Phase-space Analysis on Cluster (Group) Galaxies

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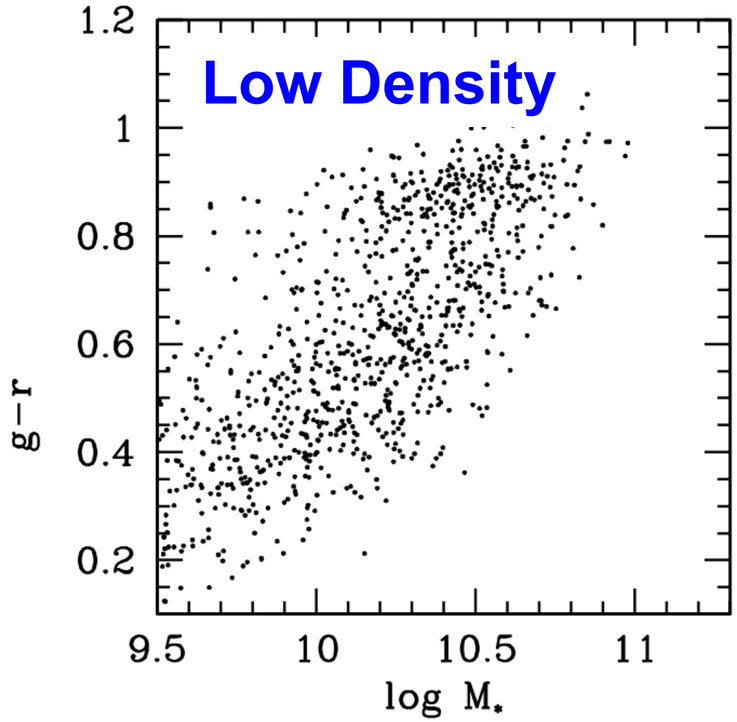
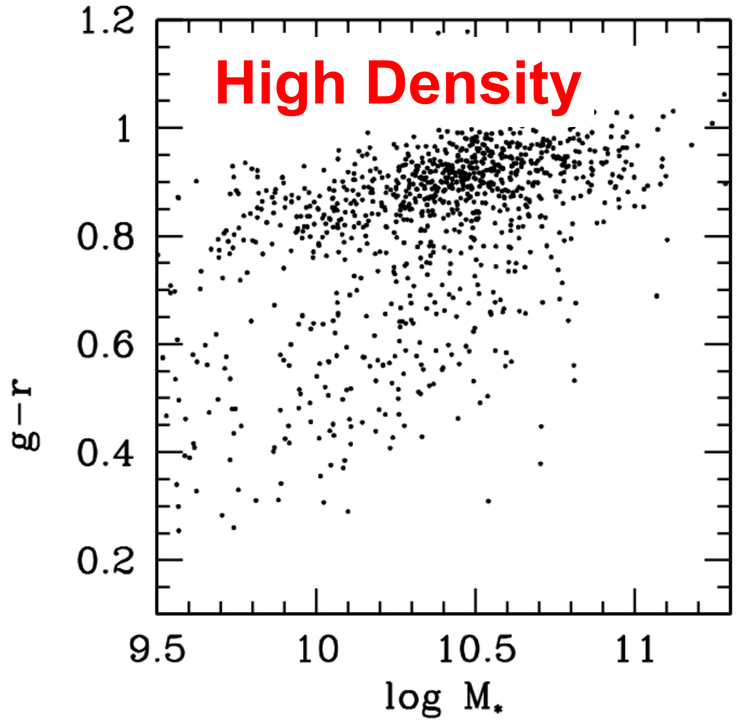
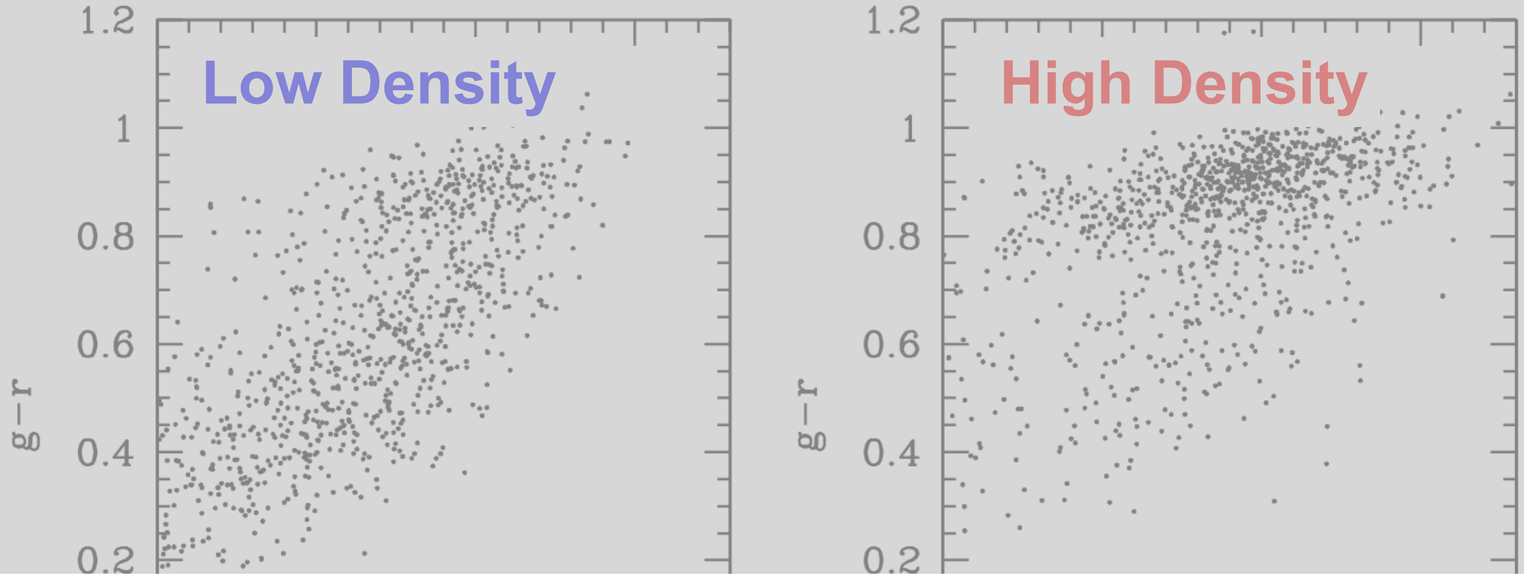
Yonsei University

9 Feb. 2021





Color-Mass Diagrams (Bi-modality)
(Kauffmann et al. 2004)



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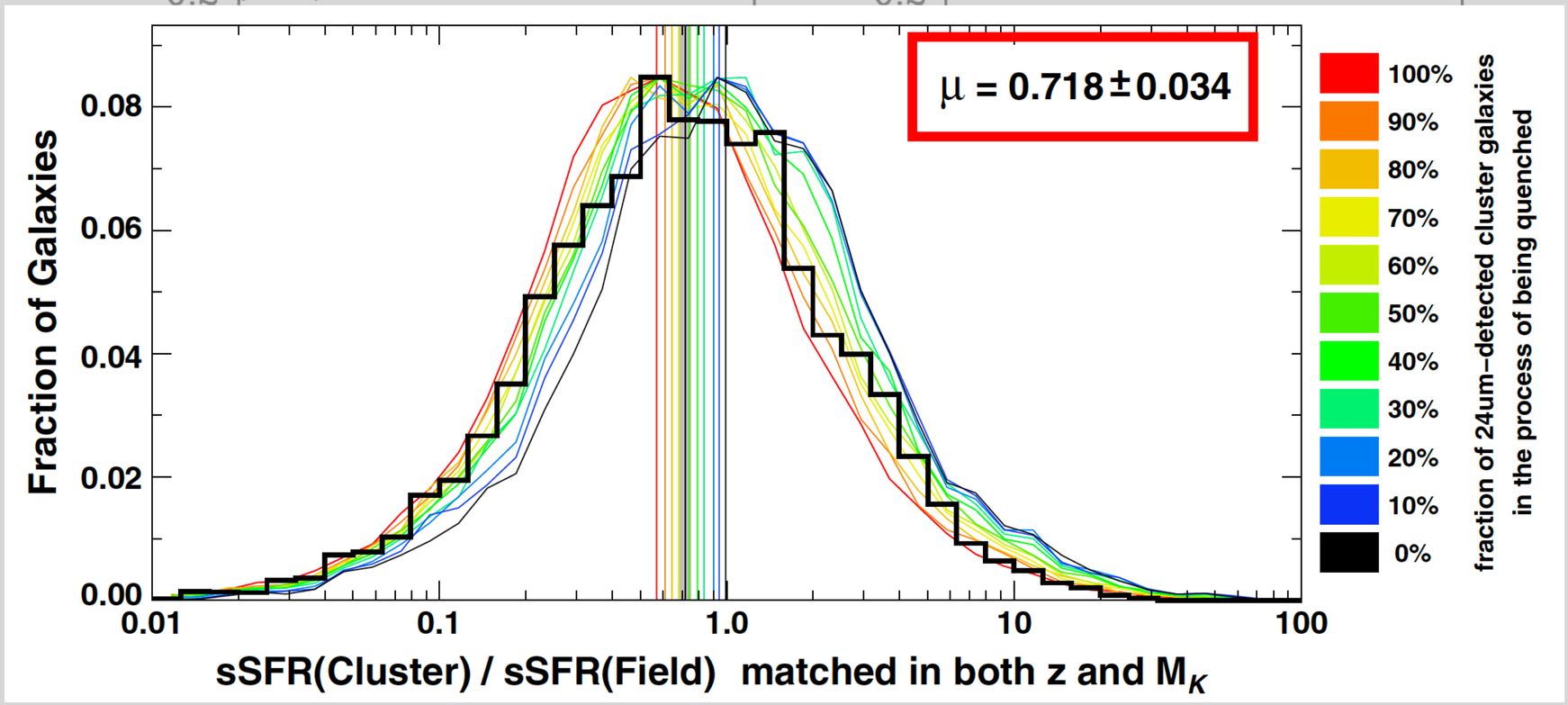
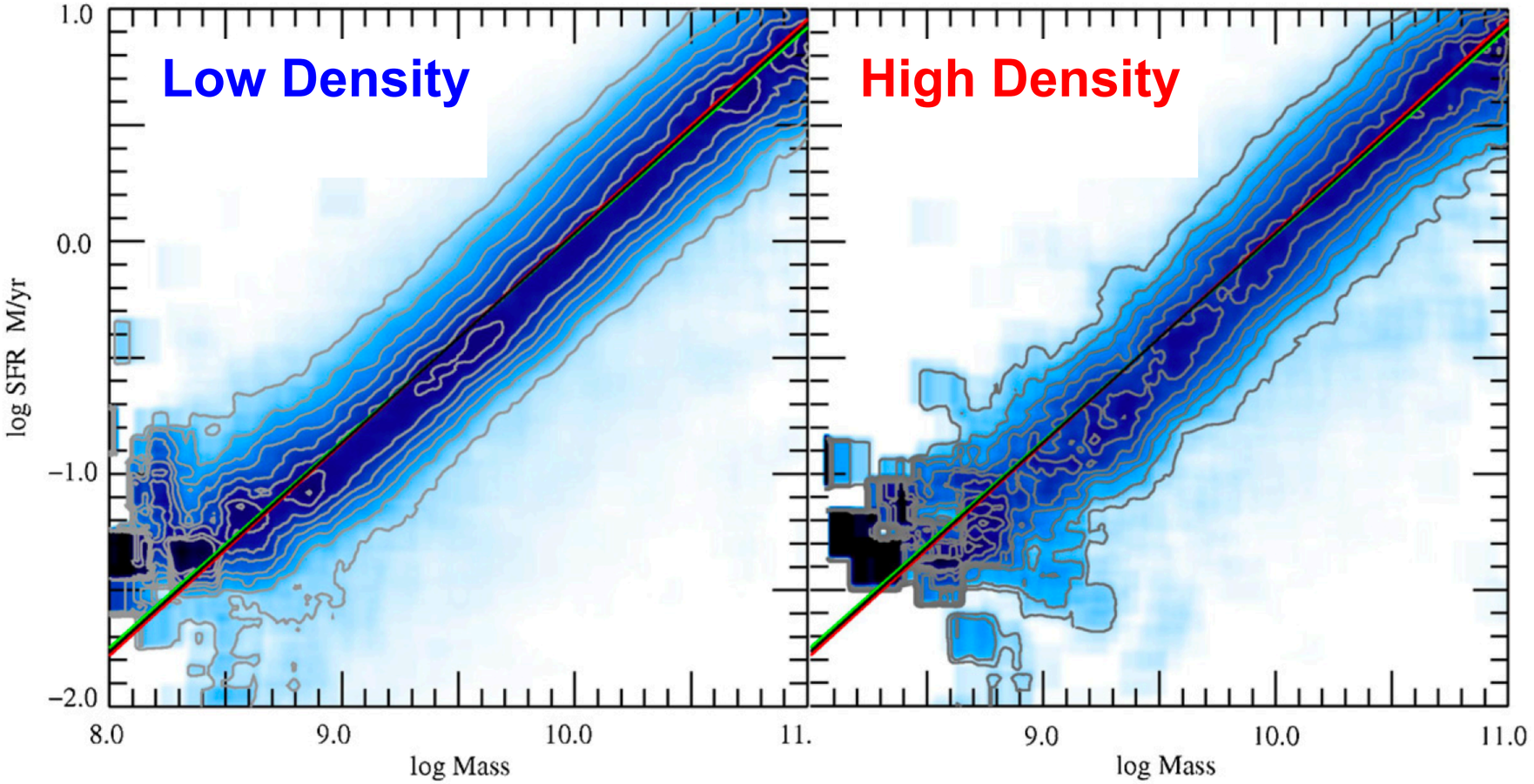


sSFR Distribution
(Haines et al. 2013)

