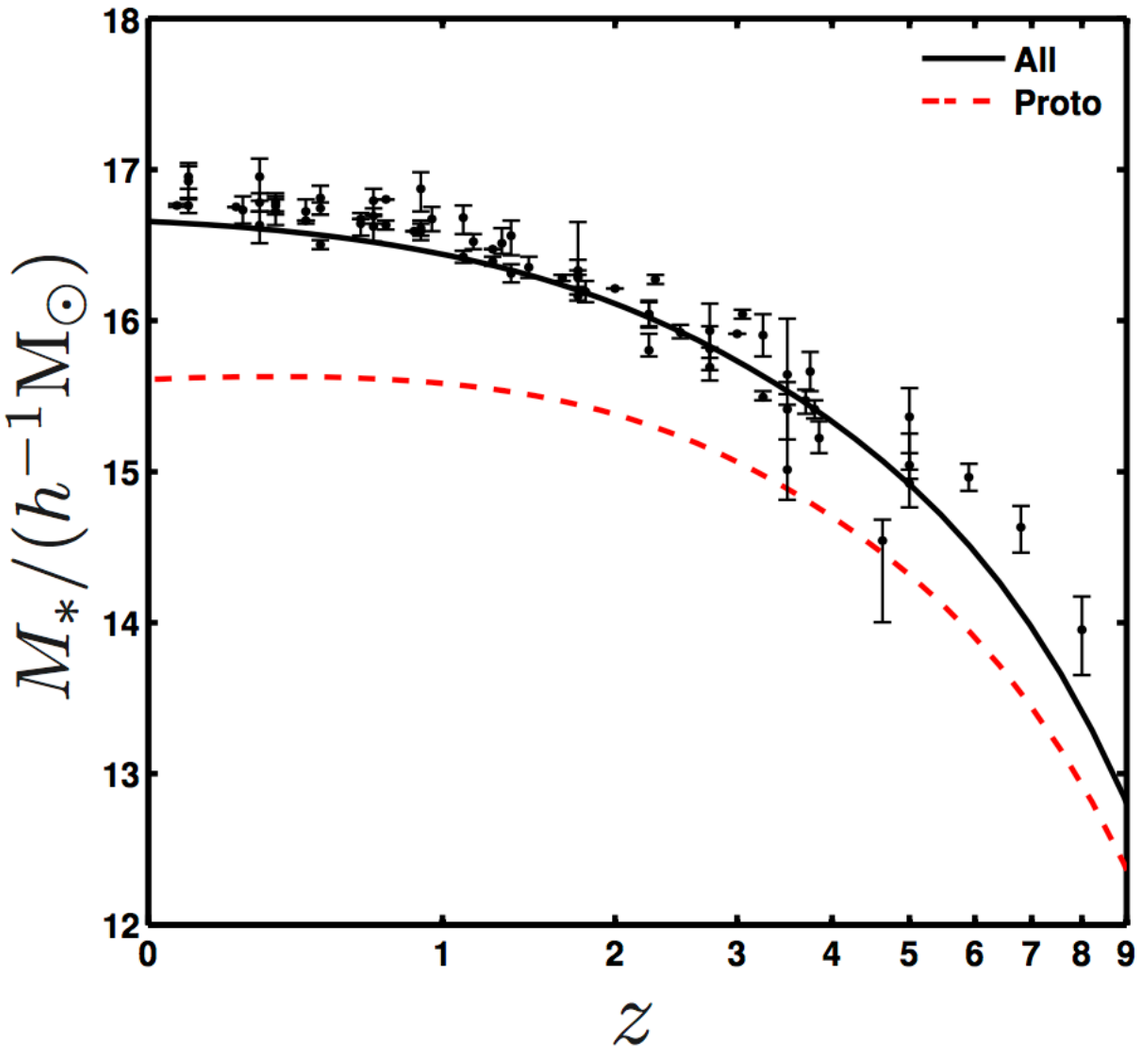
Muldrew, NH, Cooke, submitted

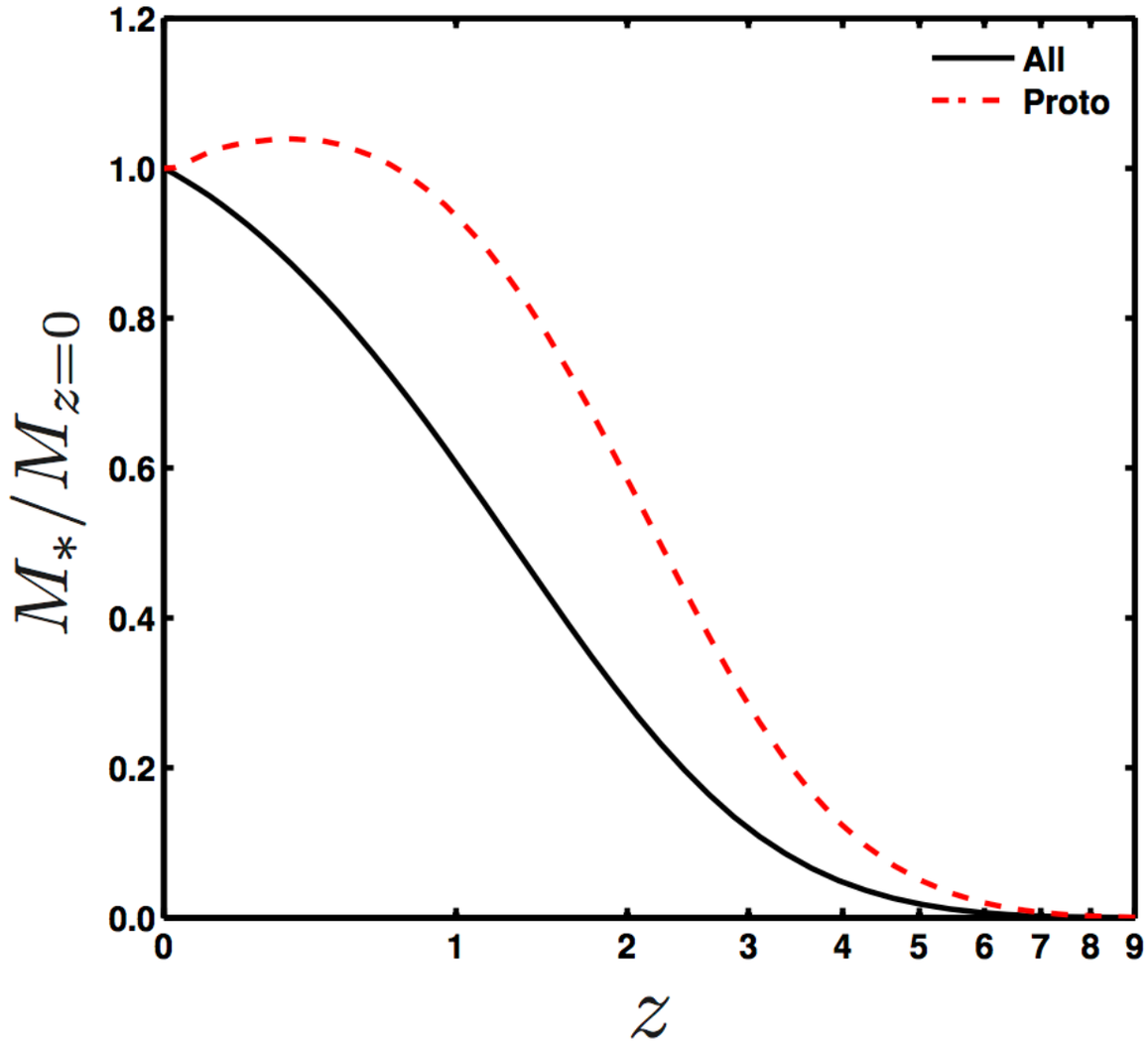
- **Stars that end up in clusters formed in protoclusters**

