# *The puzzle of the galaxy star formation quenching*

31.25 Mpc/h

SF² Project

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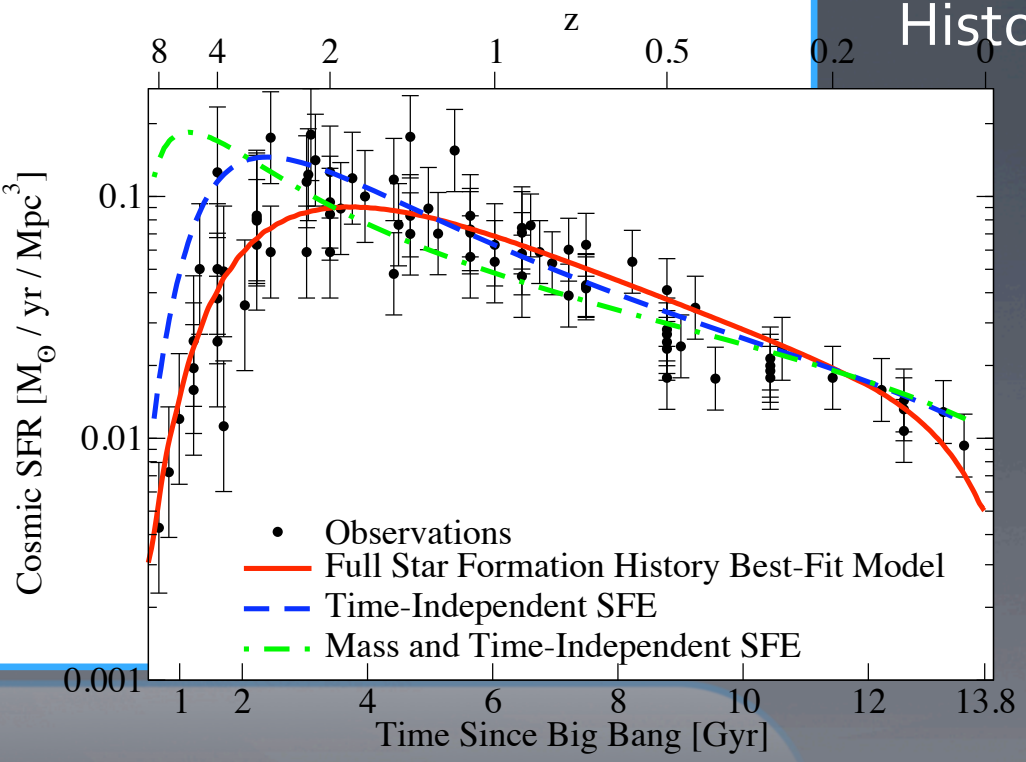
# Outline

- The $SF^2$ project and the puzzle of the SF quenching
- The role of groups in the Cosmic star Formation History
- Fast or slow quenching?
- Conclusions

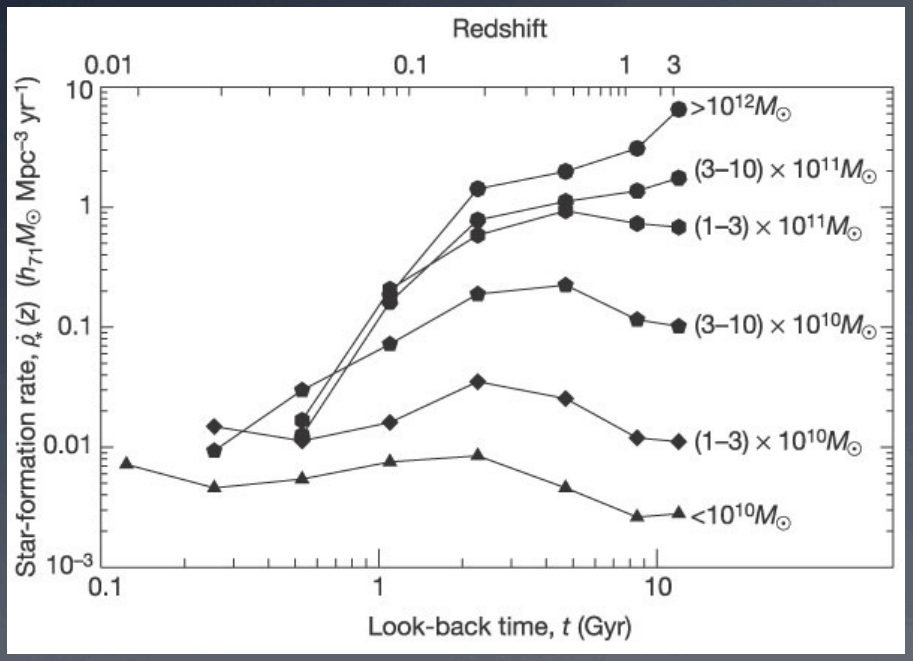
# The SF² Project

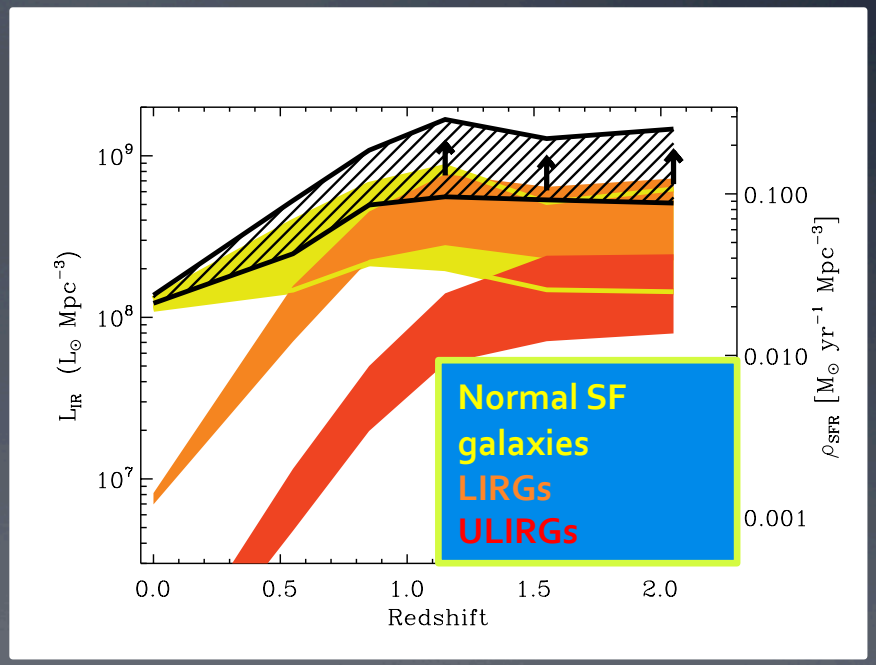
- Dramatic drop of the Cosmic Star Formation History below z~1




Behroozi et al. (2012)