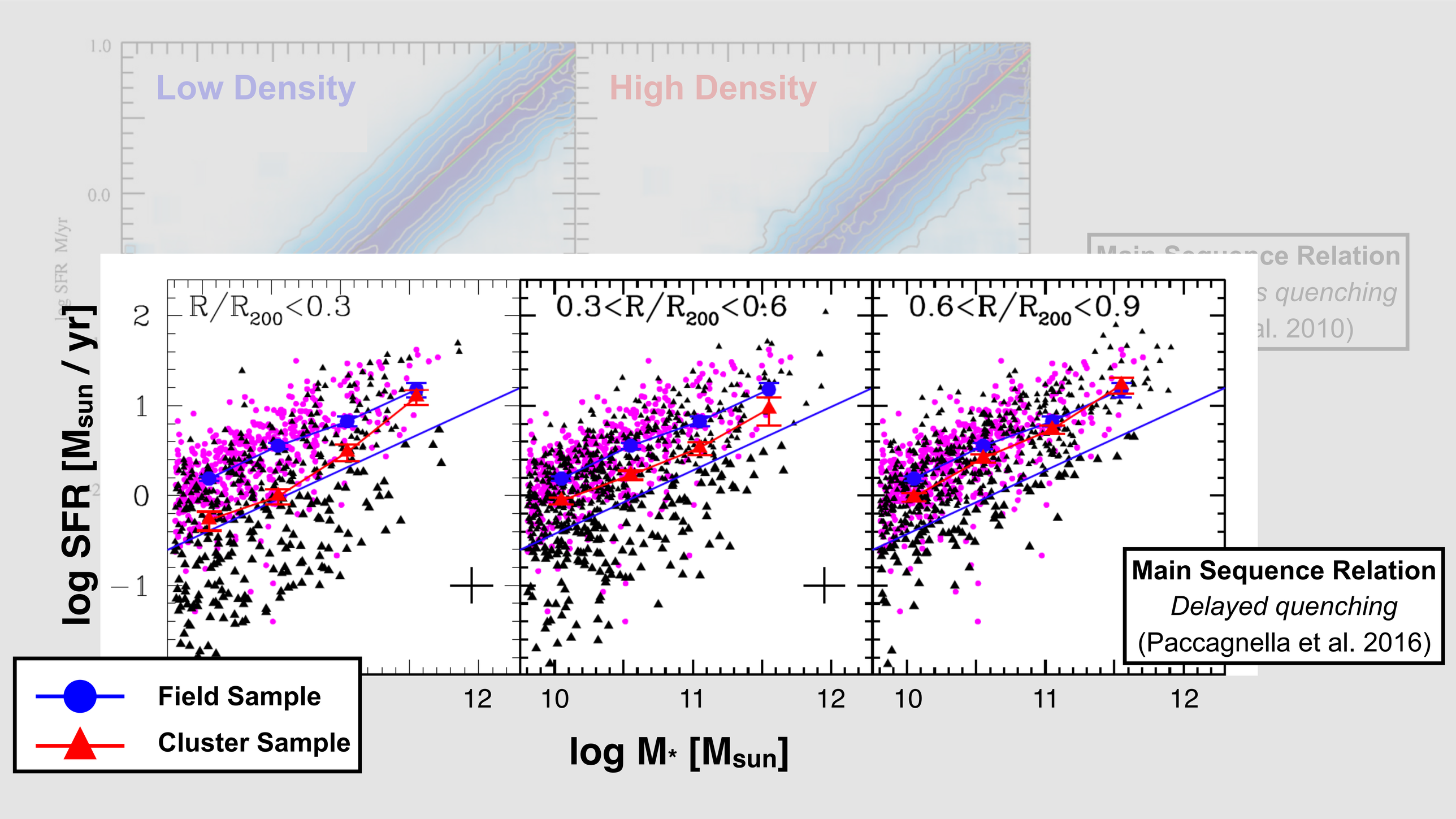
sSFR(Cluster) / sSFR(field)
for galaxies with
the same mass and redshift range

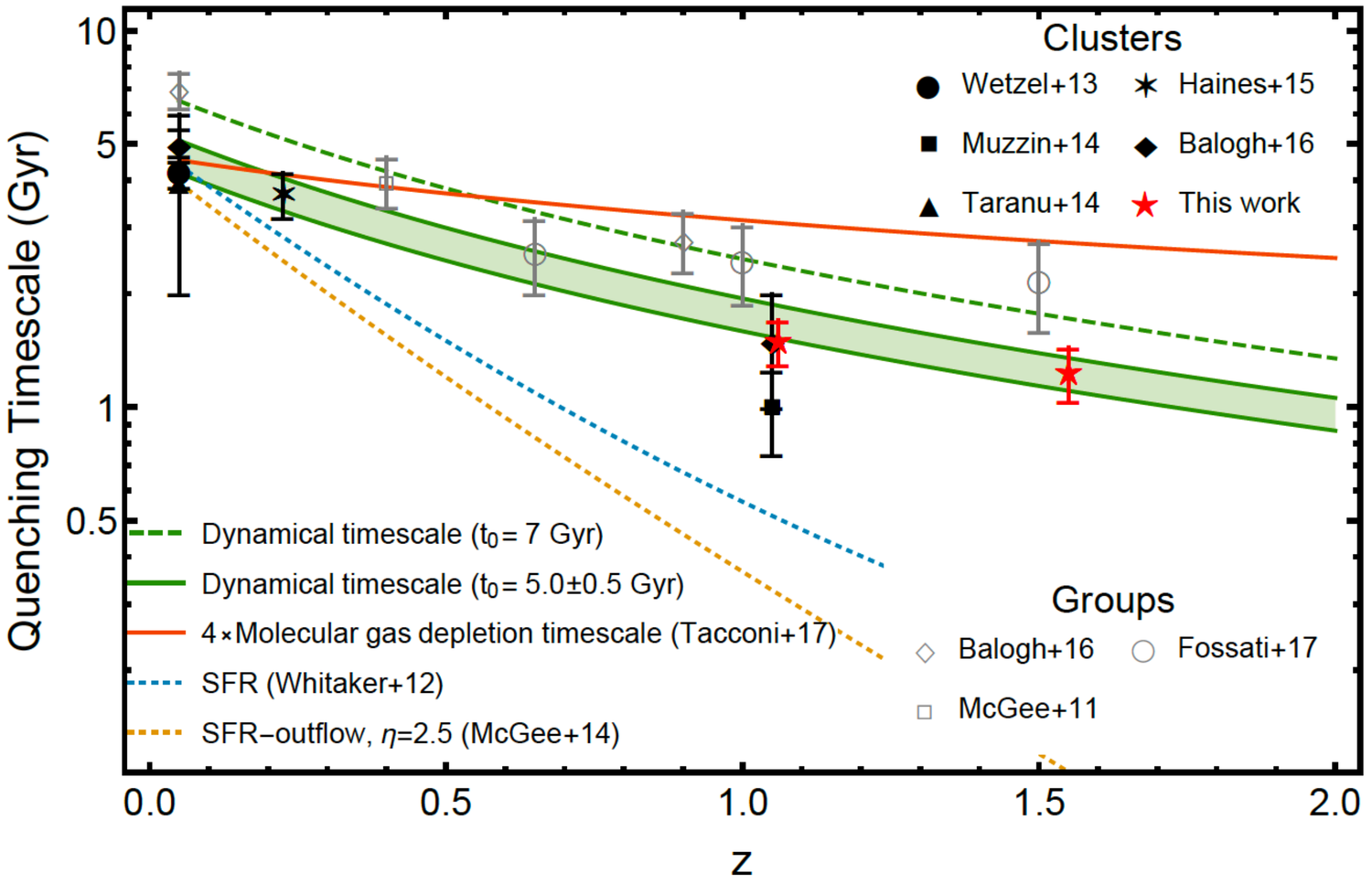


Main Sequence Relation

Instantaneous quenching

(Peng et al. 2010)


Low Density
High Density
R/R200<0.3
0.3<R/R200<0.6
0.6<R/R200<0.9
log SFR [Msun / yr]
log M* [Msun]
Field Sample
Cluster Sample
Main Sequence Relation
Delayed quenching
(Paccagnella et al. 2016)



Quenching Timescales
(Foltz et al. 2018)