- SFH peaks ~0.7Gyr earlier in protoclusters than in the field

- Stars formed over a shorter interval in protoclusters than in the field

Stellar mass growth





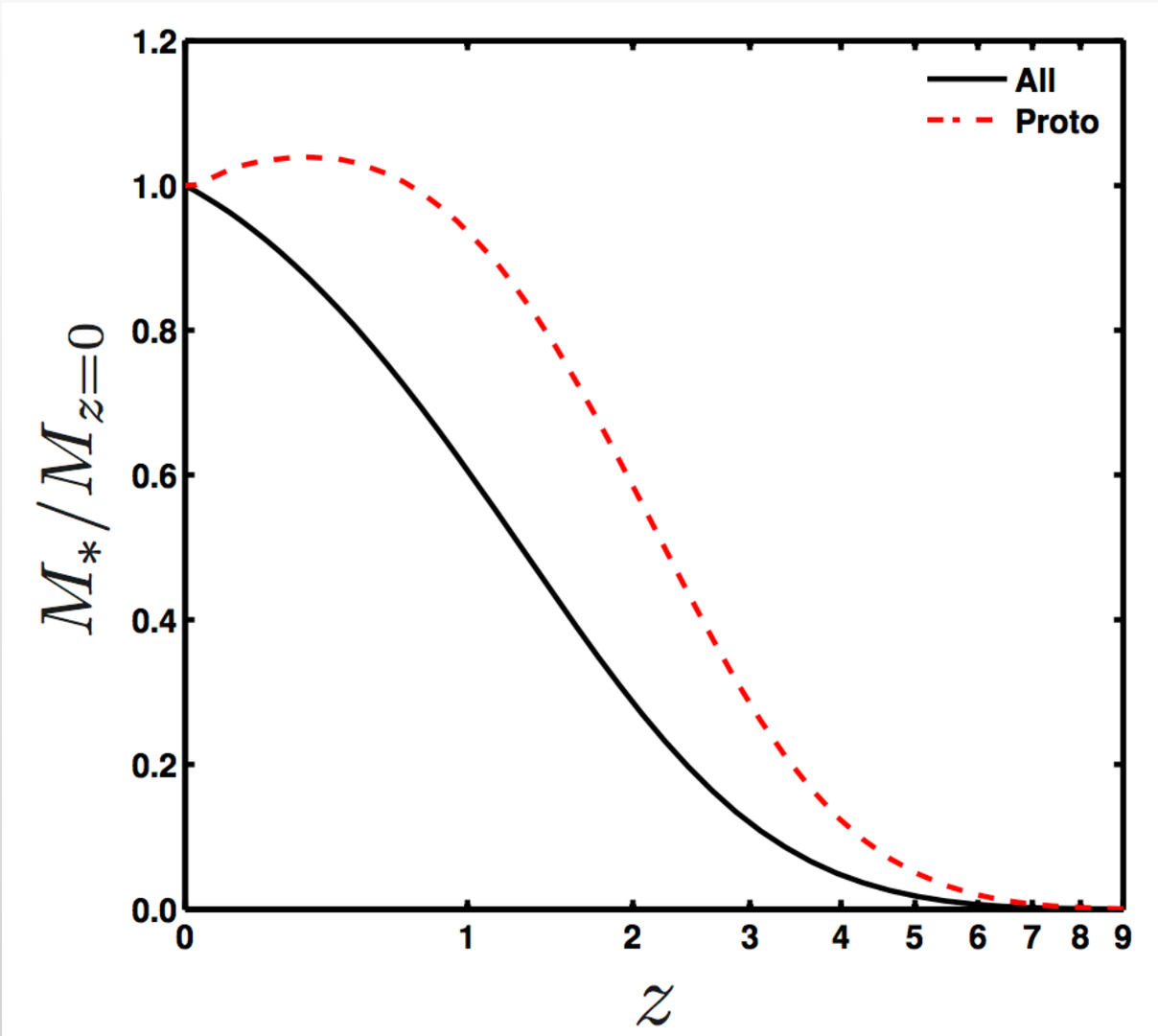
- **Stellar content in clusters formed earlier than in the field**
- 75% of field M∗ formed at z < 2, but 75% of cluster M∗ formed by z = 1.6