# The Cosmic Star Formation History

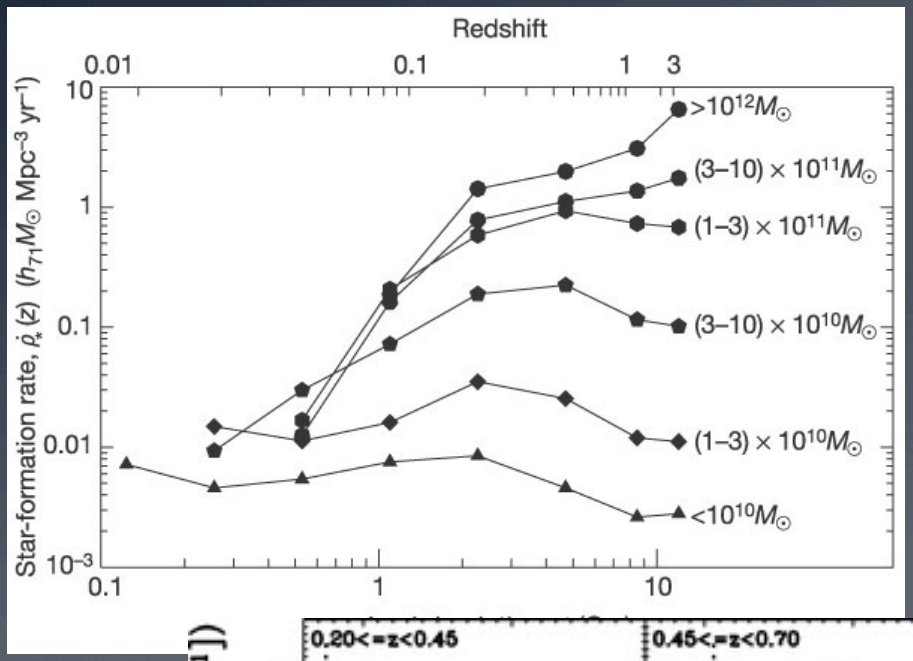


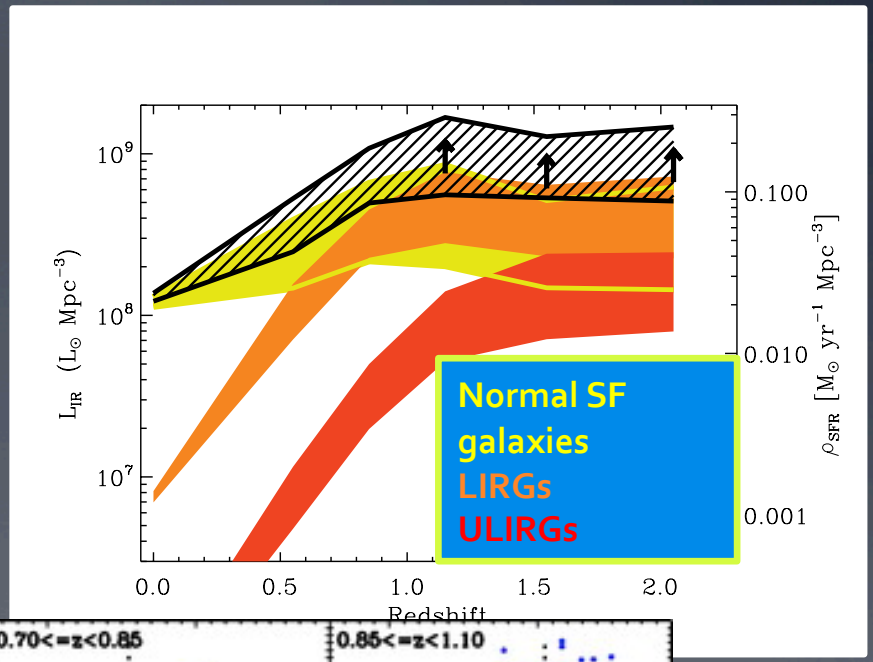



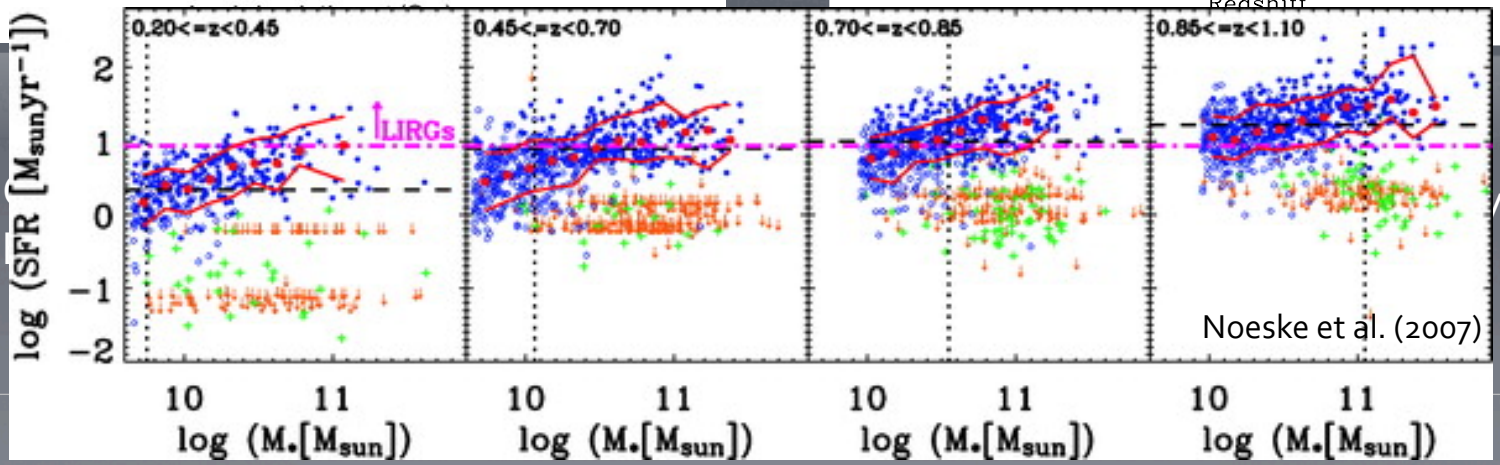

CSFH per galaxy stellar mass
Heavans et al. (2004)

CSFH per galaxy IR luminosity
Magnelli et al. (2013)

# The Cosmic Star Formation History



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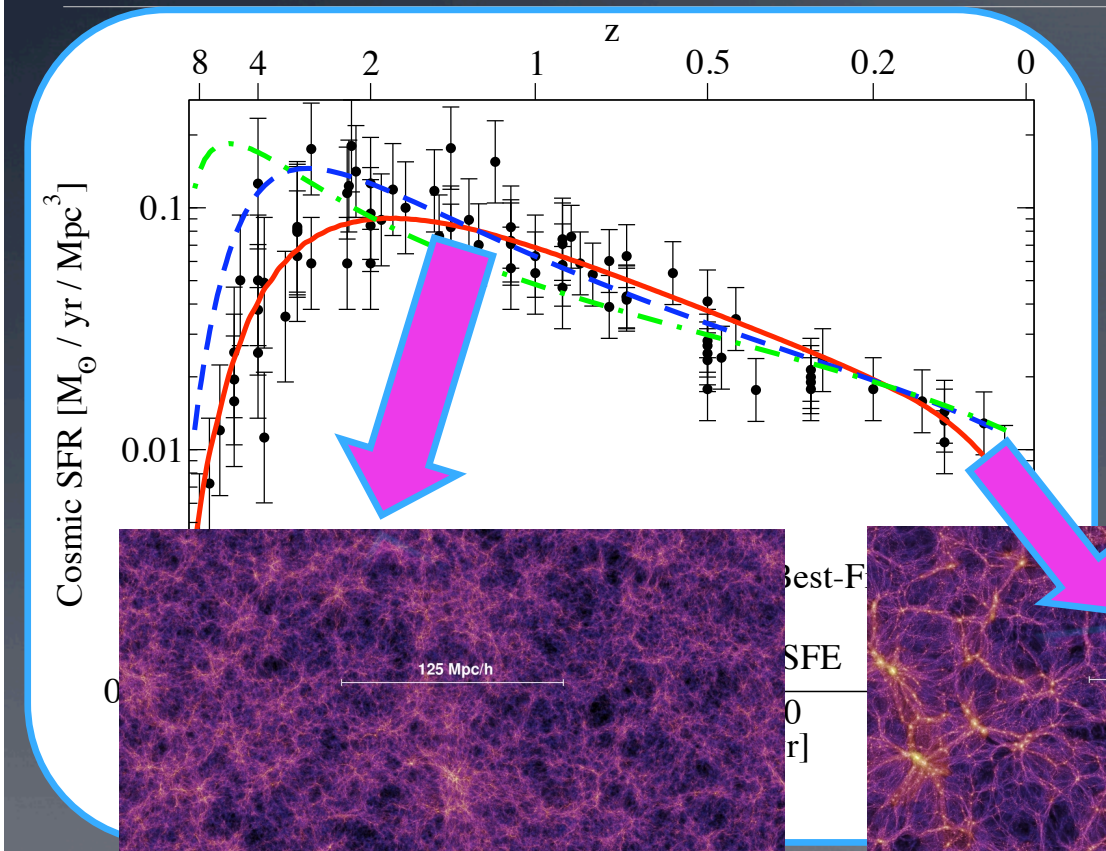
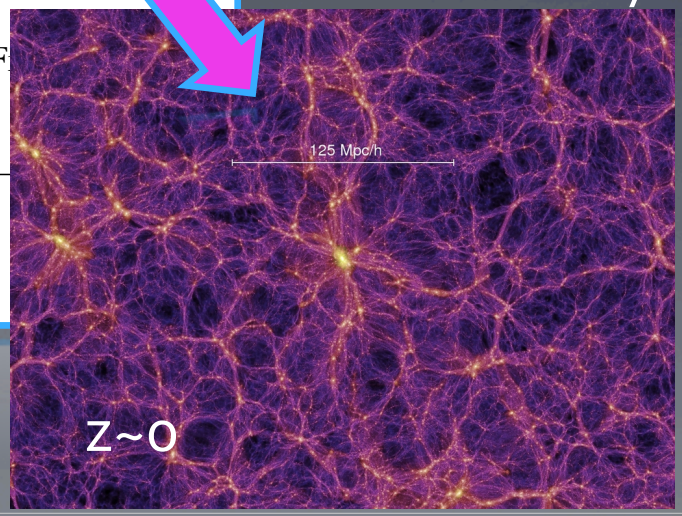