Goal of This Study

1) Derive the Star Formation History for cluster galaxies

2) Predict the Main Quenching Processes, corresponding to the derived SFH

Sample

YZiCS

- RAMSES (AMR, Teyssier 2002)
- Cosmological

  15 clusters in 200 Mpc/h

  (5e13 < $M_{cluster}/M_{\odot}$ < 1e15)
- DM+hydro
- dx=0.76 kpc/h

  dm=8e7 $M_{\odot}$

  dm_{*}=5e6 $M_{\odot}$

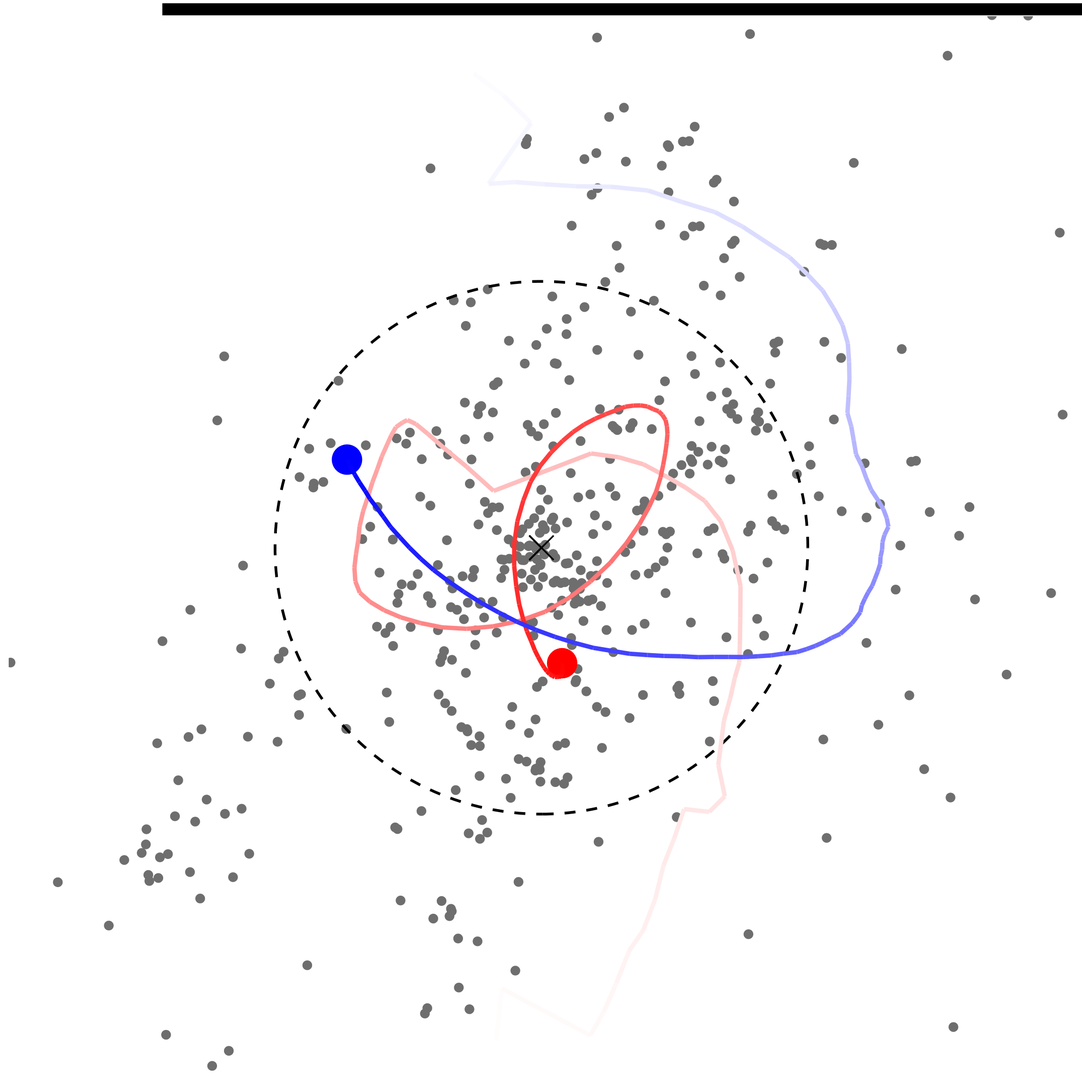
SDSS

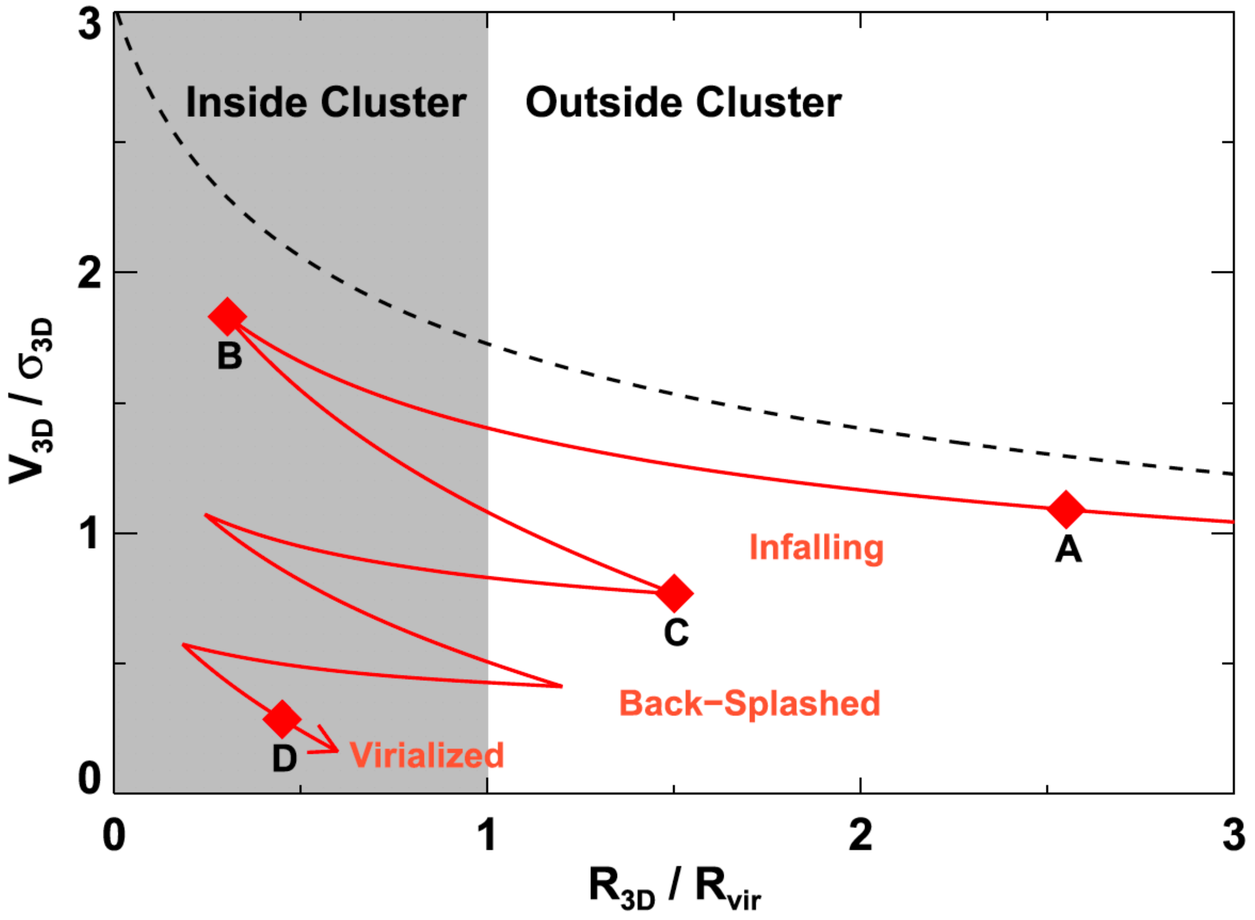
- Cluster / Group Catalog (Tempel + 14)
- ~500 hosts (with > 5e13 Msun)

  ~20,000 galaxies (with > 5e9 Msun)
- Galaxies are limited to S0 + Spiral
- SFR from SED

  (Salim+16; NUV + Opt + FIR)

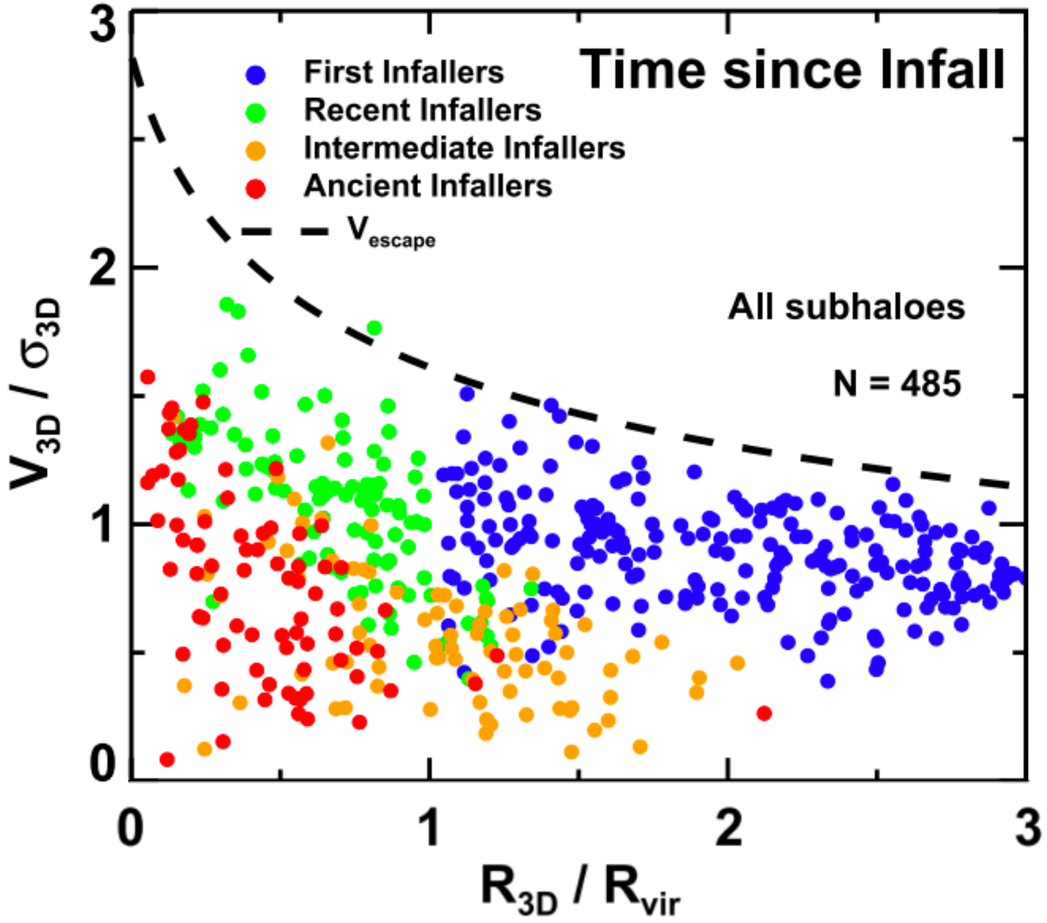
Phase-space Analysis





Time since Infall in Phase-space

Phase-space Distribution of a massive cluster
(Rhee et al. 2017)



A good separation in phase-space

> Orbital parameters would not be so different

(e.g., Wetzel 2010)

> Similar crossing times for infalling galaxies

(e.g., Jung+18)

- **First Infallers**: $T_{inf} < 0$
- **Recent Infallers**: $0 < T_{inf} < 3$ Gyr
- **Intermediate Infallers**: $3 < T_{inf} < 6$ Gyr
- **Ancient Infallers**: $T_{inf} > 6$ Gyr

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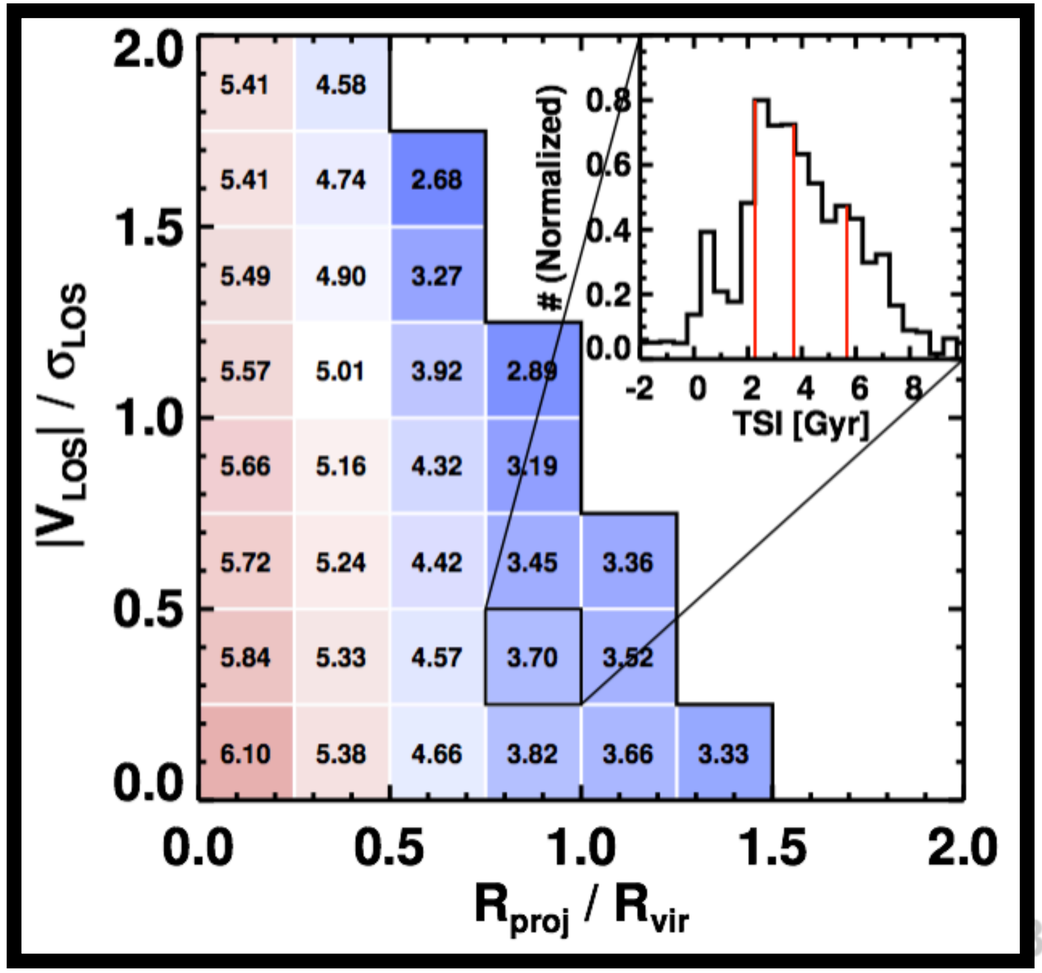