Metal enrichment

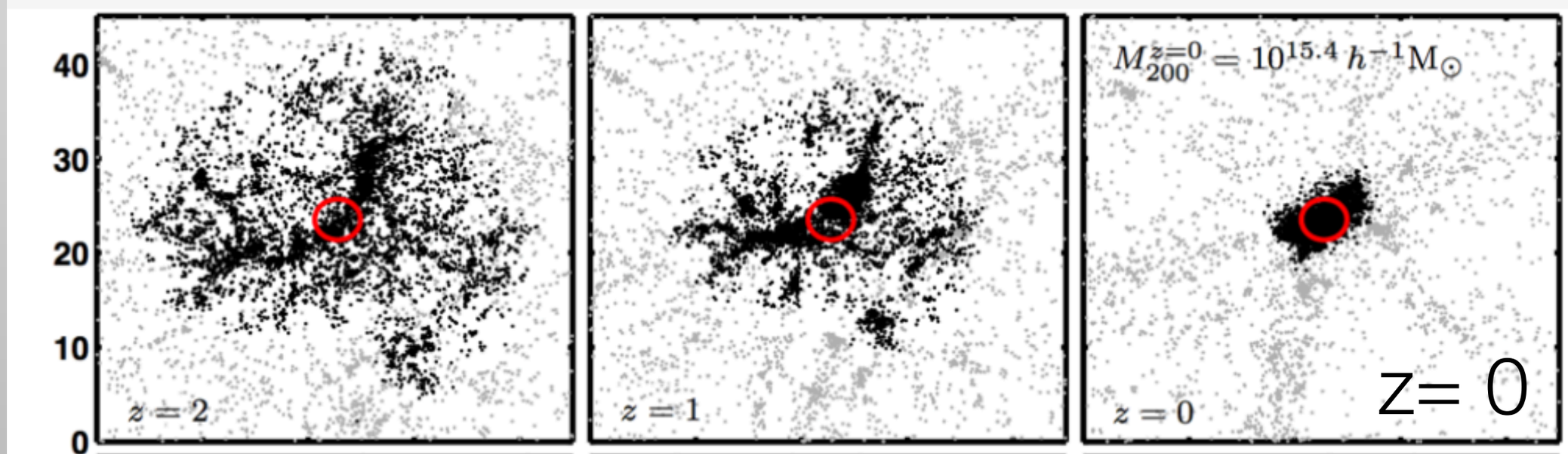
- Total metallicity $Z = M_* y$

- **Metal enrichment occurred earlier in protocluster than in field**