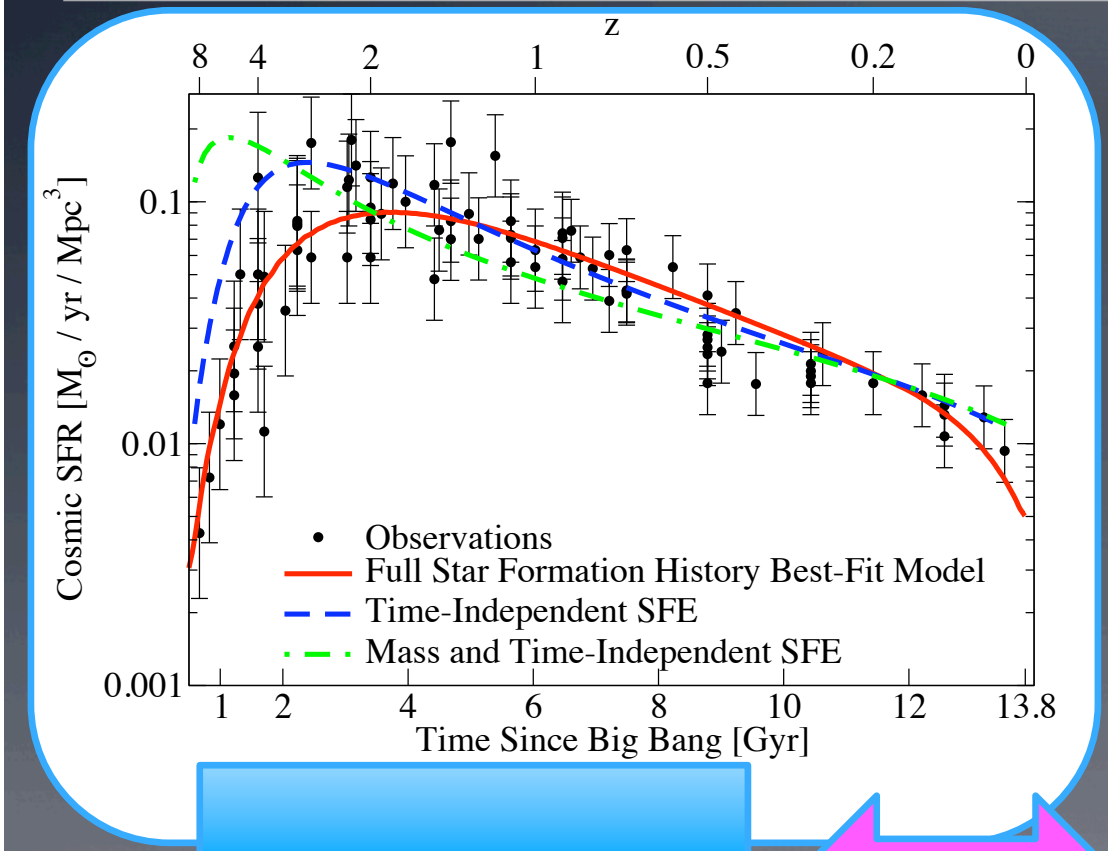





- Dramatic drop of the Cosmic Star Formation History below z~1
- Below z~1 number density of massive halos increases by a factor of 10

Springel et al. (2005)

# The SF² Project



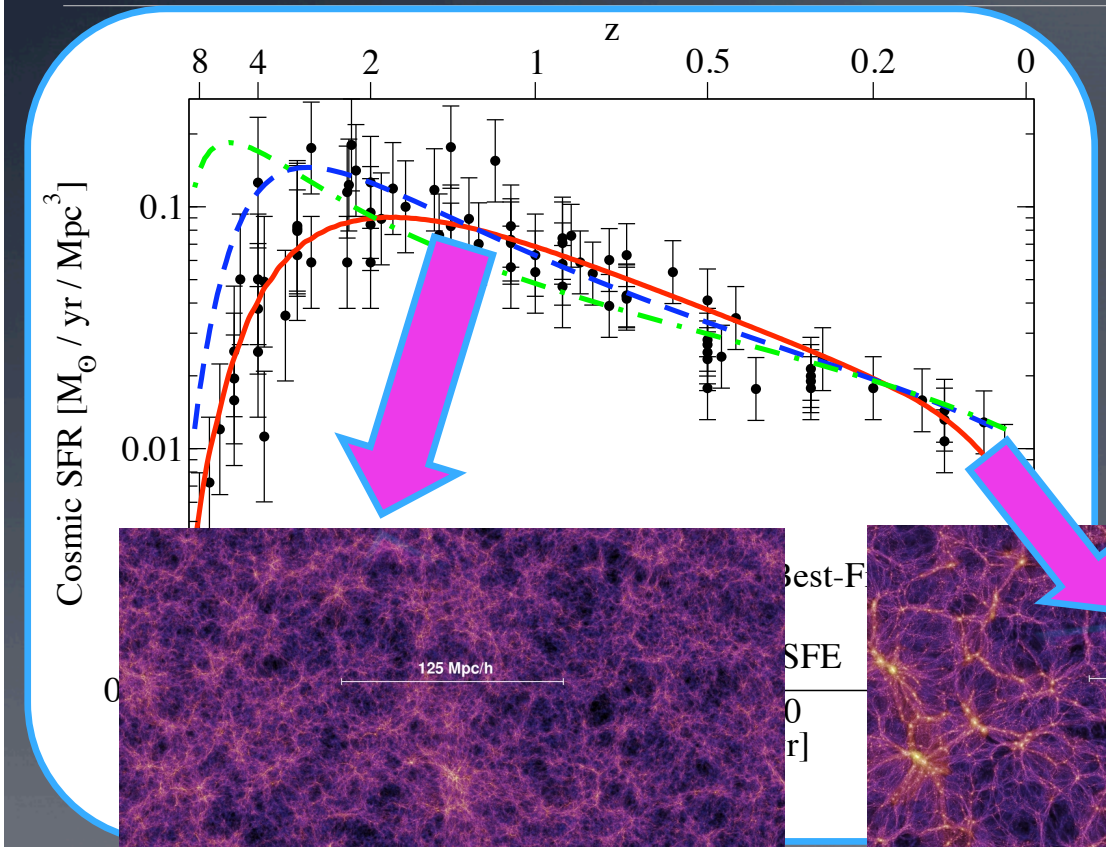

- Dramatic drop of the Cosmic Star Formation History below z~1
- Below z~1 number density of massive halos increases by a factor of 10

Galaxy **SF** activity

quenching

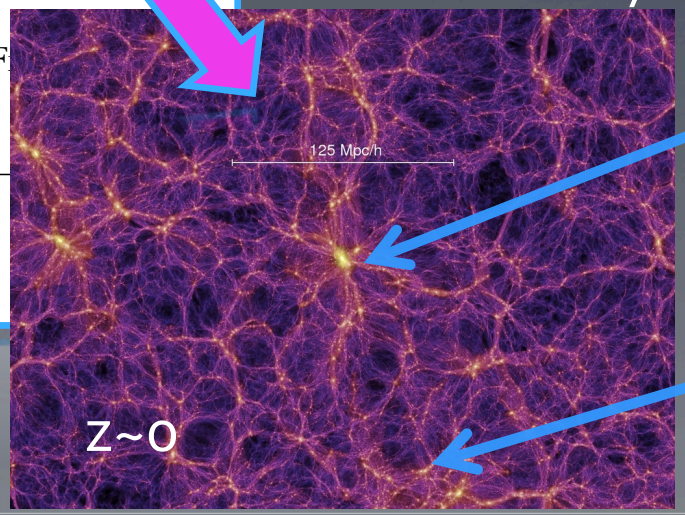
**S**tructure **F**ormation Process

# The SF² Project










- Dramatic drop of the Cosmic Star Formation History below z~1
- Below z~1 number density of massive halos increases by a factor of 10

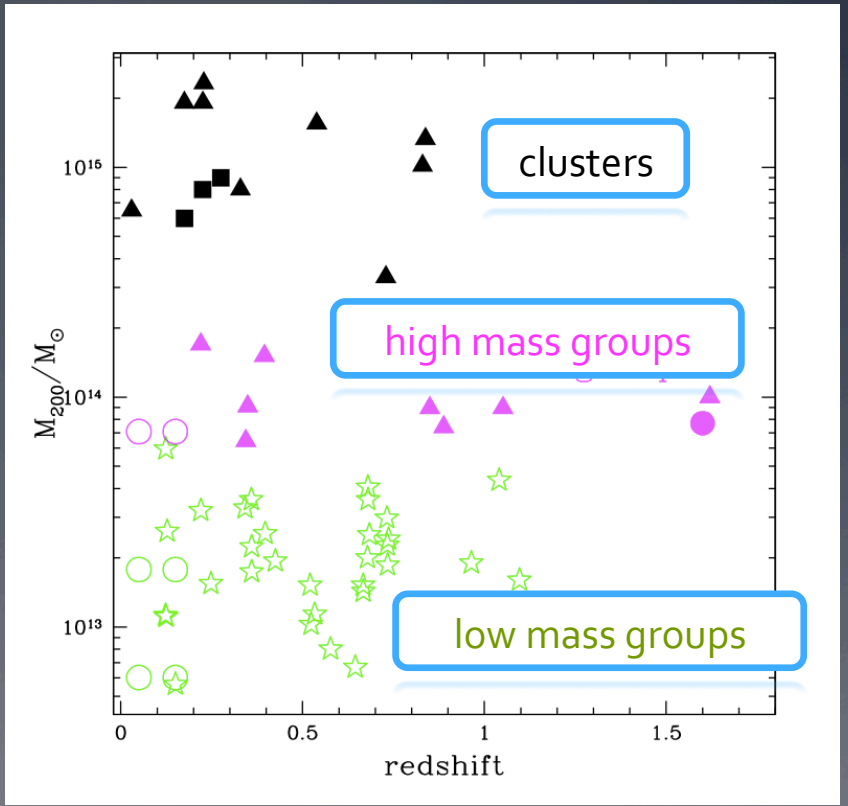
**2%** of the stellar mass in the Universe