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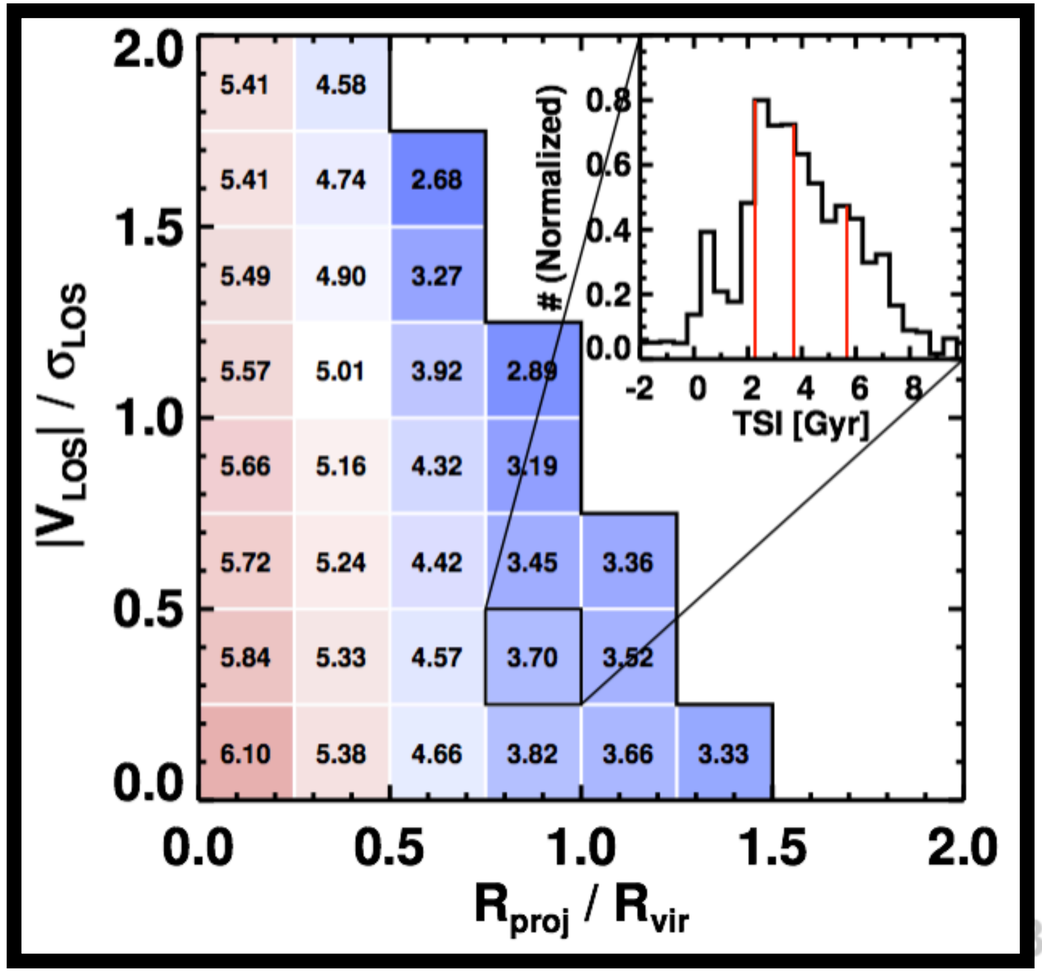
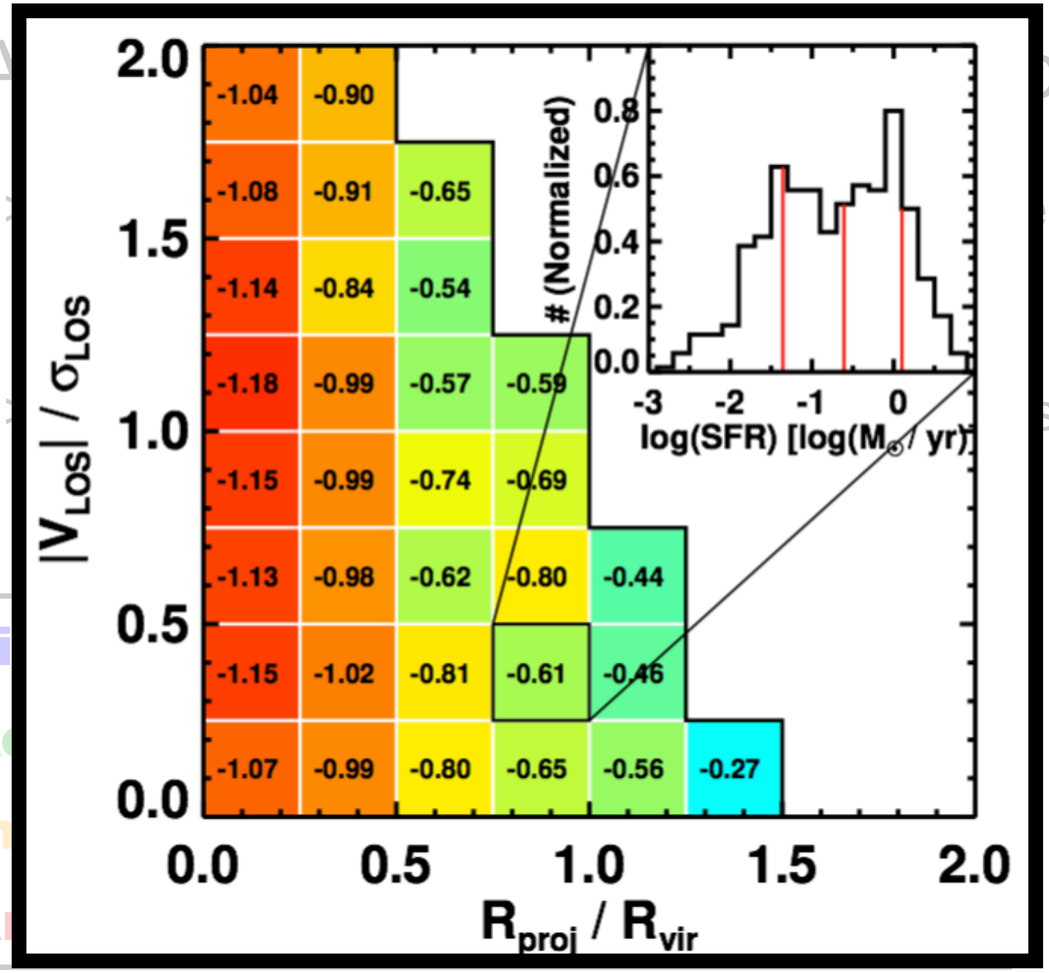
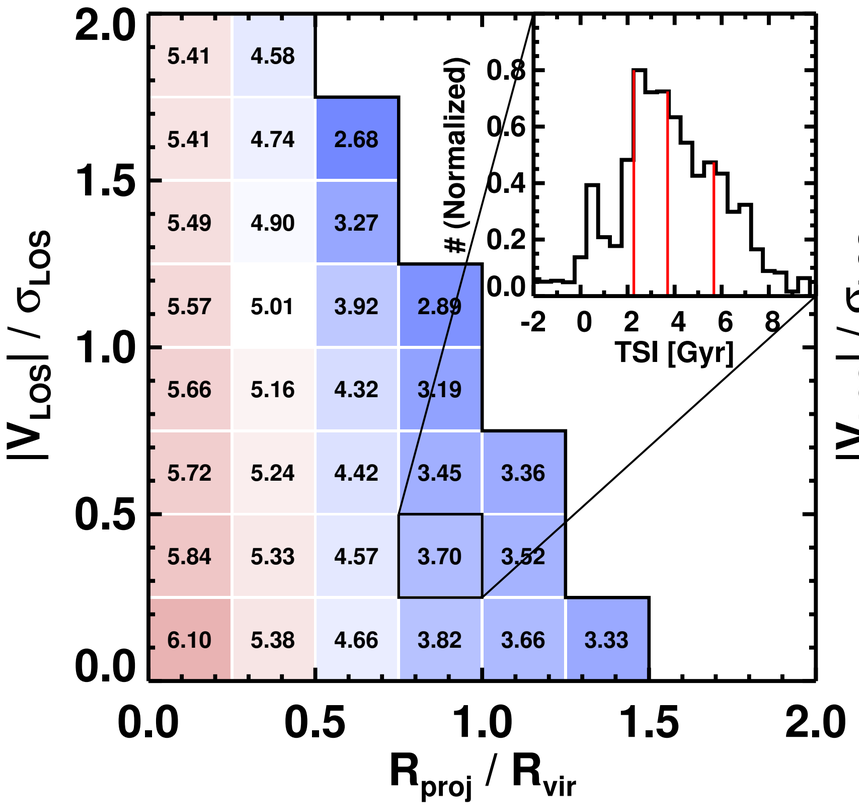


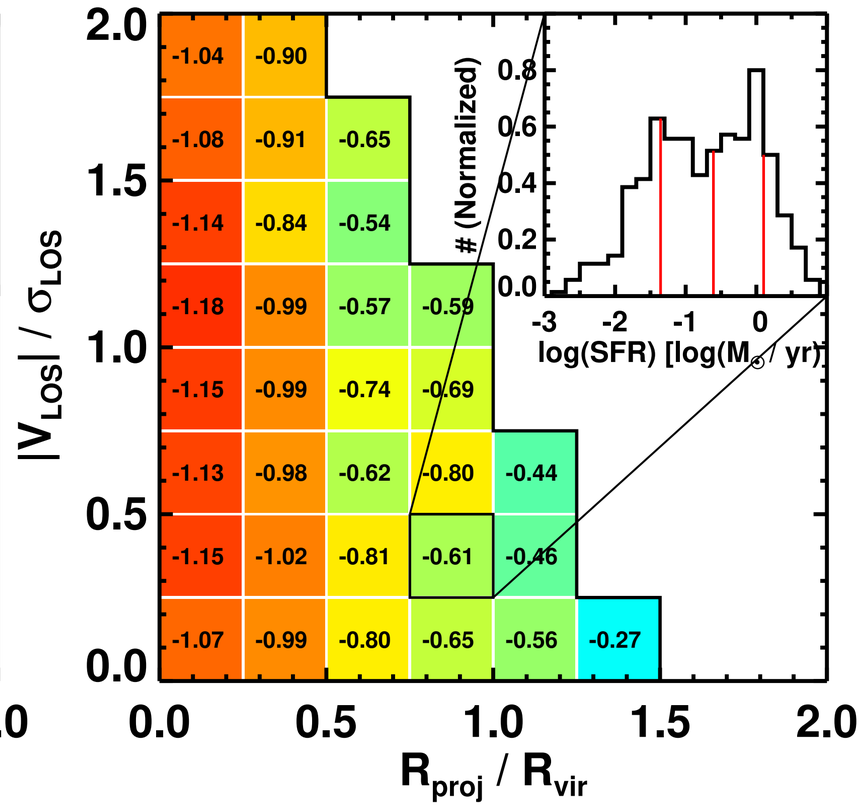


SFR vs. TSI Relation from Abundance Matching

Time Since Infall (From Sim-)