- Results in uniform ICM metallicity Simionescu+2015,2017; Mantz+2017

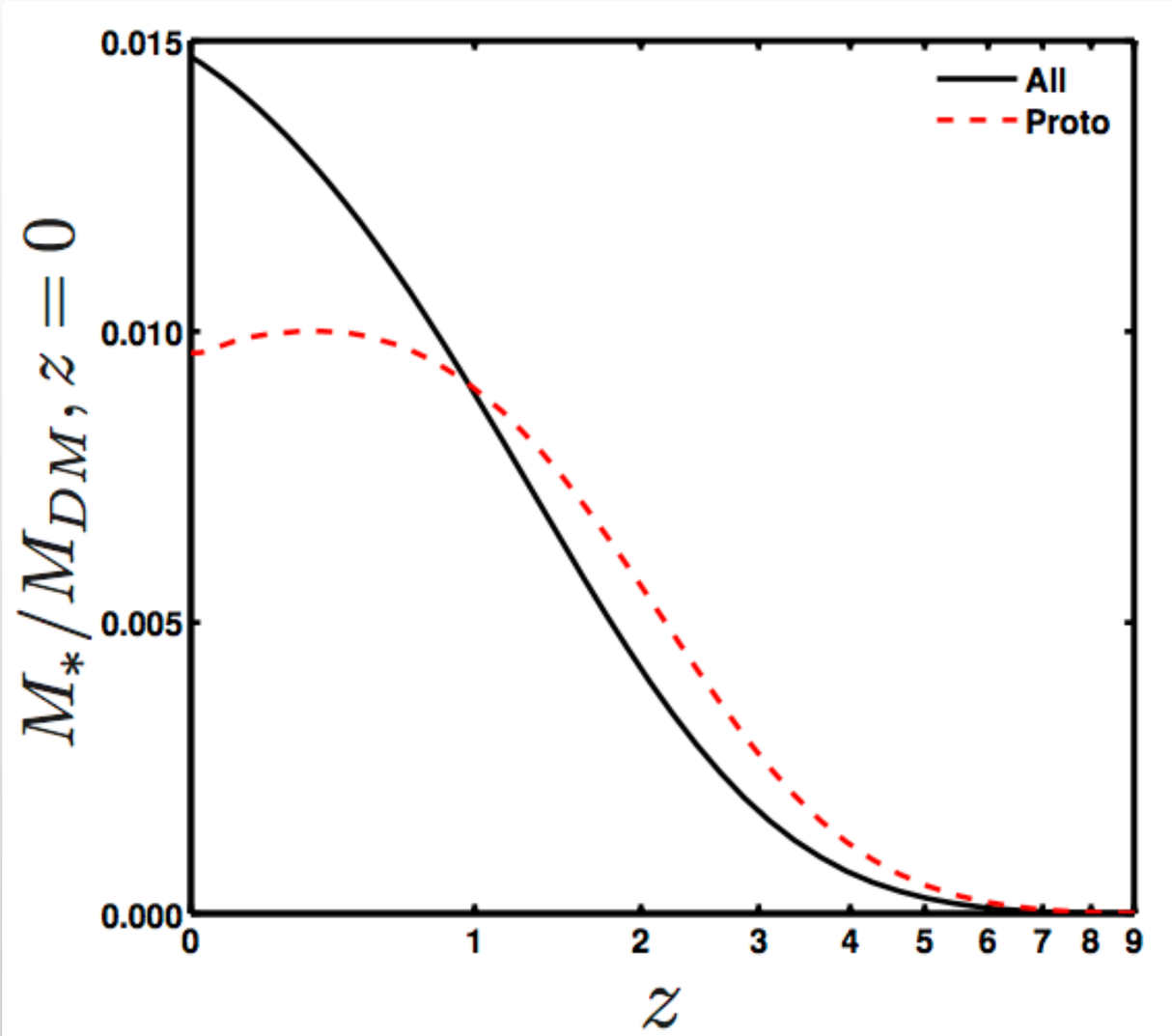


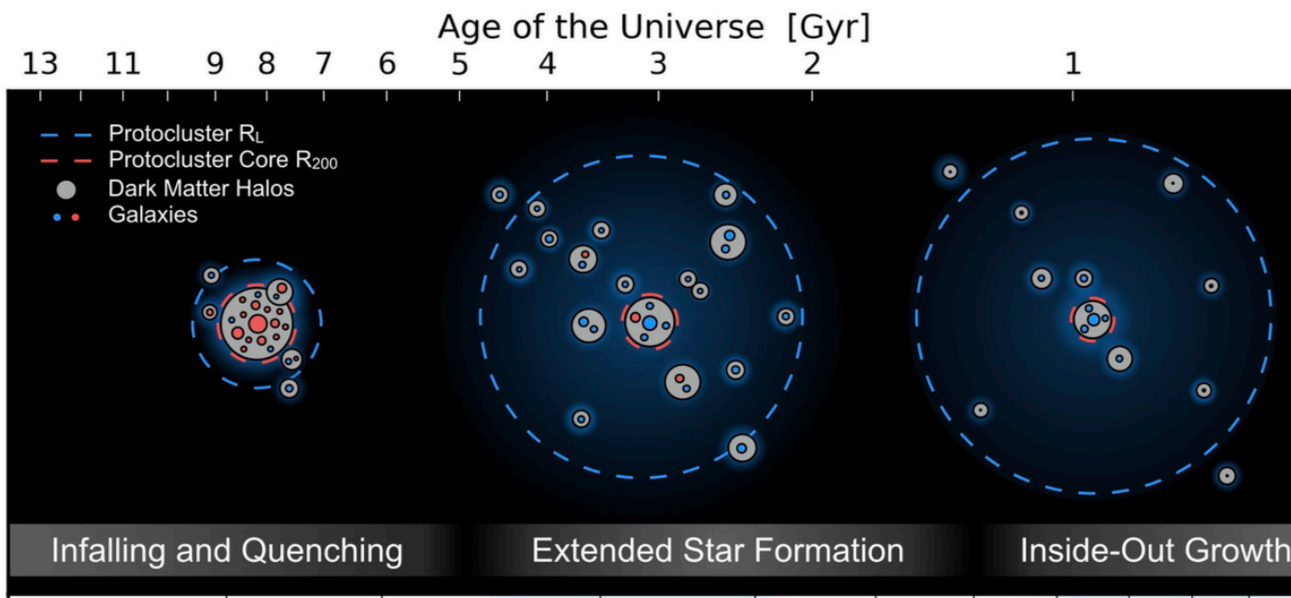
z= 2 z= 1



Star formation efficiency