**60%** of the stellar mass in the Universe

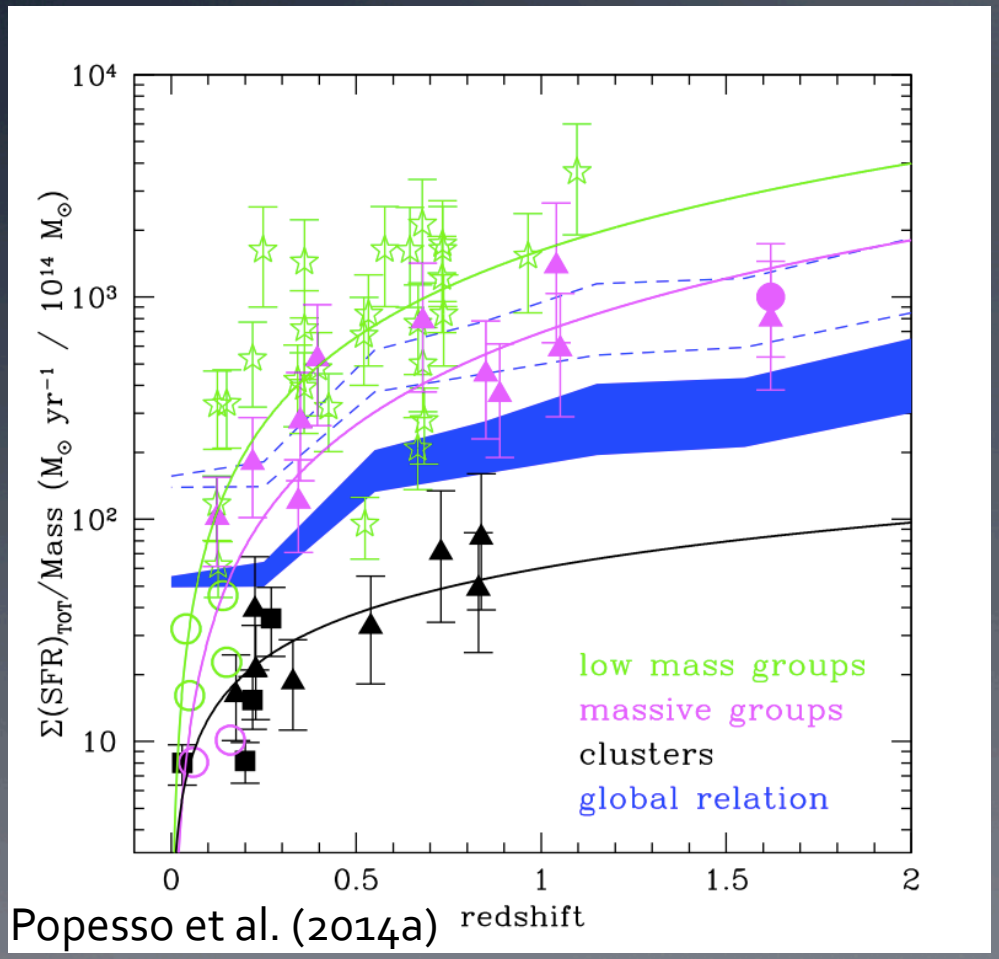
Springel et al. (2005)

# The dataset

- Sample of X-ray selected galaxy groups in COSMOS, CDFN, ECDFS
- + stacked groups of Guo et al. (2014, SDSS) at z< 0.3, LoCuss clusters at 0.15<z<0.3 and Smail et al. (2014) massive group at z~1.6
- Galaxy members spectroscopically confirmed
- Galaxy SFR derived from mid-far-infrared data (MIPS, PACS)



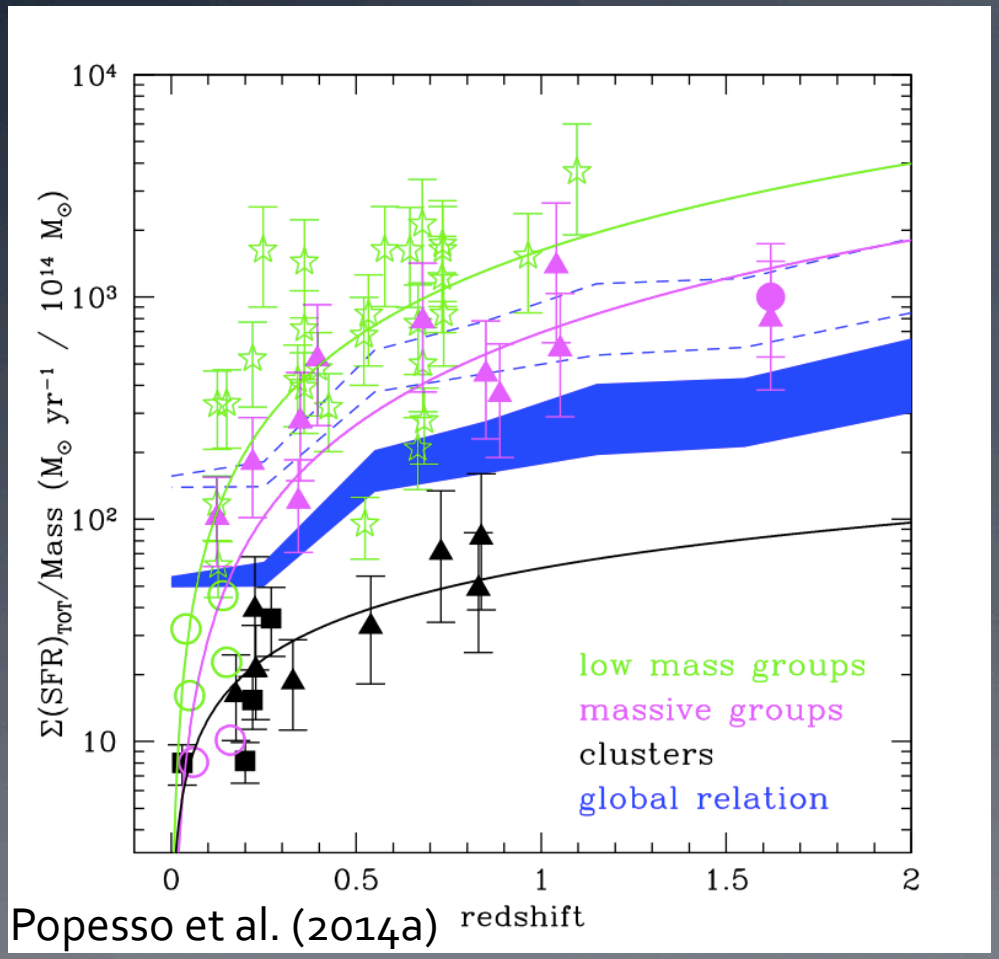
# Total SFR, halo mass and redshift: a fundamental plane




Popesso et al. (2014a)

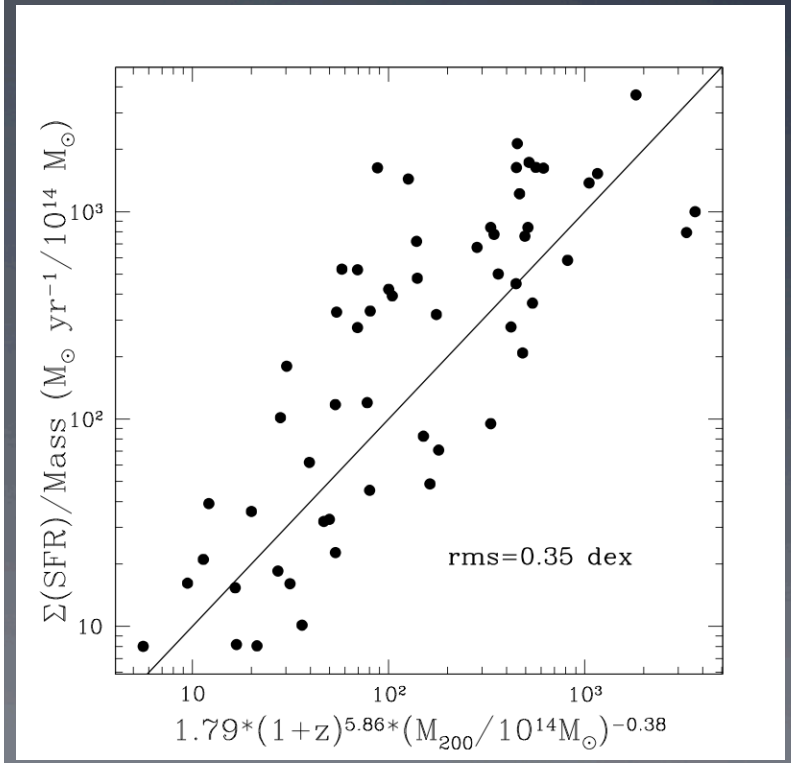
- Total SFR (ΣSFR): sum of the SFR of group/cluster members
- Total mass of the host dark matter halo
- redshift

# Total SFR, halo mass and redshift: a fundamental plane




Popesso et al. (2014a)