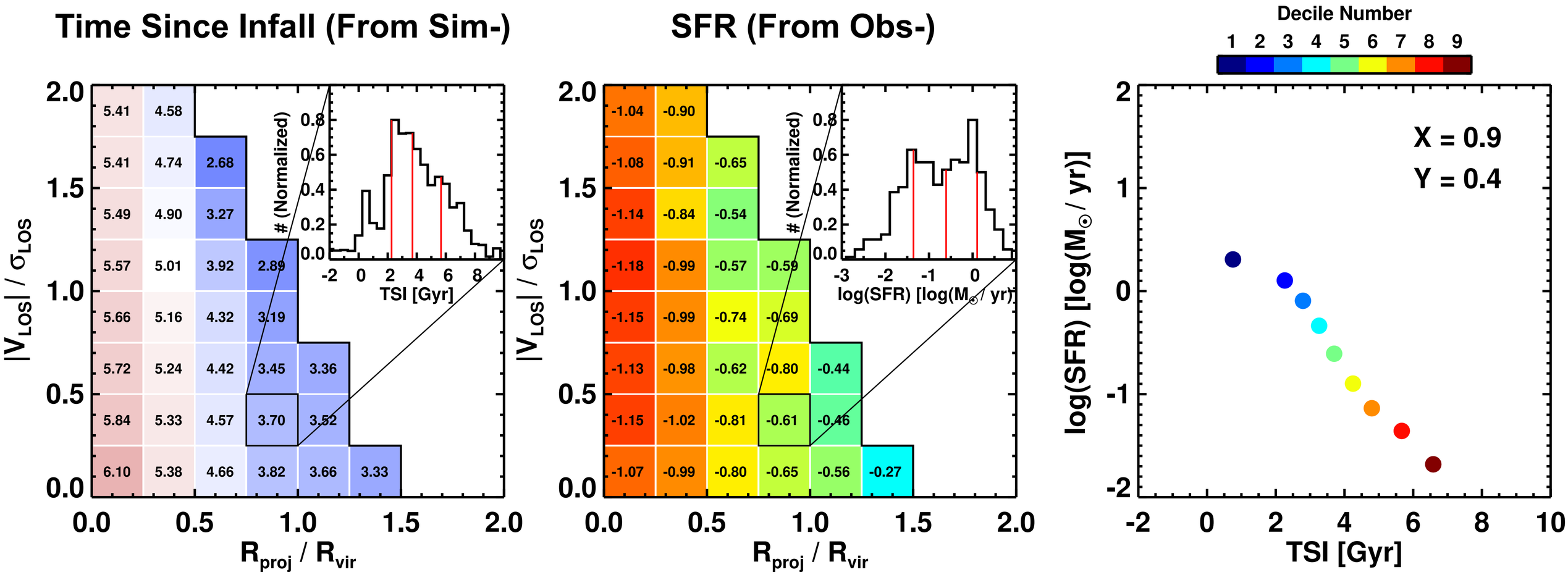


SFR (From Obs-)



Main Hypothesis: SFR is negatively correlated with TSI

SFR vs. TSI Relation from Abundance Matching



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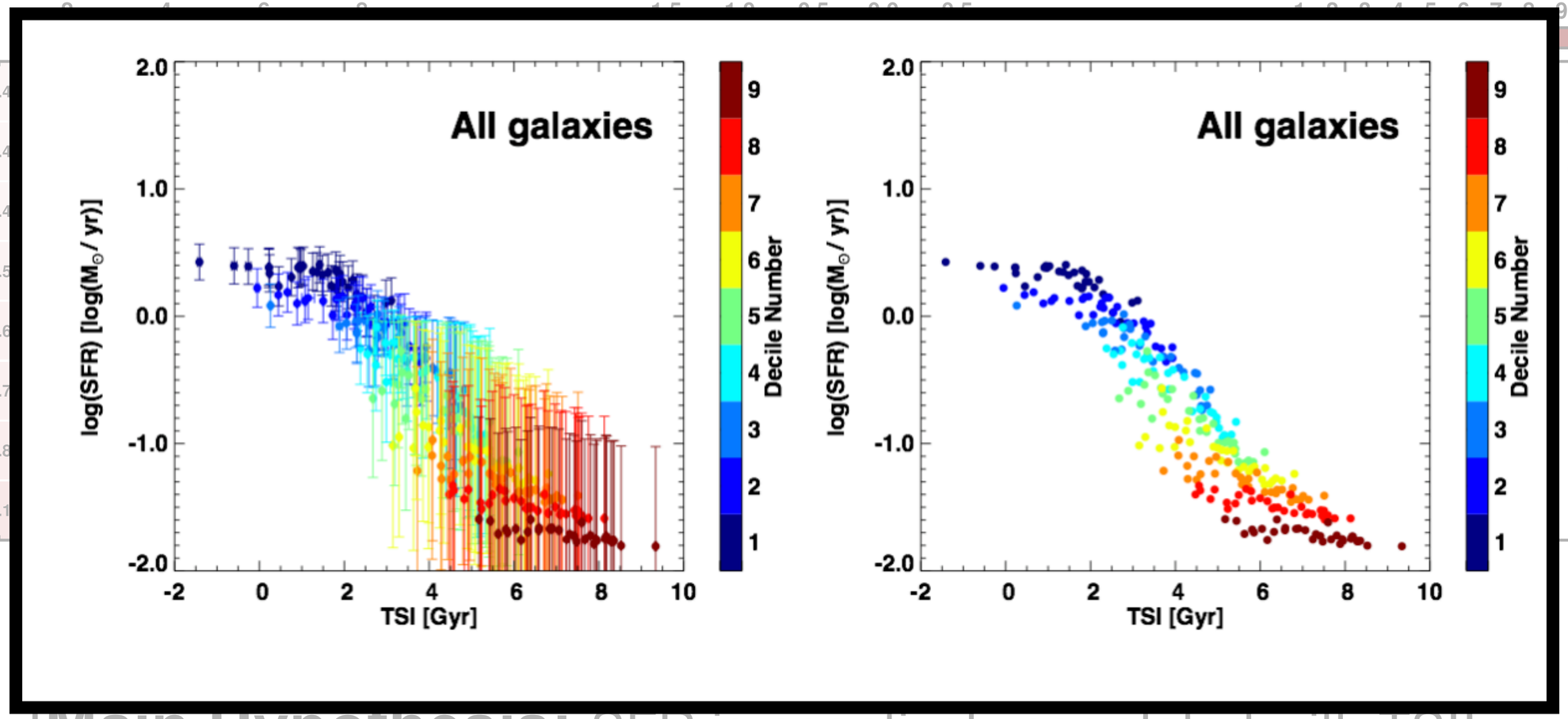

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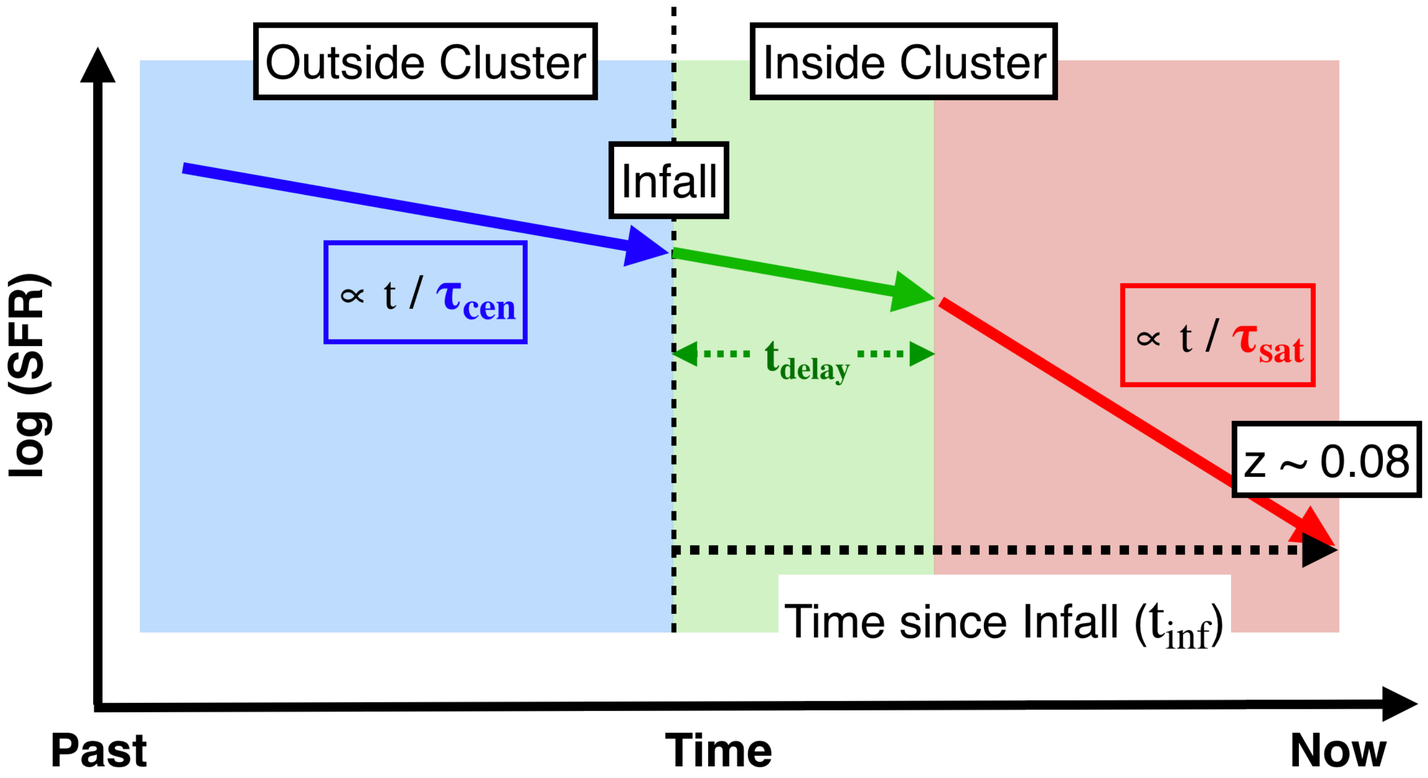
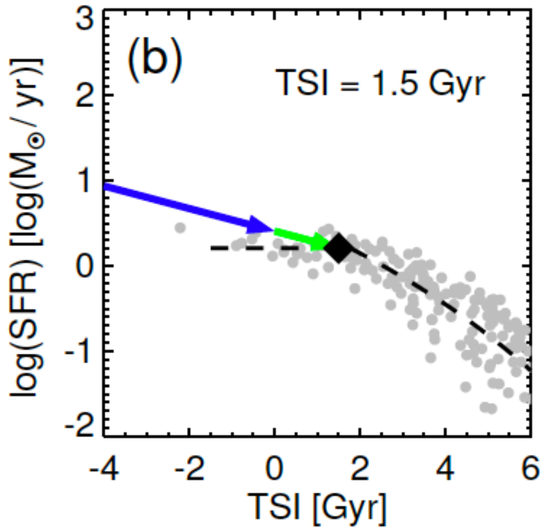
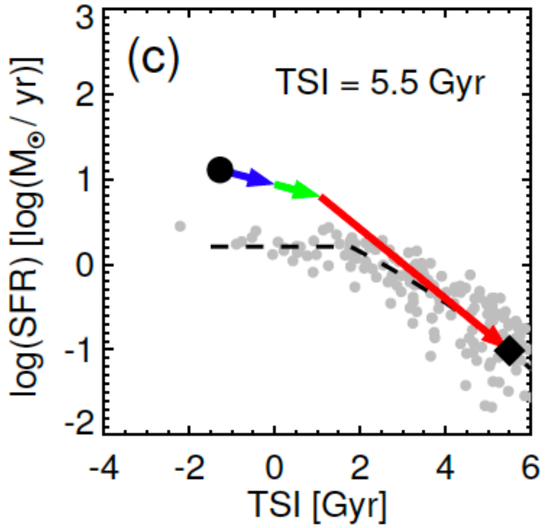
SFH Model