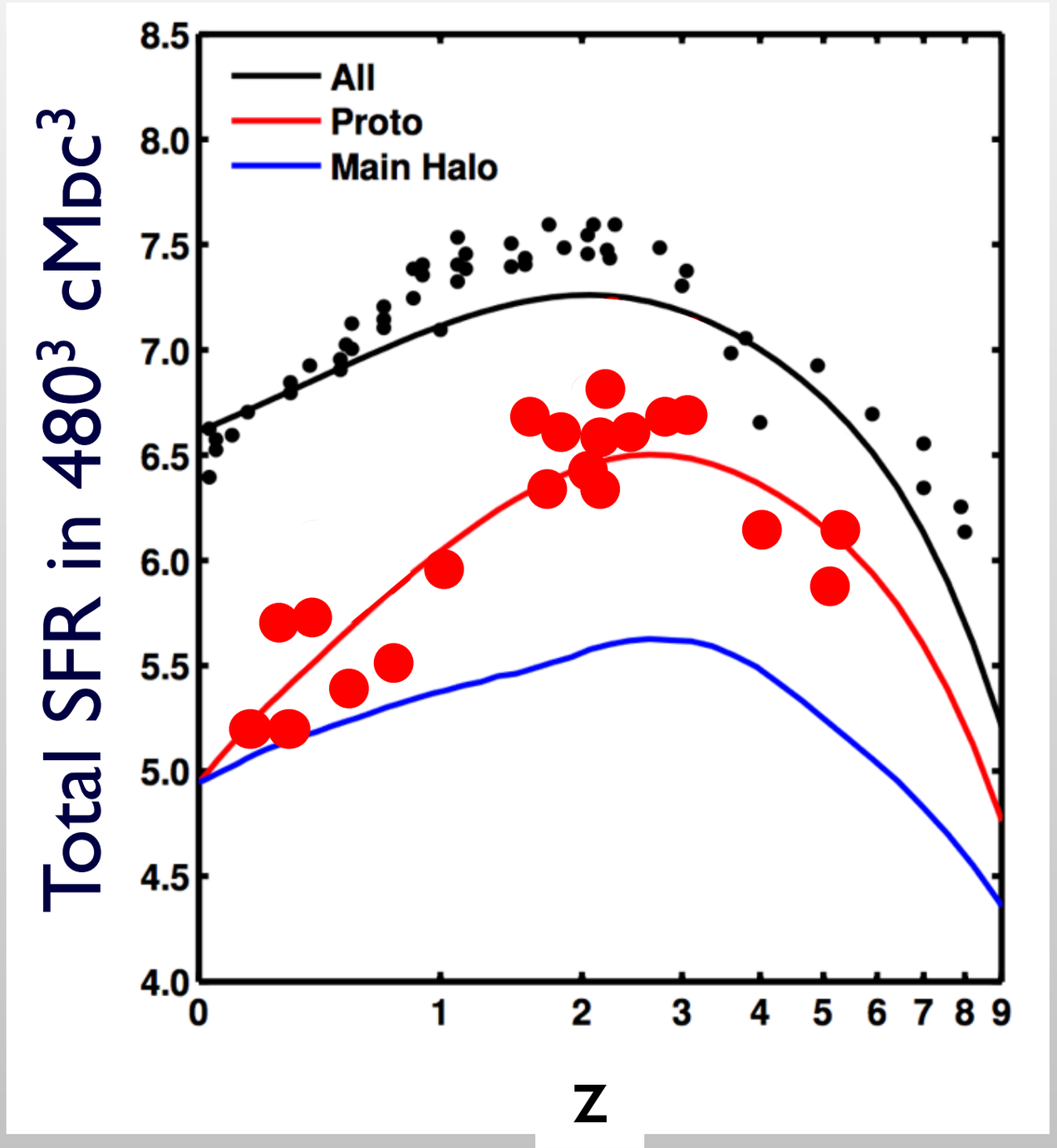
- Normalised by DM halo mass
- Stars form **more** efficiently in protoclusters at z > 1
- Stars form **less** efficiently in protoclusters at z < 1