- Plane with a scatter of ~0.35 dex



# Contribution of massive halos to the CSFH

**Total SF activity of halos in a given mass range (ΣSFR-halo mass-z plane)**

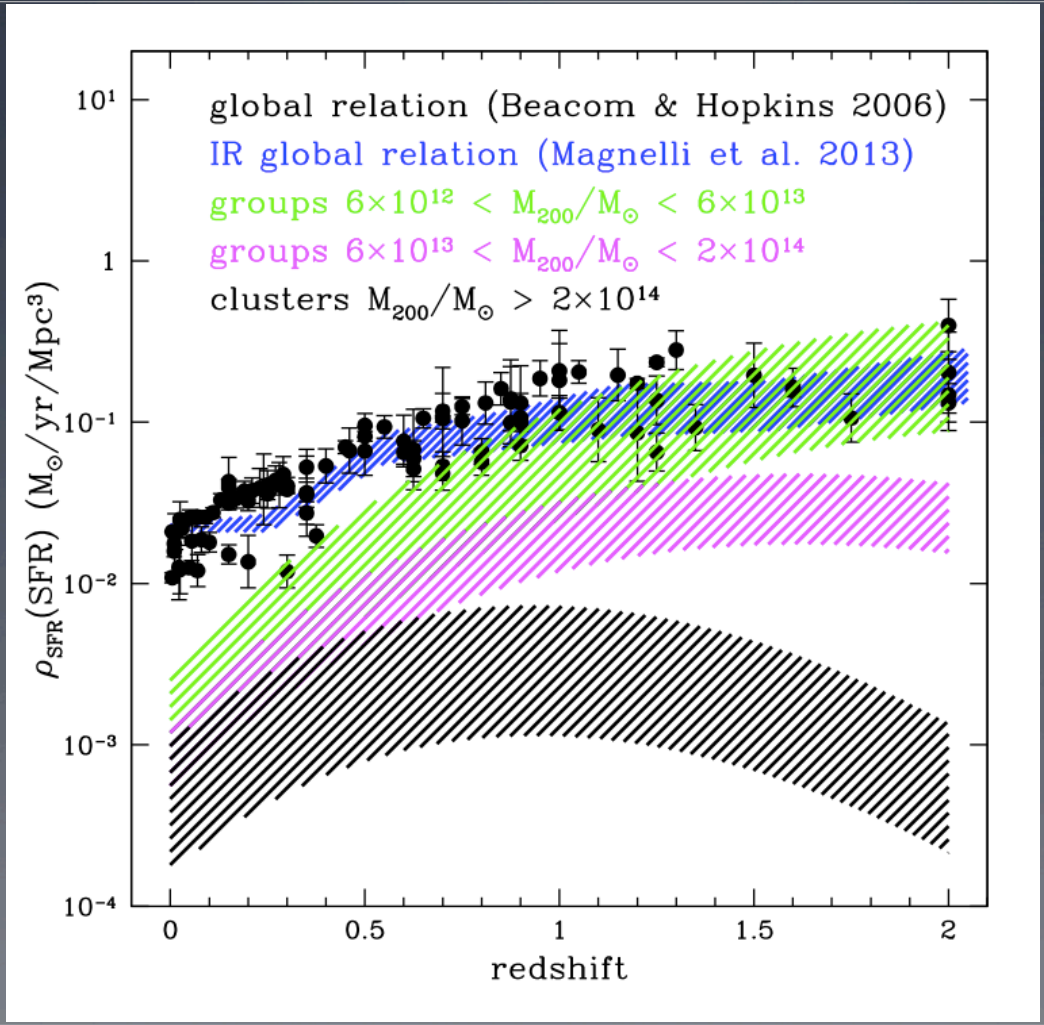
×

**Evolution of the comoving number density of such halos (WMAP 9 cosmology)**

=

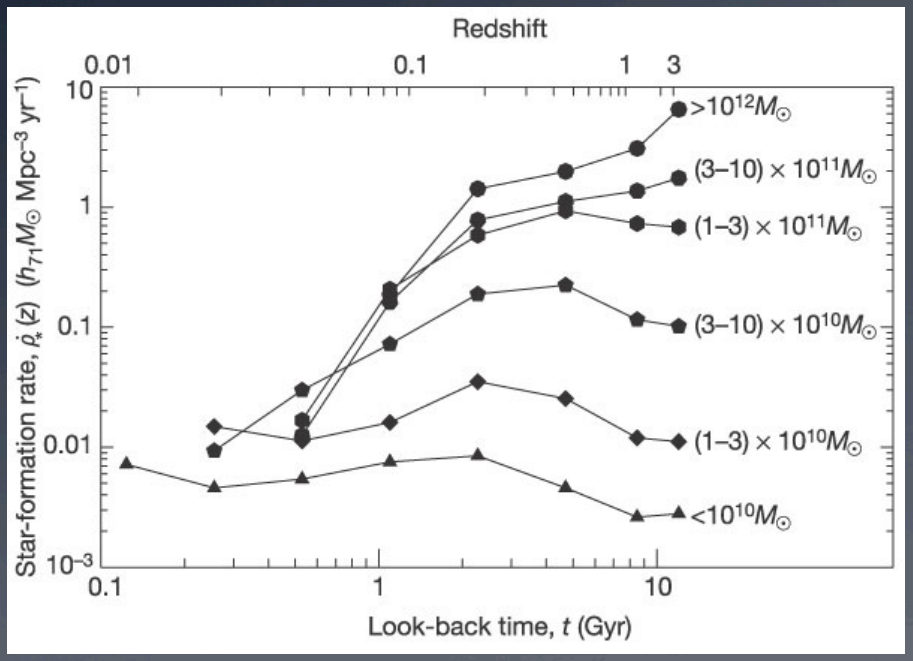
**Contribution of such halos to the CSFH**

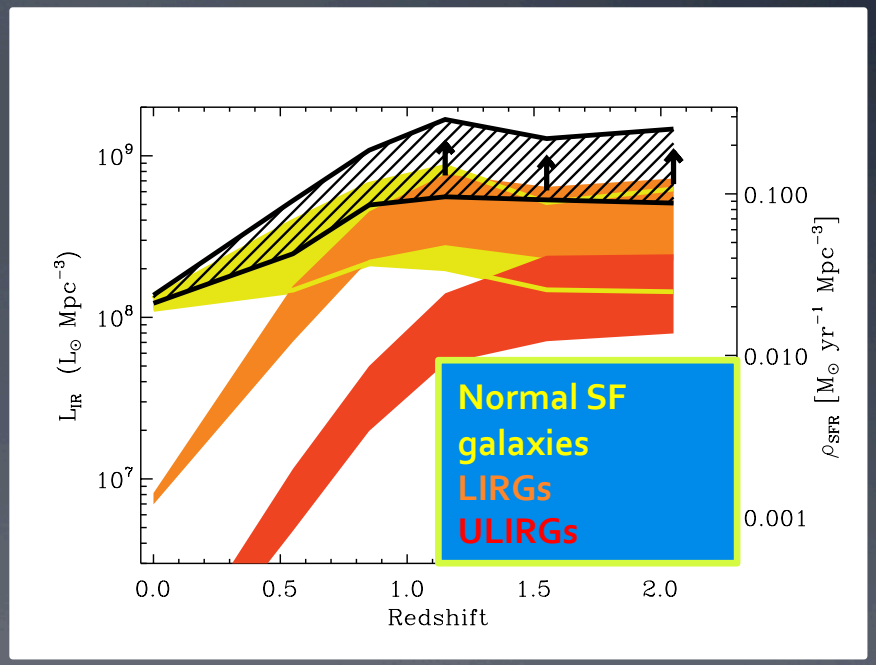
# Contribution of massive halos to the CSFH




Popesso et al. (2014a)

# The Cosmic Star Formation History

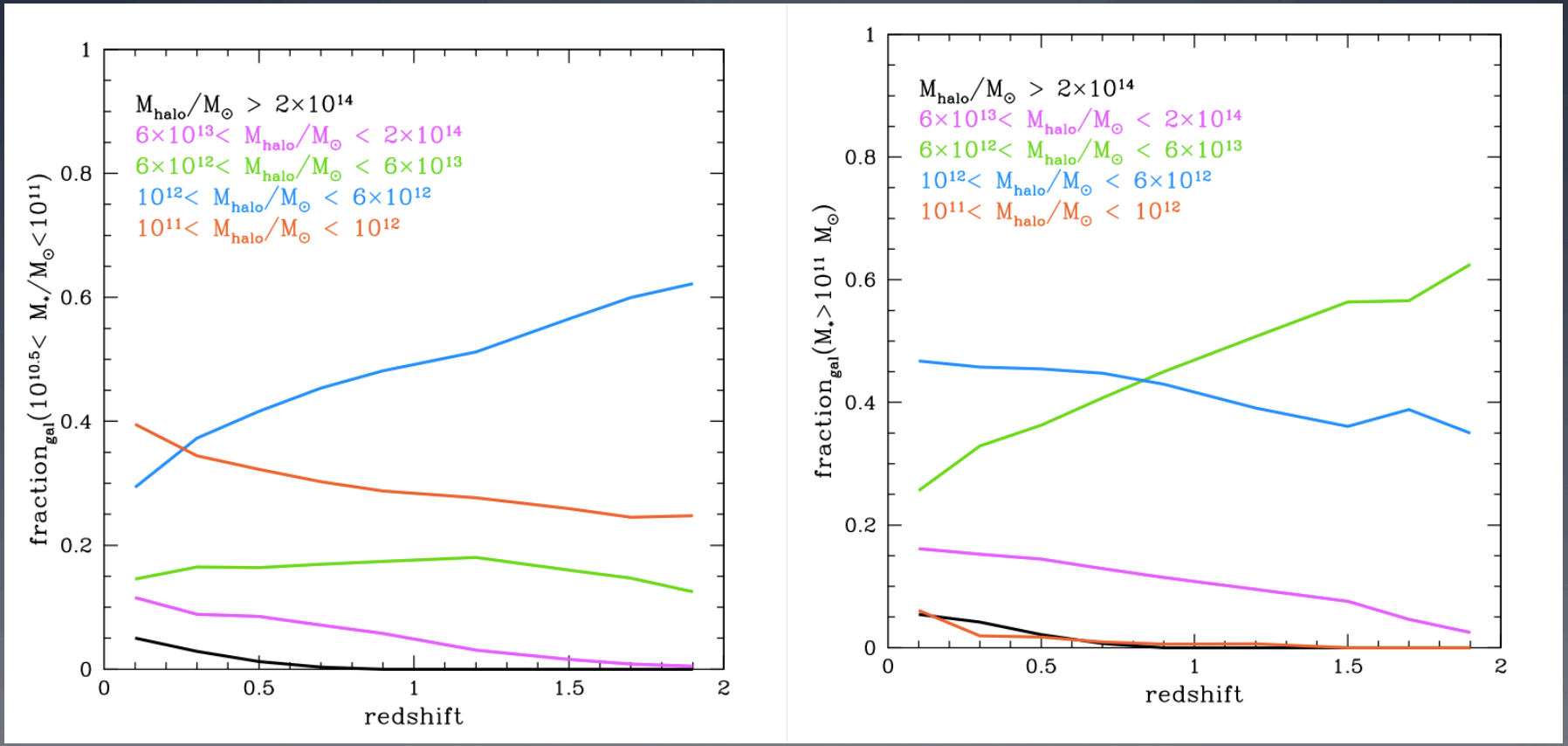



CSFH per galaxy stellar mass
Heavans et al. (2004)