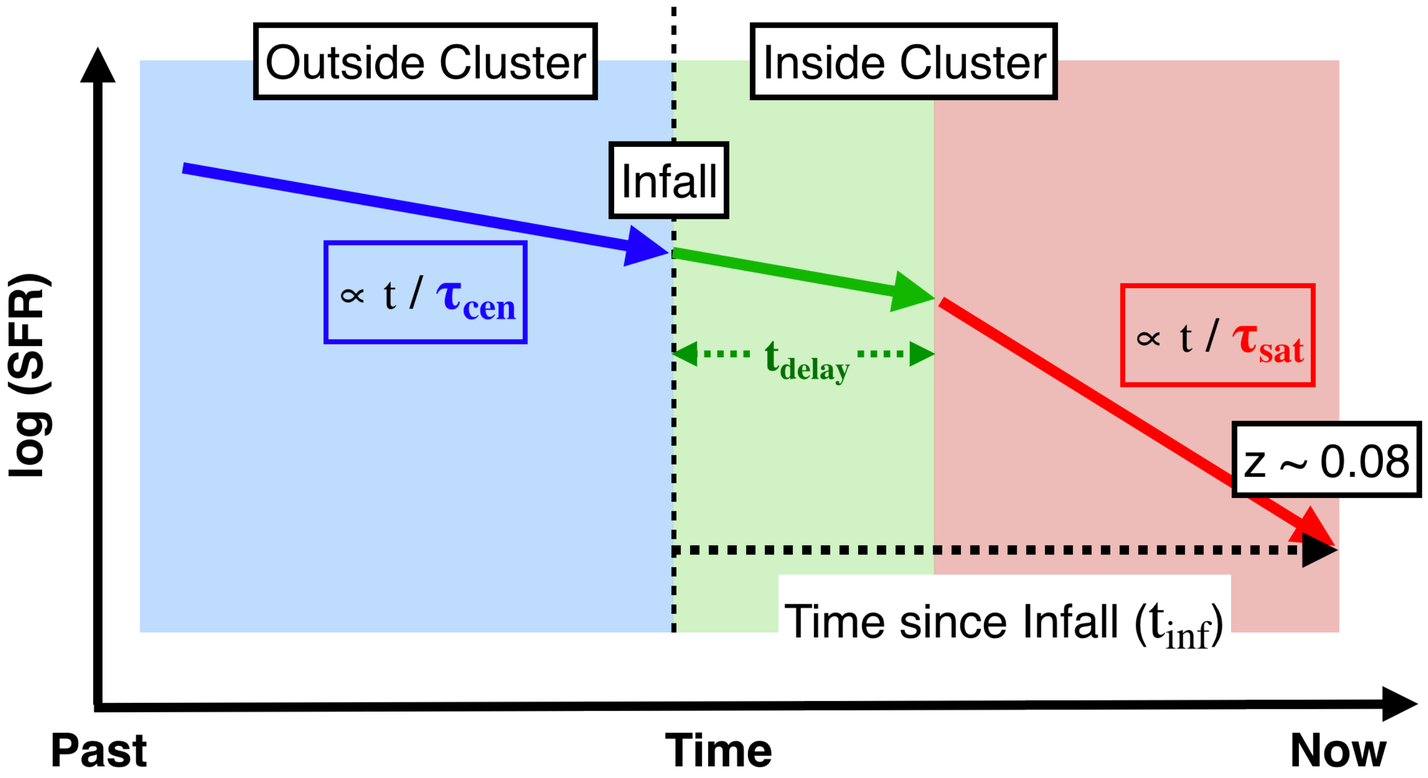


A SFH Model for Cluster Galaxies



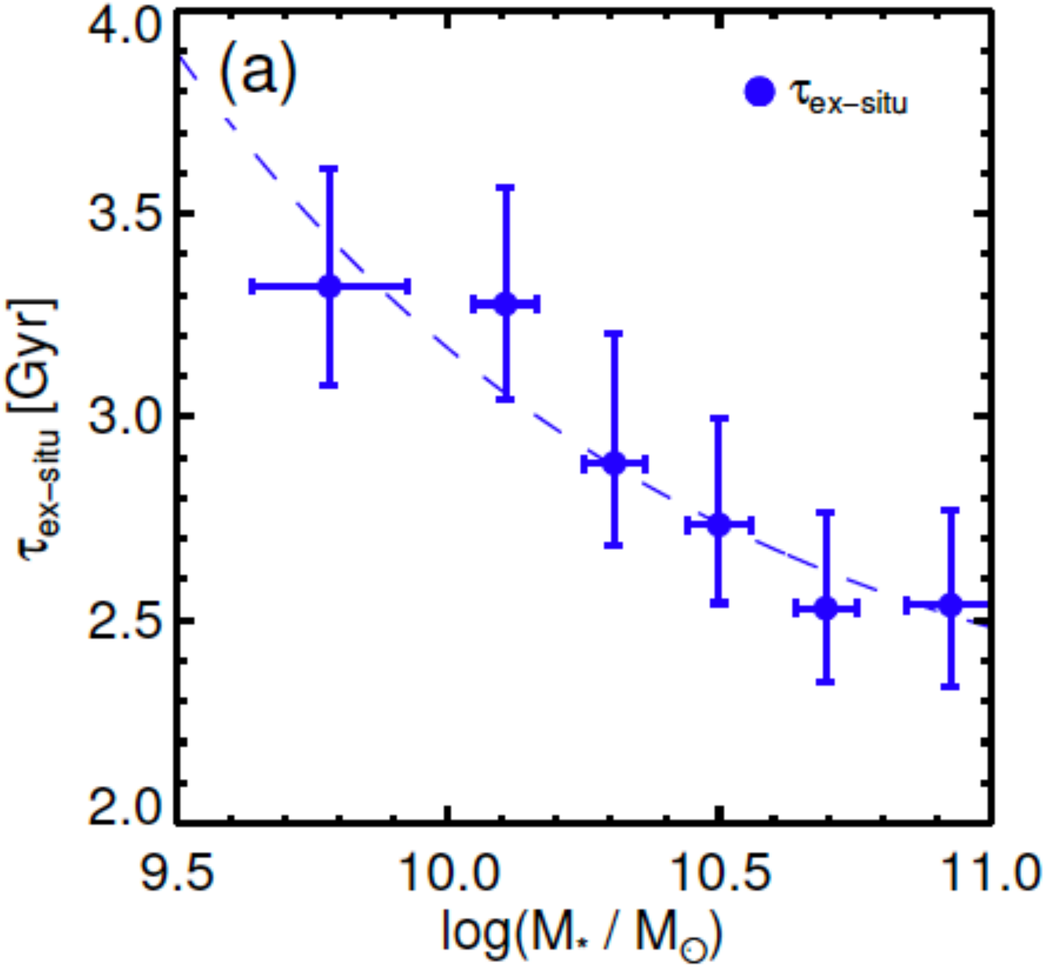


Quenching Timescale outside Cluster



A SFH Model for Cluster Galaxies

Rhee et al. 2020



Quenching Timescale outside Cluster

- 2.5 - 3.5 Gyr, with the mass trend: ~$(M_*)^{-1}$

  (e.g., Noeske et al. 2007)

  > Low SF efficiency for massive galaxies

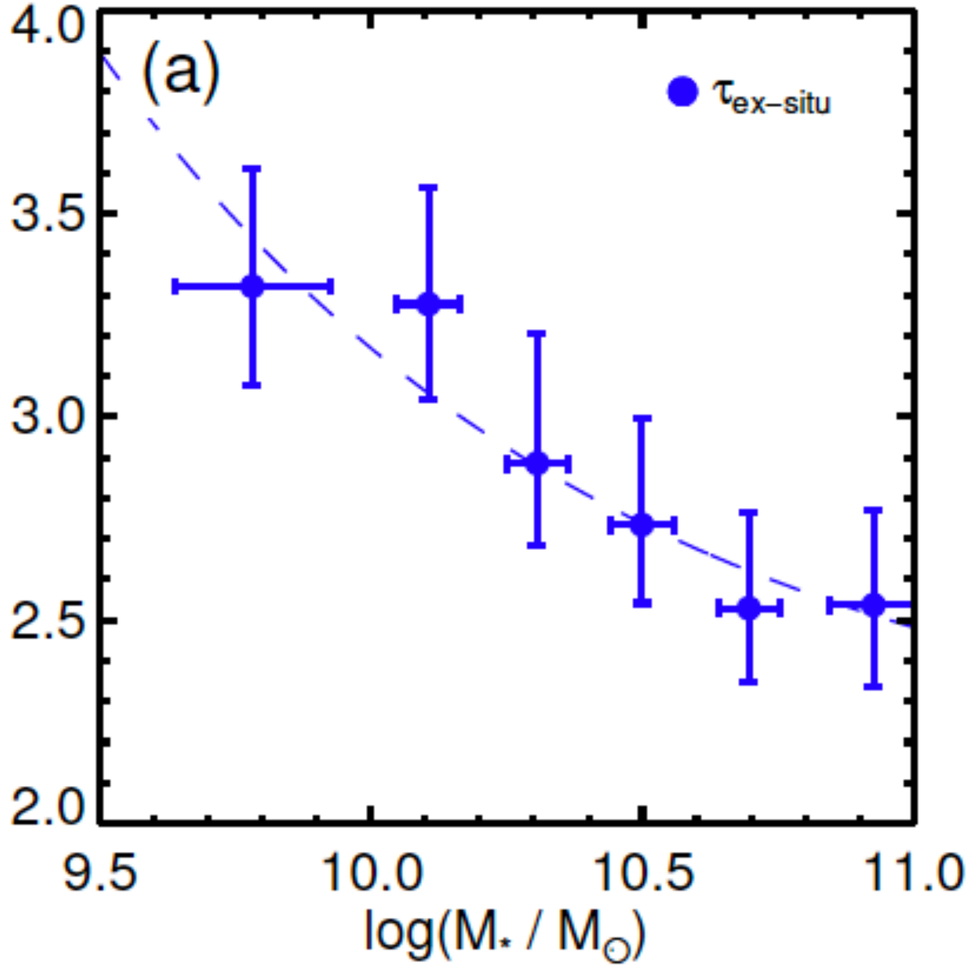
  > analogous to mass quenching (Peng+10)

- Lower than the e-folding timescale in the global SFH

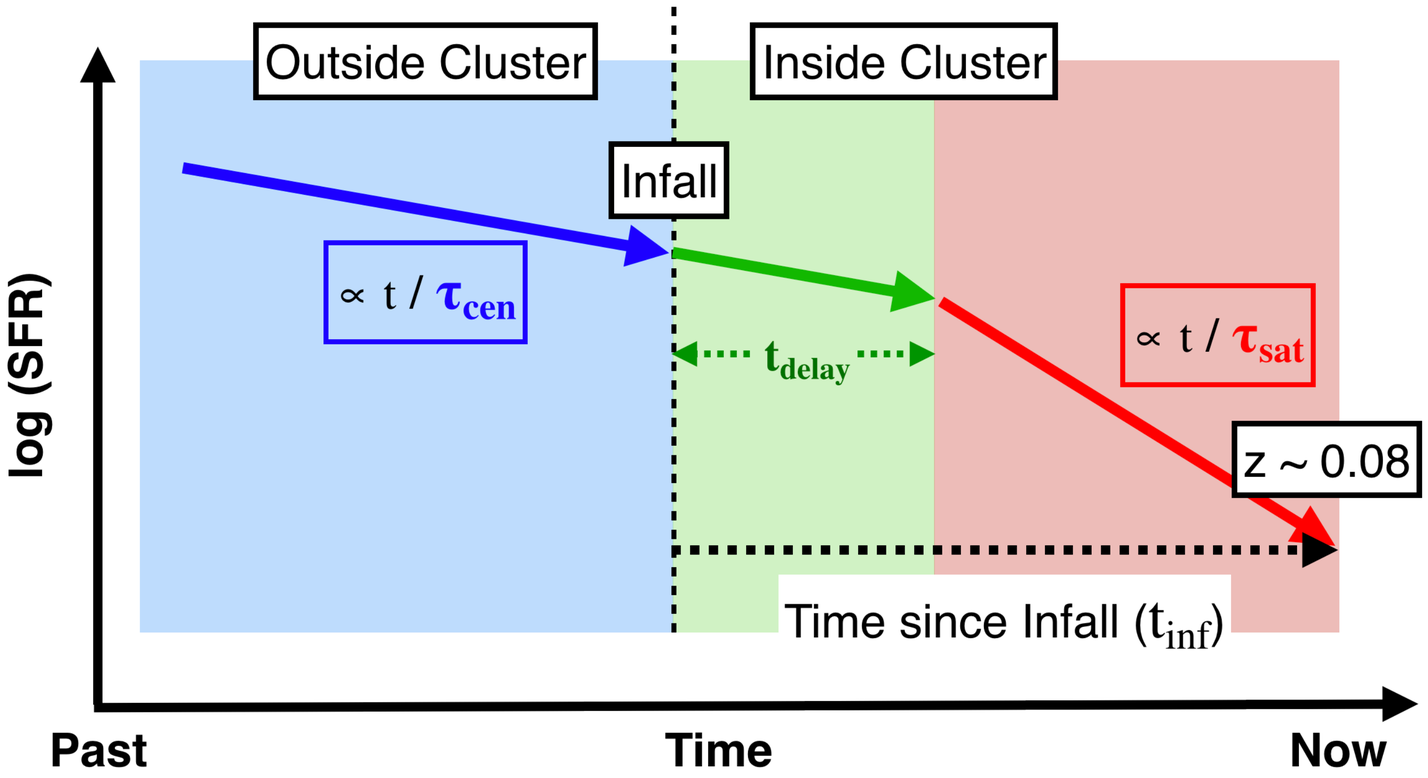
  (~ 4 Gyr; Madau & Dickinson 2014)