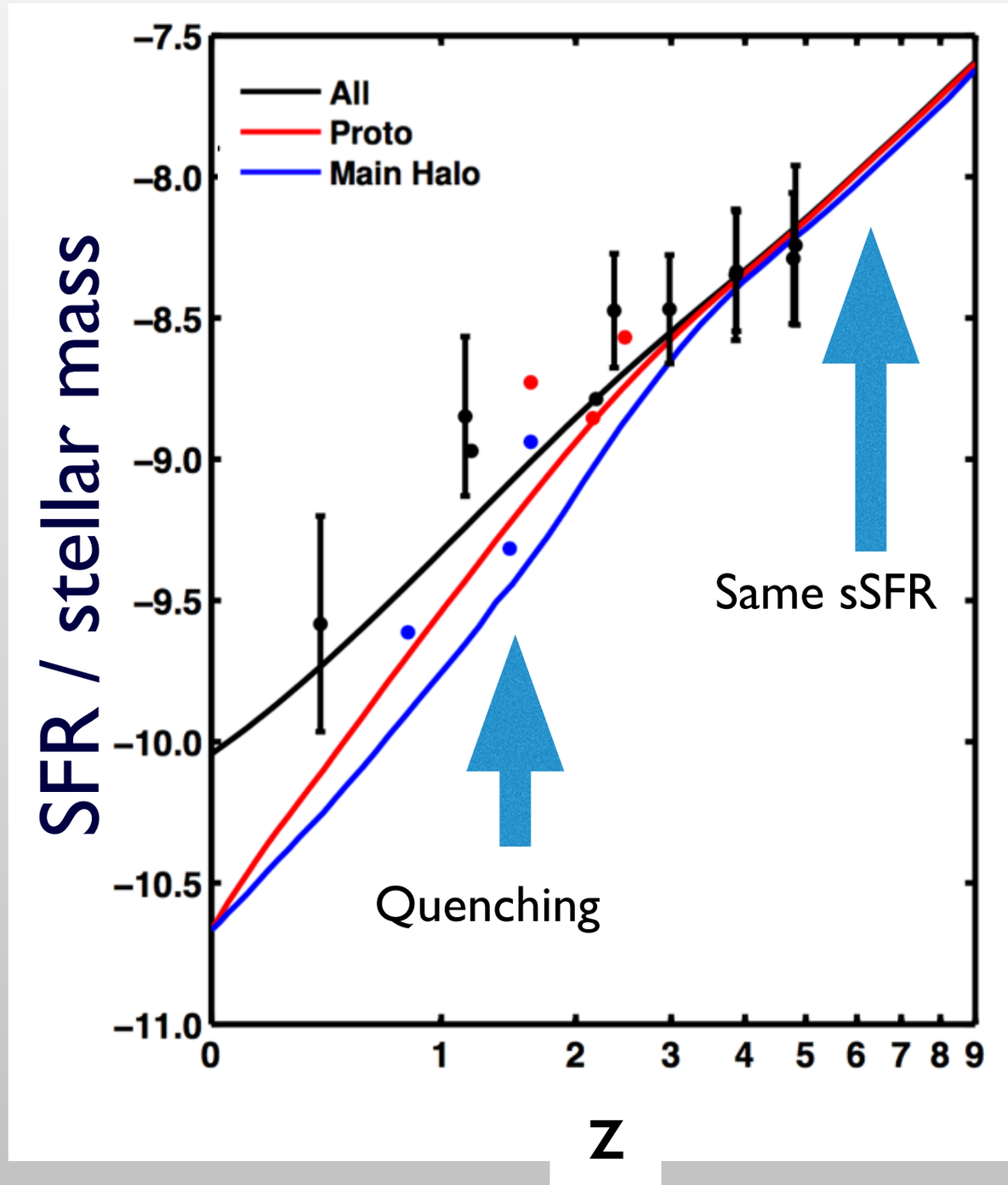




Chiang+ 2017

Quenching causes the different SFH





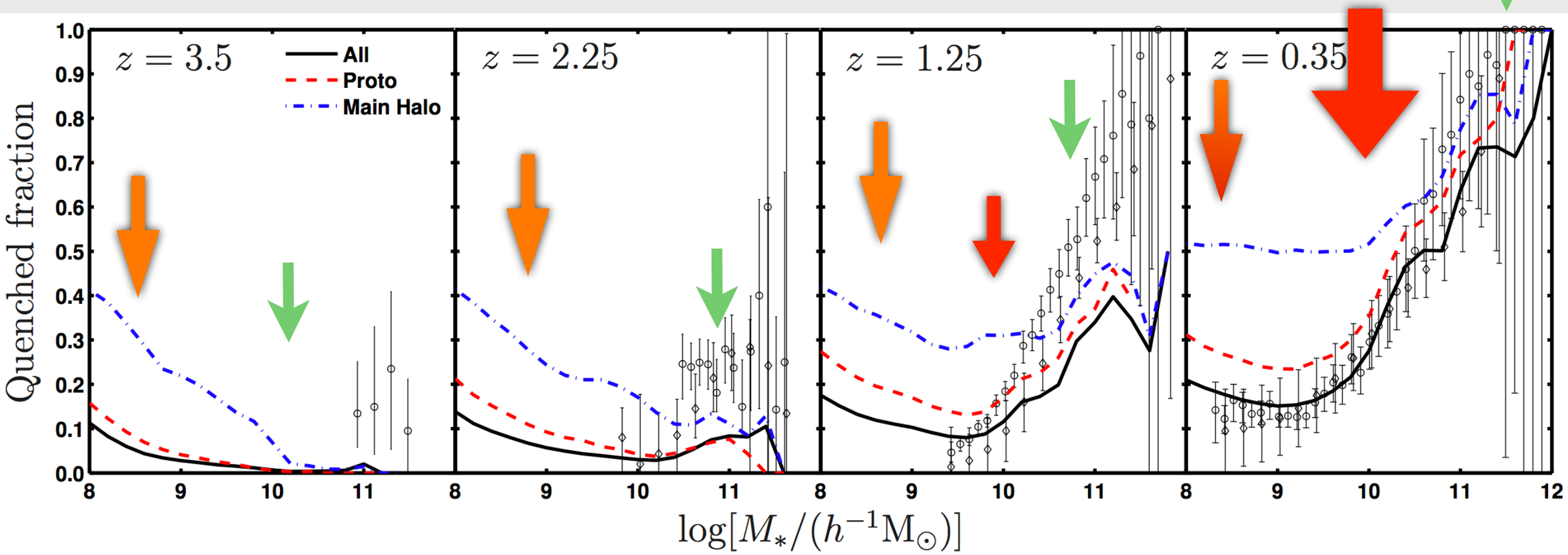
Muldrew, NH, Cooke, submitted

What causes cluster galaxies to quench?