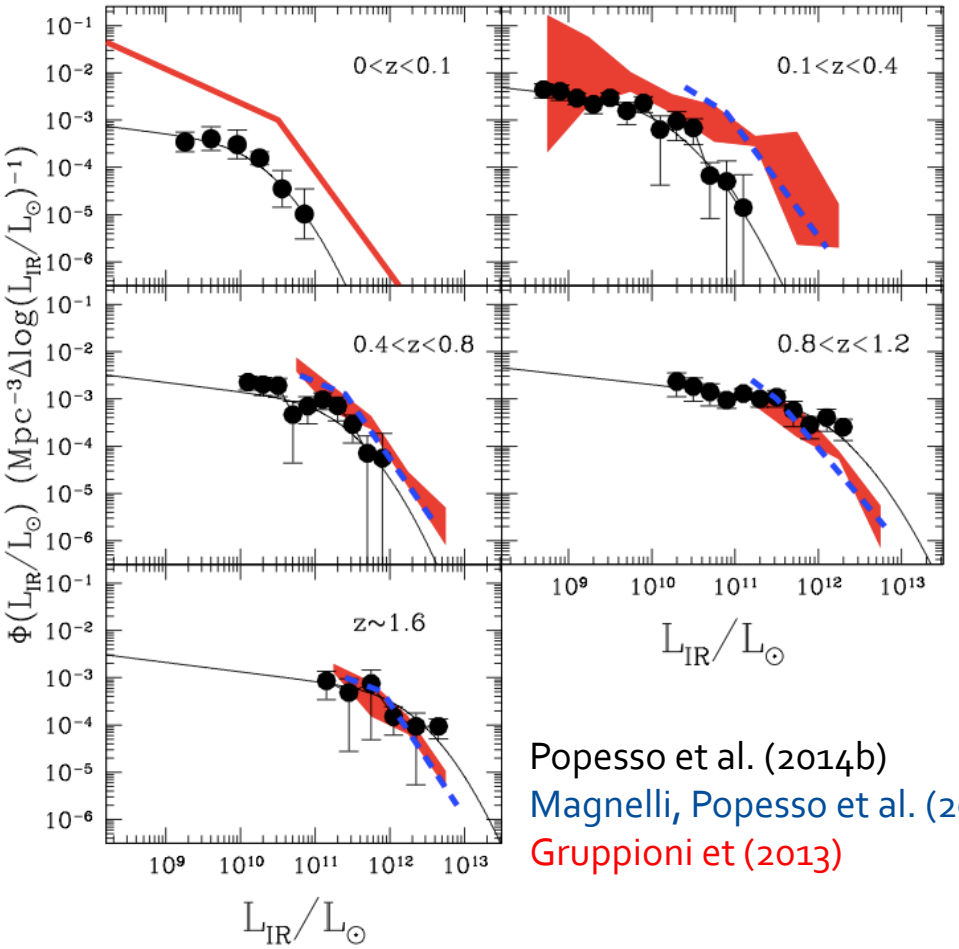
CSFH per galaxy IR luminosity
Magnelli et al. (2013)

# Which galaxy in which halo?




Popesso et al. (2014a)

# The SFR distribution in massive halos




Popesso et al. (2014b)
Magnelli, Popesso et al. (2013)
Gruppioni et (2013)

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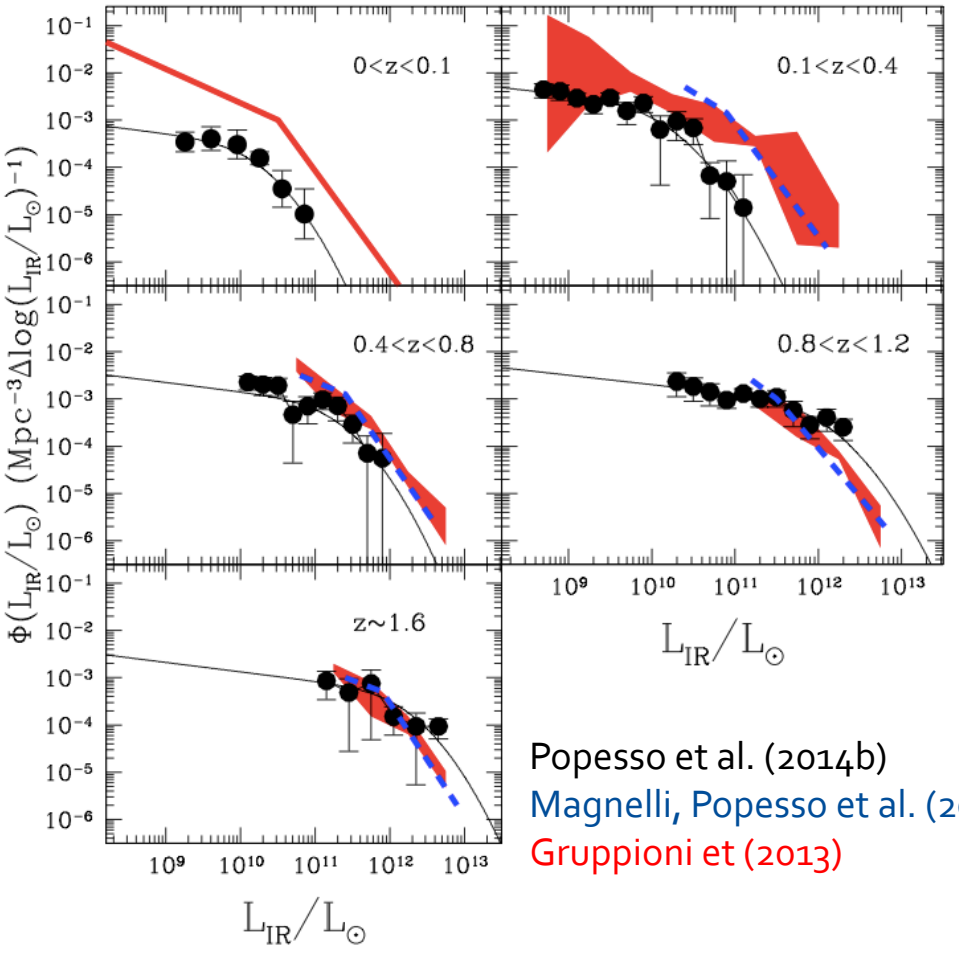