  > Presence of environmental effects for infalling galaxies prior to infall (e.g., Pre-processing)

Rhee et al. 2020



Delay Time



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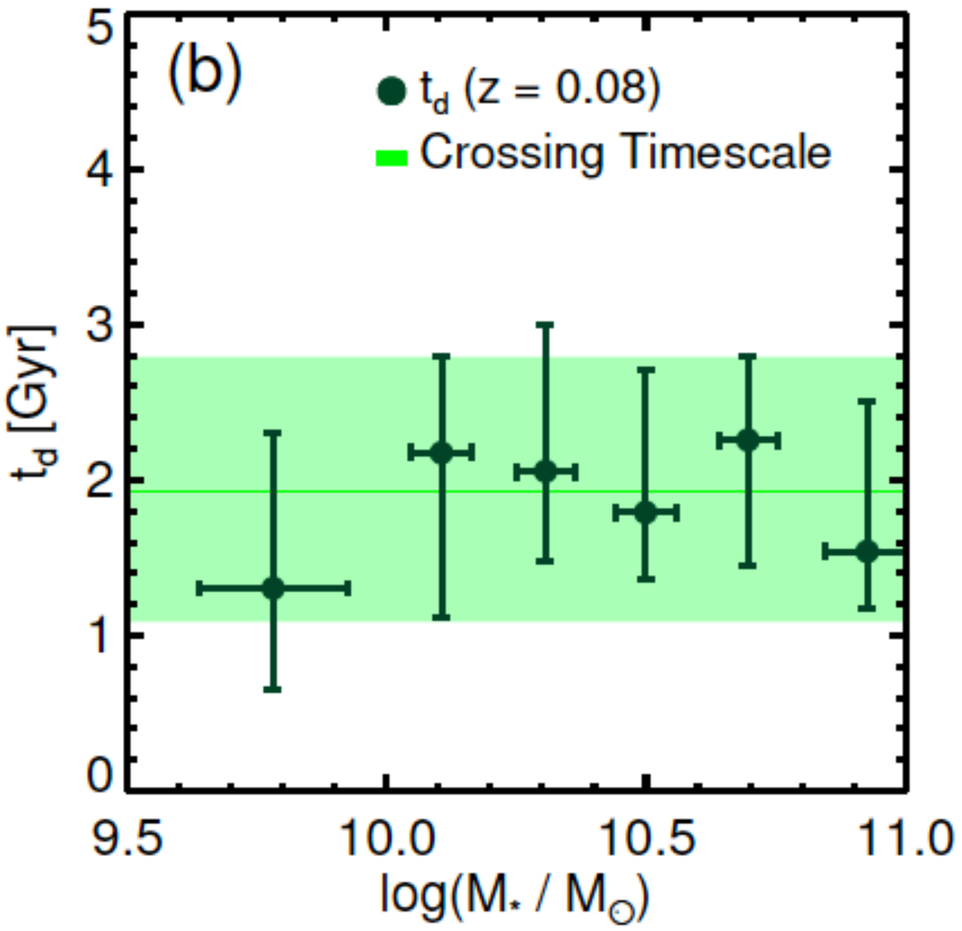


Delay Time

- ~ 2 Gyr, consistent with the crossing time

  (e.g., Tal+14; Fossati+17, …)

  > The pace of quenching is maintained during the first crossing time into the cluster.

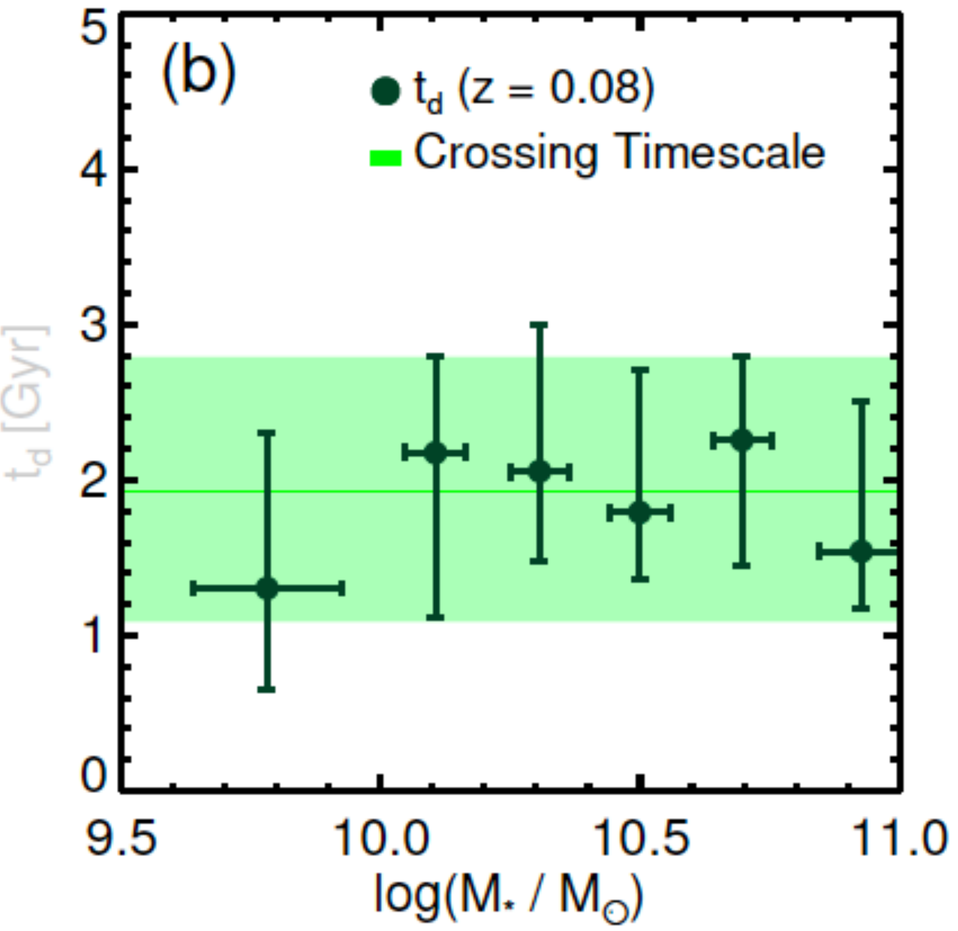
  > Independently confirm the delay-then-rapid quenching pattern (Wetzel + 13)

- Quenching remains gentle for the first time

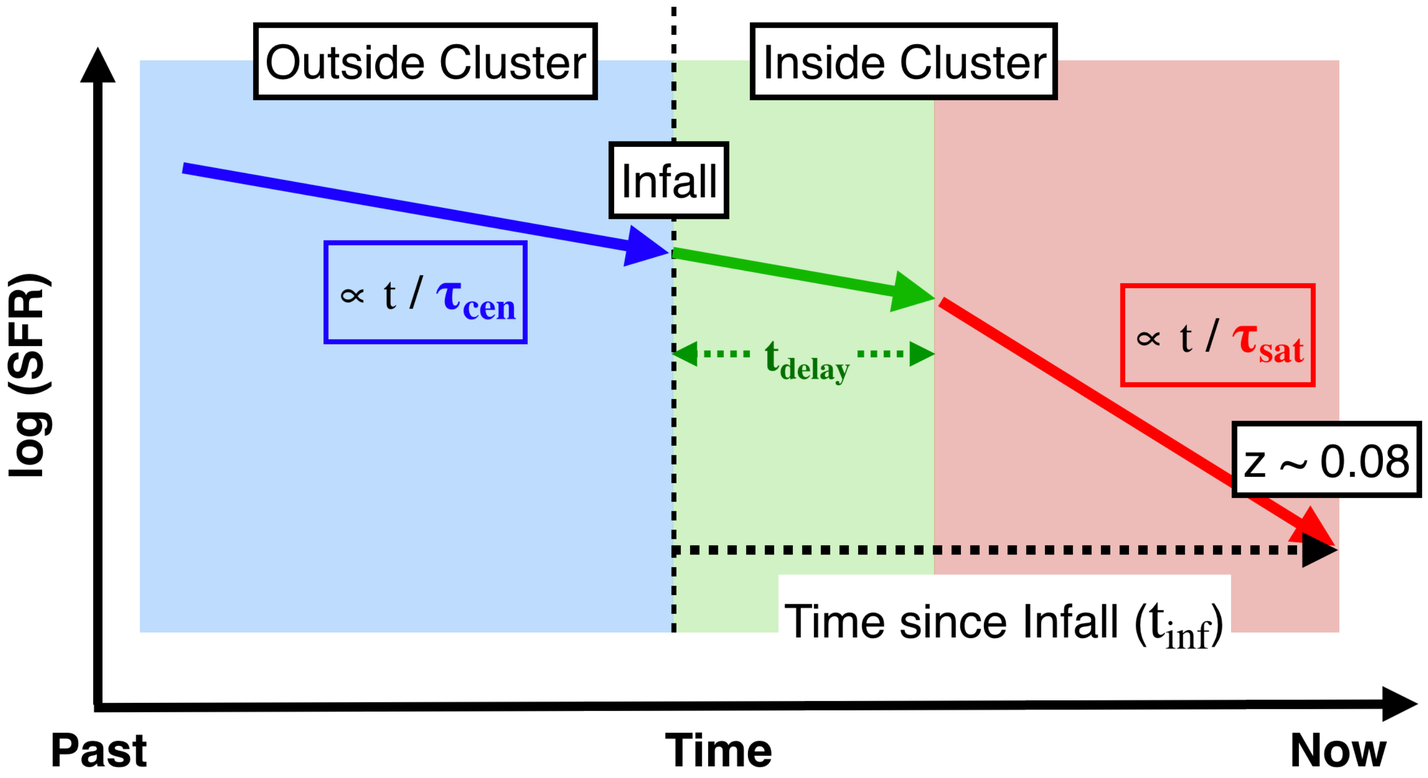
  > Gas loss will happen primarily on hot and neutral gas, less affecting SFR.

log (SFR)

Rhee et al. 2020



Quenching Timescale inside Cluster



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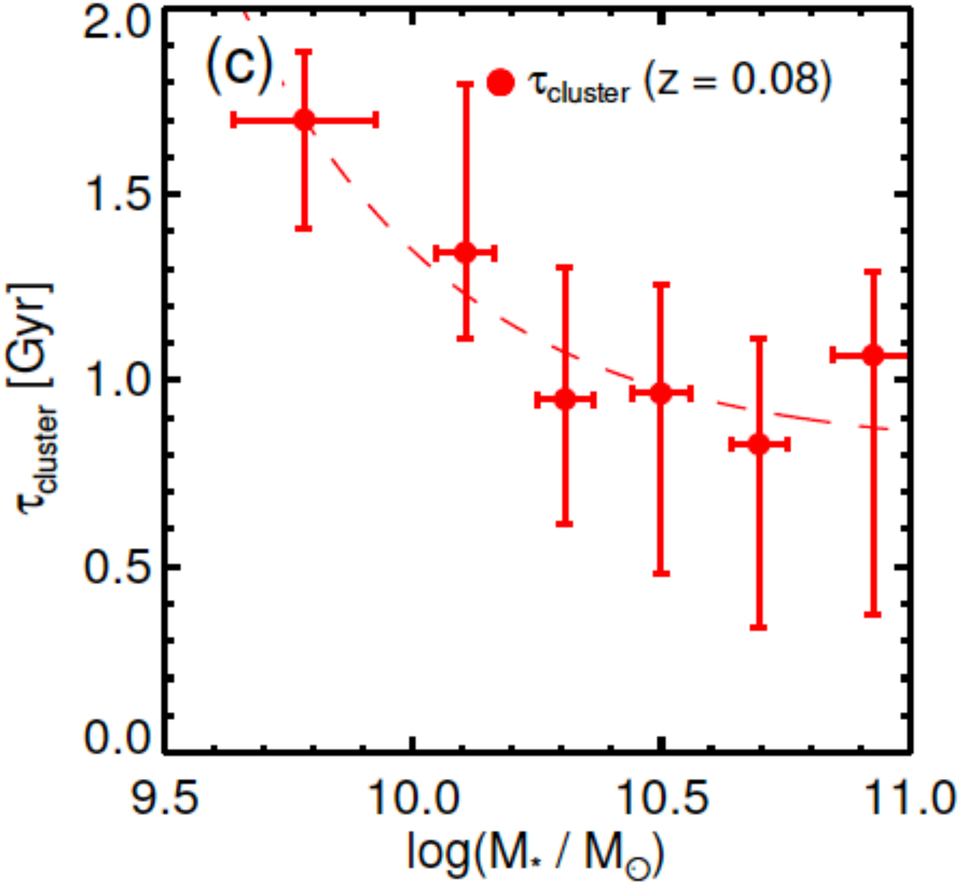