Stellar feedback but no rejuvenation

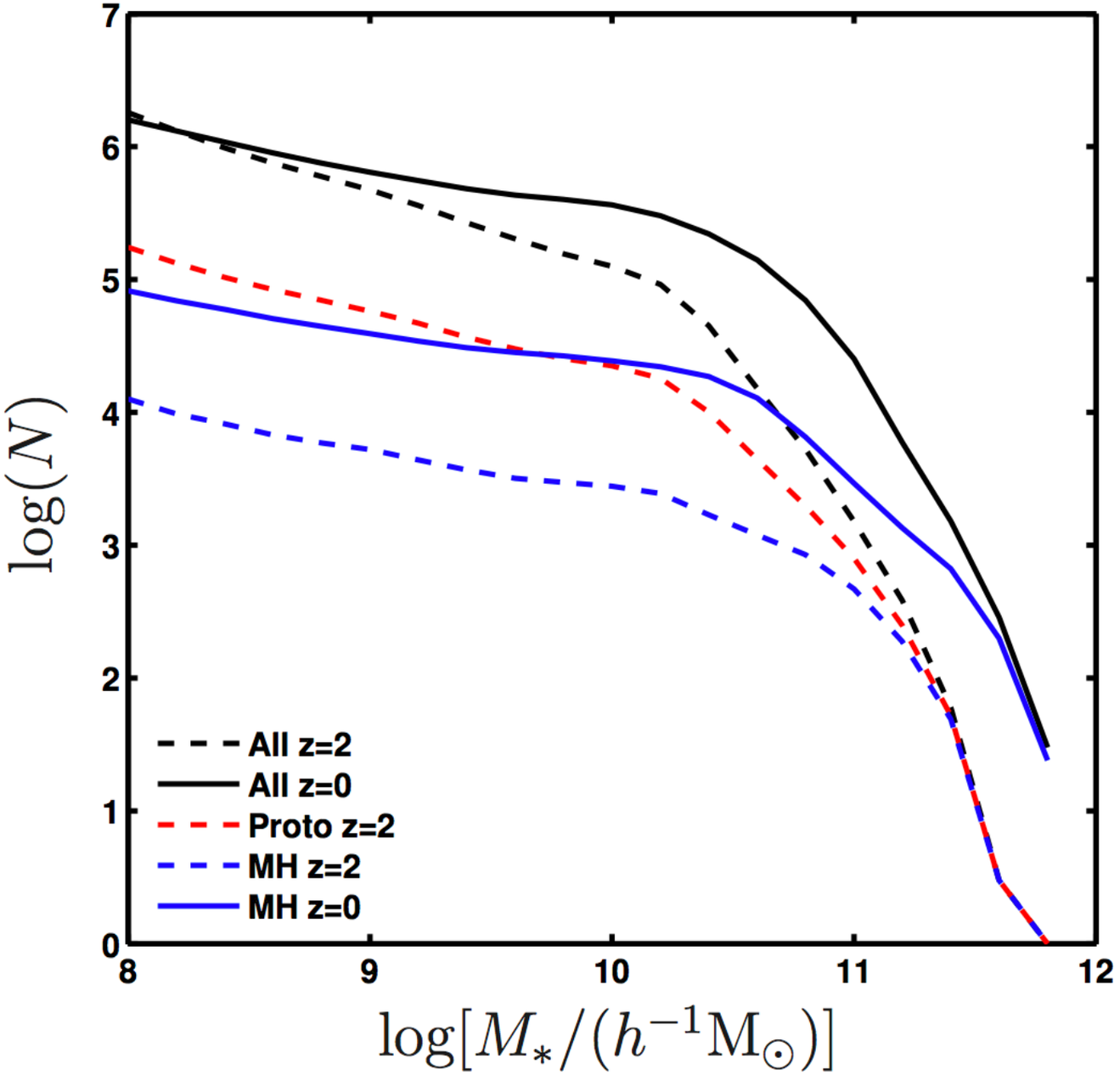
AGN heating

Ram pressure stripping



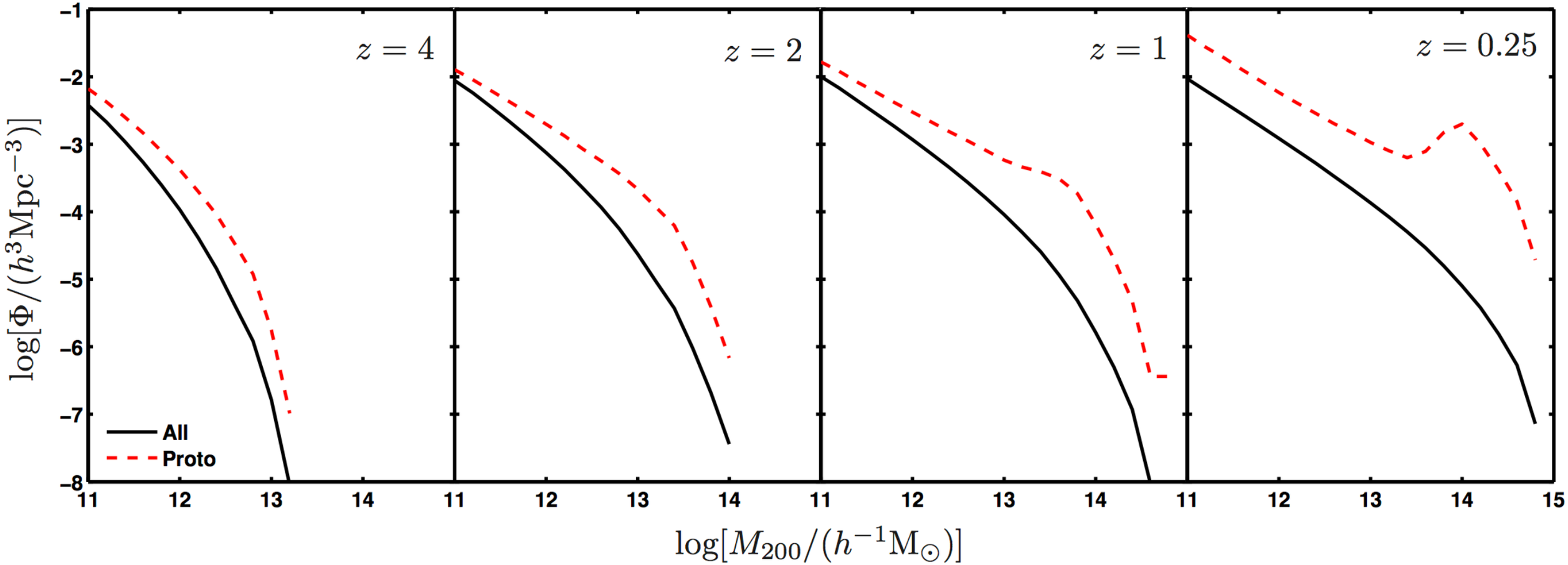
Recent protocluster/cluster studies have measured fq: Nantais 2016, 2017; Cooke 2016; Lee-Brown 2017- see talks on Thursday. (Lots of variation and they do not agree well with models)

Galaxy assembly



- Stars redistribute
- 380 protocluster galaxies at z=2, become 260 z=0 cluster galaxies.
- 2>z>1 galaxies merge
- 1>z>0 galaxies disrupt to form ICL

Dark matter halo mass function



- Underlying root cause of different SFH is the halo mass function
- At high-z: large concentration of halos means efficient star formation
- At intermediate and low redshift: flatter HMF slope results in efficient tidal and ram-pressure stripping, AGN feedback

Conclusions

- The SFHs of protocluster and field galaxies differ: the SFR peaks ~0.7 Gyr earlier and extends over a shorter period of time in protoclusters than in the field.

- Metals formed early in protoclusters and were mixed during cluster collapse.

- Stars form **more** efficiently in protoclusters at $z > 1$. Stars form **less** efficiently in protoclusters at $z < 1$.

- Stellar mass redistributed in protoclusters during collapse