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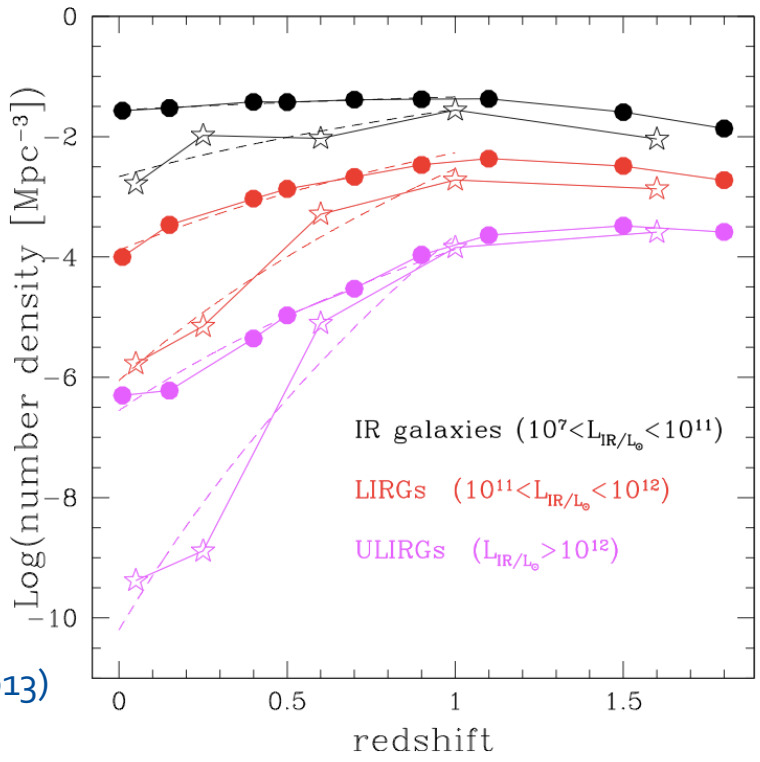
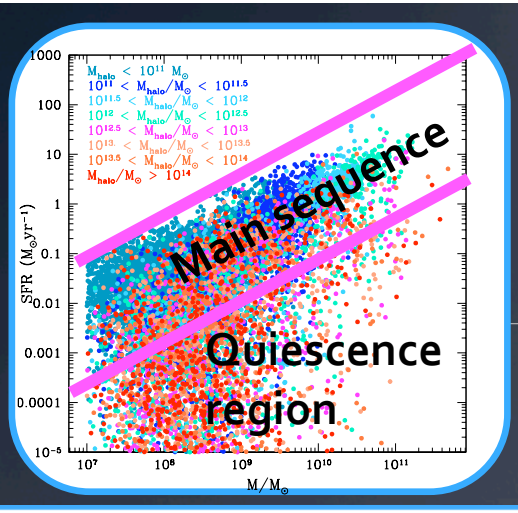
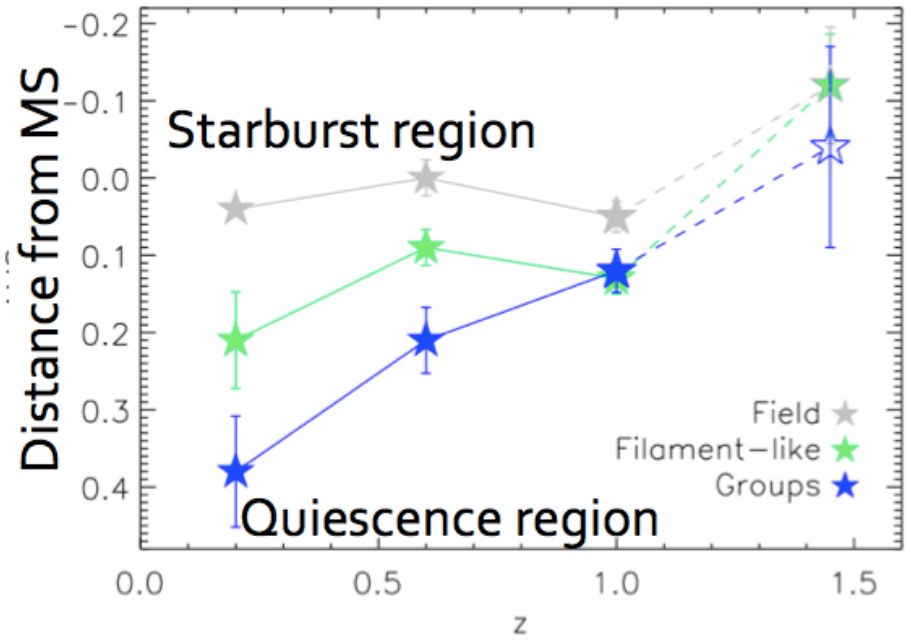
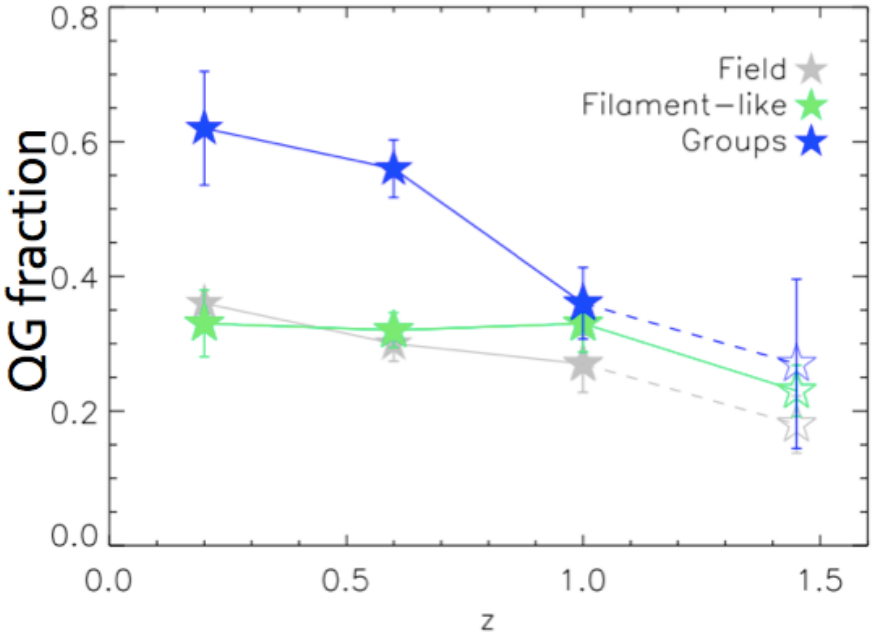




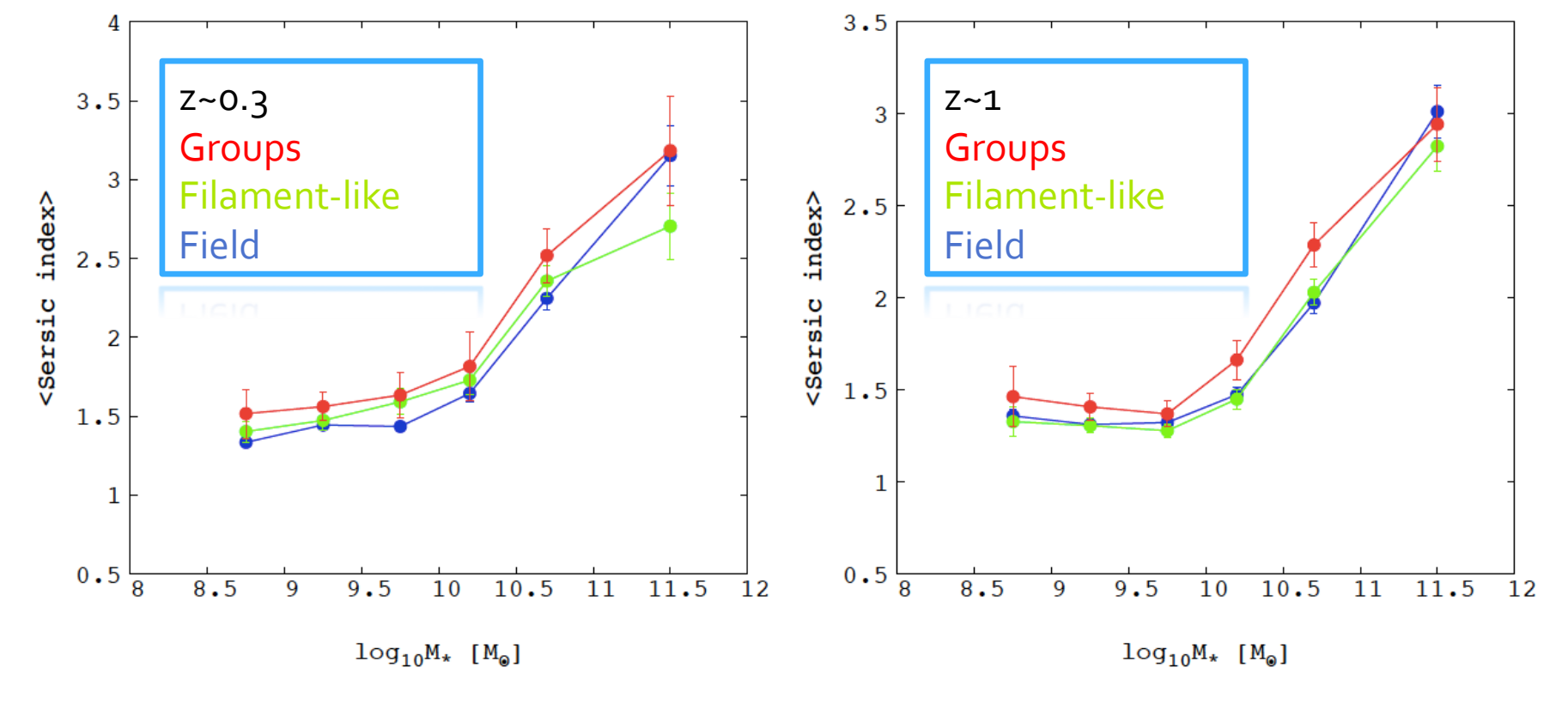

# Group galaxies & Main Sequence




Ziparo, Popesso, Finoguenov et al. (2013)

# Group galaxies, Main Sequence Morphology




Erfanianfar, Popesso, Biviano et al. (in prep.)

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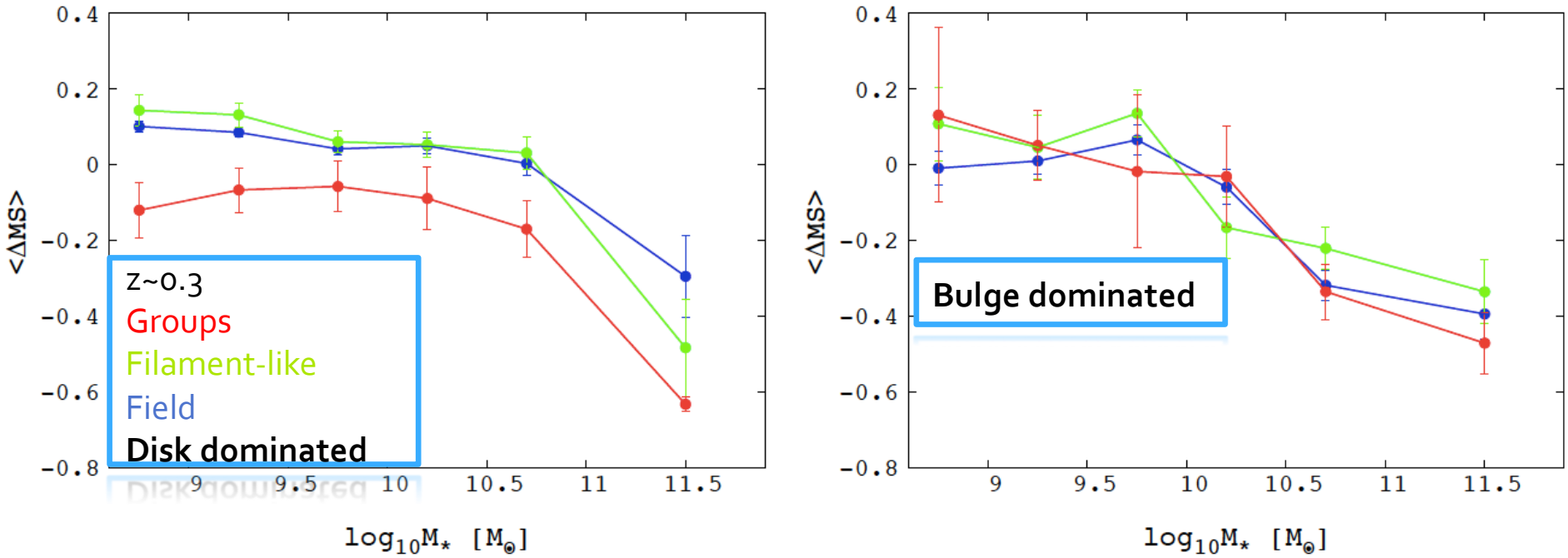


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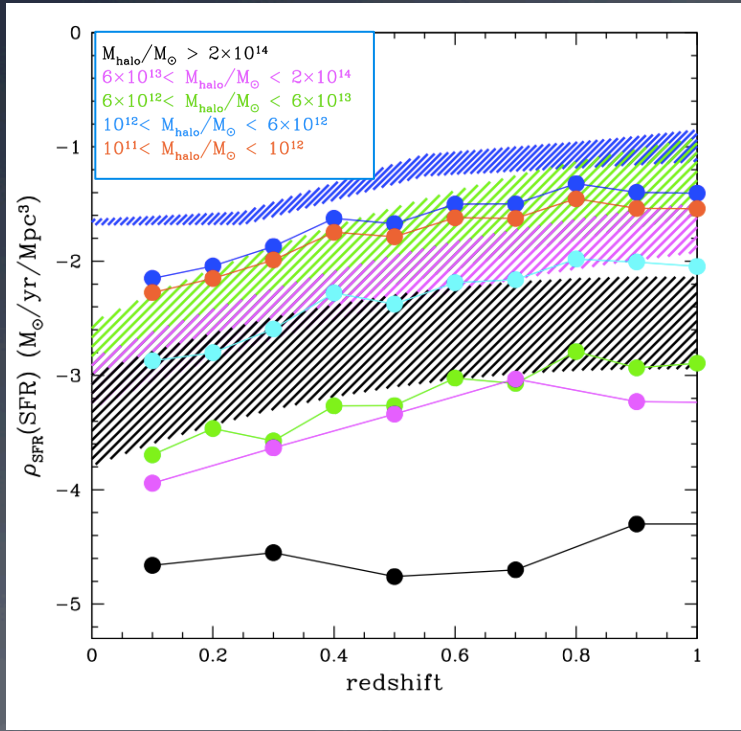
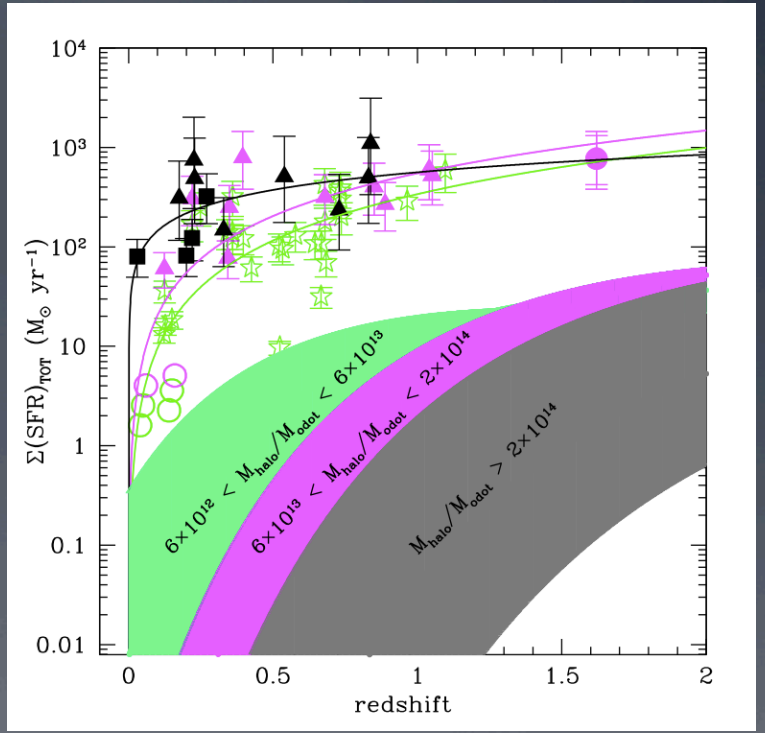
# Fast satellite quenching




Semi-amalytical model
(Guo et al. 2011)

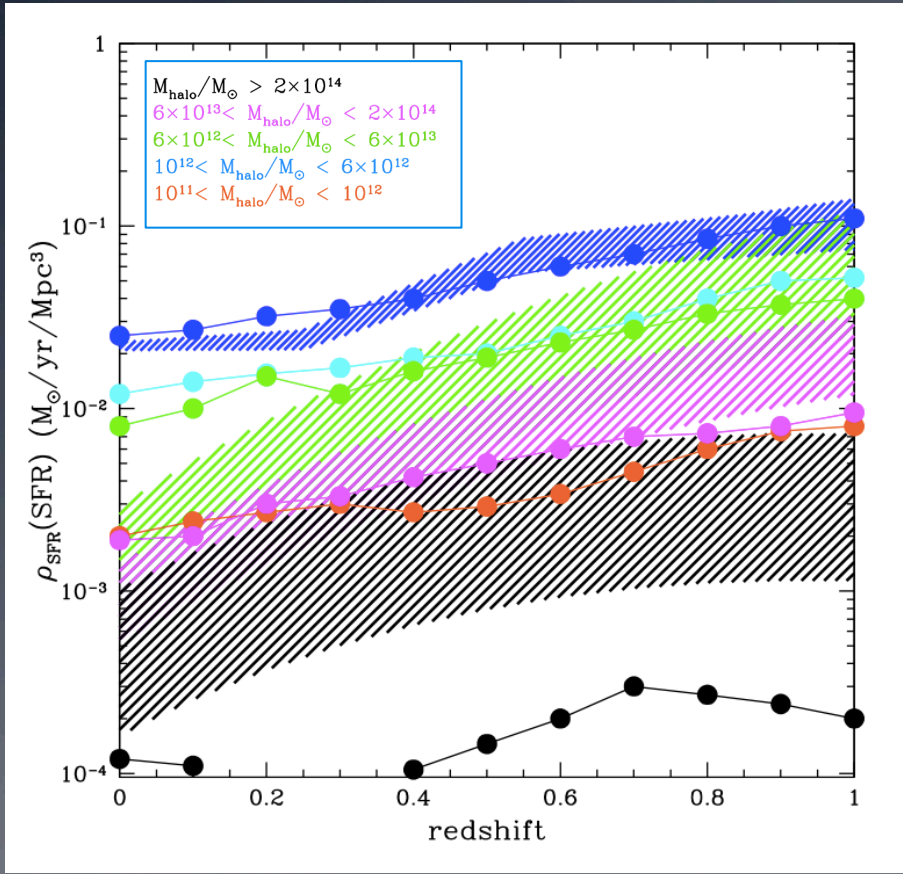



Mass abundance matching model
(Moster et al. 2012)

Immediate quenching of satellites when they enter more massive halos

**Satellite overquenching**

# Slow Satellite quenching




Mass abundance matching model (Bethermin et 2013)

- Cold-hot mode accretion transition (Kereš et al. 2005):
  - Satellites keep their "identity" for a while before experiencing massive parent halo effect (Simha et al. 2009, Cen 2011)
- Ram pressure + starvation (Cen 2014)

**Quenching timescale 2-3 Gyrs**

# Conclusions

- CSFH is dominated at z~1 by massive galaxies in habiting massive halos ($M_{halo}$~ $10^{13}$ $M_{\odot}$ → *halo downsizing*)
- Galaxies in massive halos experience a significantly faster evolution with respect of the low mass halo galaxies: their star formation activity is quenched more rapidly
- At z~1 group galaxies are on the MS as low mass halo galaxies but they depart from it by z~0 toward the quiescence region
- SF quenching takes place before morphological transformation in massive halos.
- The quenching process must be slow (2-3 Gys timescale):
  - cold to hot accretion mode transition
  - ram pressure stripping + starvation