Quenching Timescale inside Cluster

- 1 - 2 Gyr, with the stellar mass trend

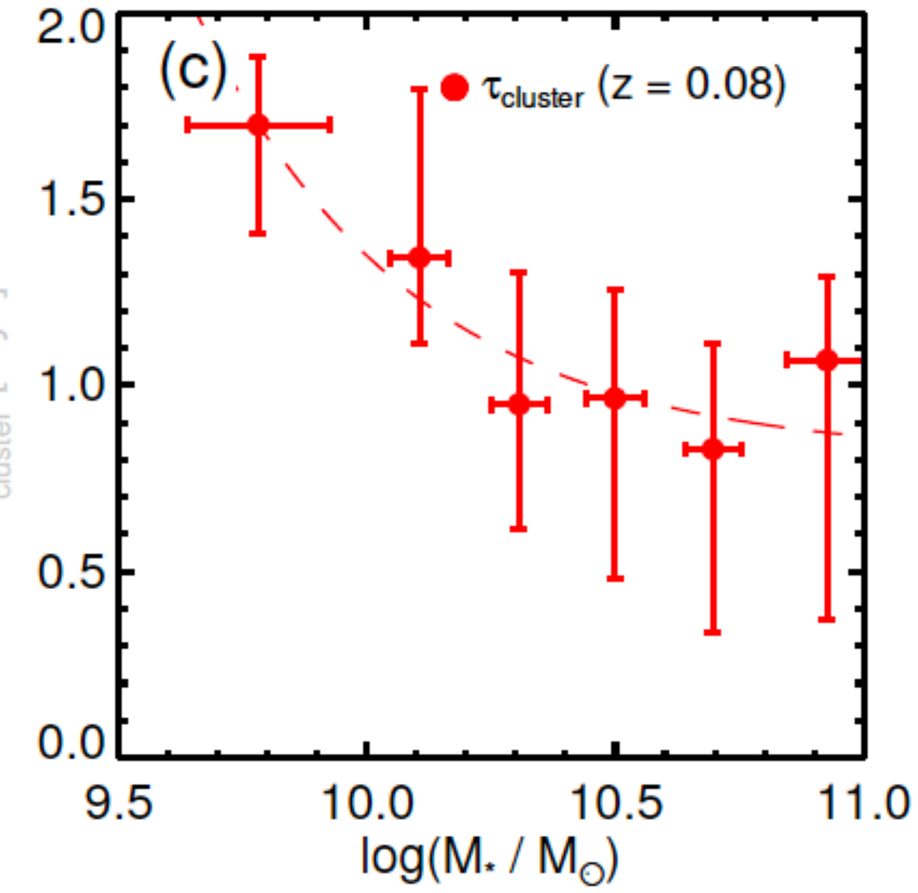
  > Short quenching timescales; galaxies are quickly quenched (ram pressure stripping as the main candidate?)

- Maybe different cold gas fraction at the infall epoch

  > Low gas fraction for massive galaxies due to mass quenching ,so that they are quenched faster (e.g., Jung+18)

  > While less massive galaxies can form stars much longer period of time, yielding longer quenching timescales

Rhee et al. 2020



Conclusion

- **Quenching Timescales are measured by combining Sim- and Obs- through the Phase-Space Diagram**

  > 3 Gyr (outside cluster): Mass quenching outside clusters is important

  > 2 Gyr (delay time): Gentle quenching during the first pericenter passage

  > 1 Gyr (inside cluster): Violent quenching after the first pericenter passage

- **Delay-then-rapid quenching pattern for cluster galaxies**

- **(Future) Extend the sample to group-sized halos**

Future Work I - PSA for Group

The Legacy Project

- **Zoom-in DM-only Sims From the original volume of (1600 Mpc/h)^3**
- **It is designed to sample > 7 sub regions regarding their mean density (void, -2sigma, -1, 0, 1, 2, cluster)**

  (Still running…)
- **Initical condition : MUSIC at z = 99?**
- **DMonly (gadget)**
- **Halofinder : Rockstar + FoF**

Name	L_{box} (Mpc/h)	L_{box}^{hr} (Mpc/h)	N^{hr}	$N_{eff.}$	m_p (M_o)	Comment
mean	1600.0	83.0	1700^3	32768^3	1.32E+7	zoom-in box
m1s	1600.0	83.0	1700^3	32768^3	1.32E+7	zoom-in box
m2s	1600.0	83.0	1700^3	32768^3	1.32E+7	zoom-in box
p1s	1600.0	83.0	1700^3	32768^3	1.32E+7	zoom-in box
p2s	1600.0	83.0	1700^3	32768^3	1.32E+7	zoom-in box
cluster	1600.0	83.0	1700^3	32768^3	1.32E+7	zoom-in box

Future Work I - PSA for Group

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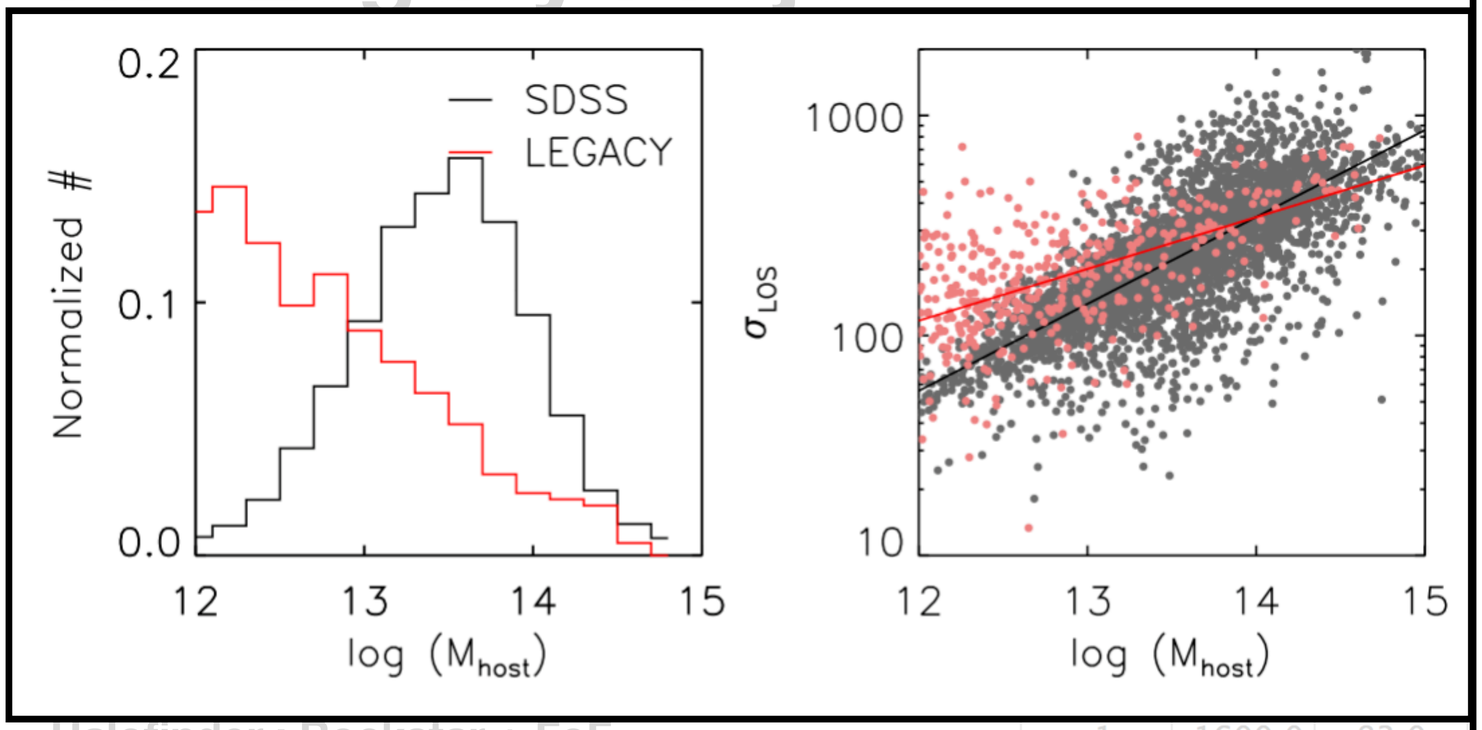

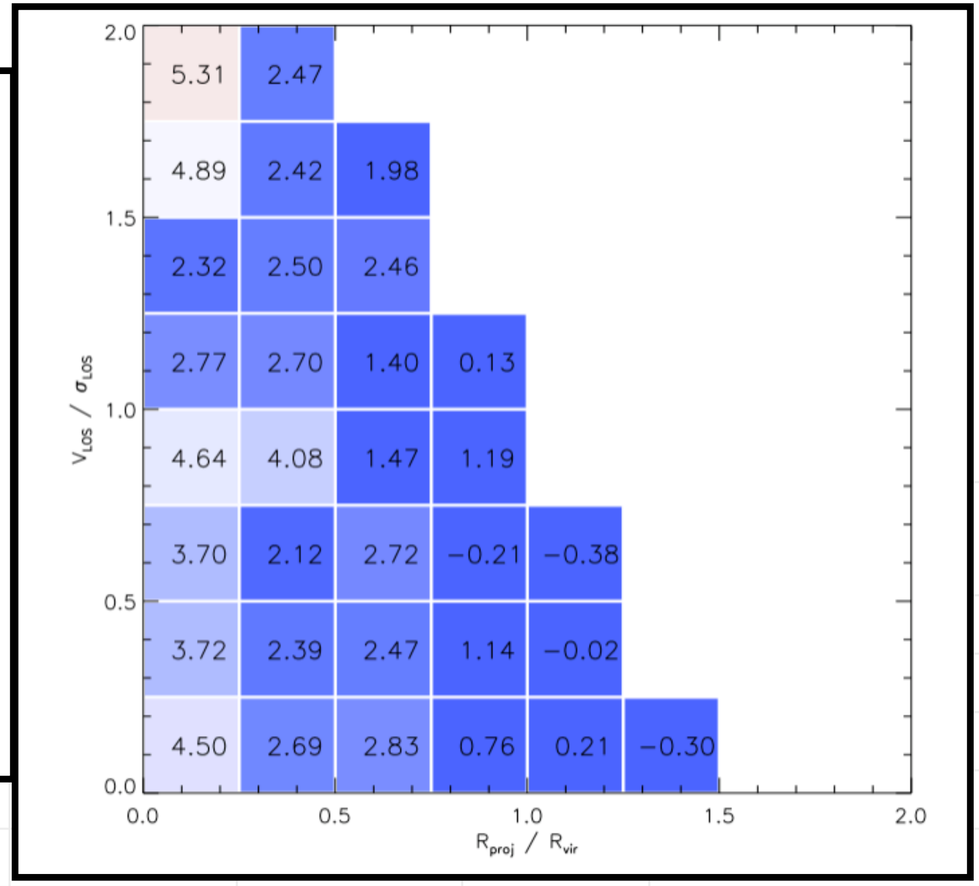

- Halofinder : Rockstar + FoF

p1s	1600.0	83.0				
p2s	1600.0	83.0				
cluster	1600.0	83.0	1700^3	32768^3	1.32E+7	zoom-in box

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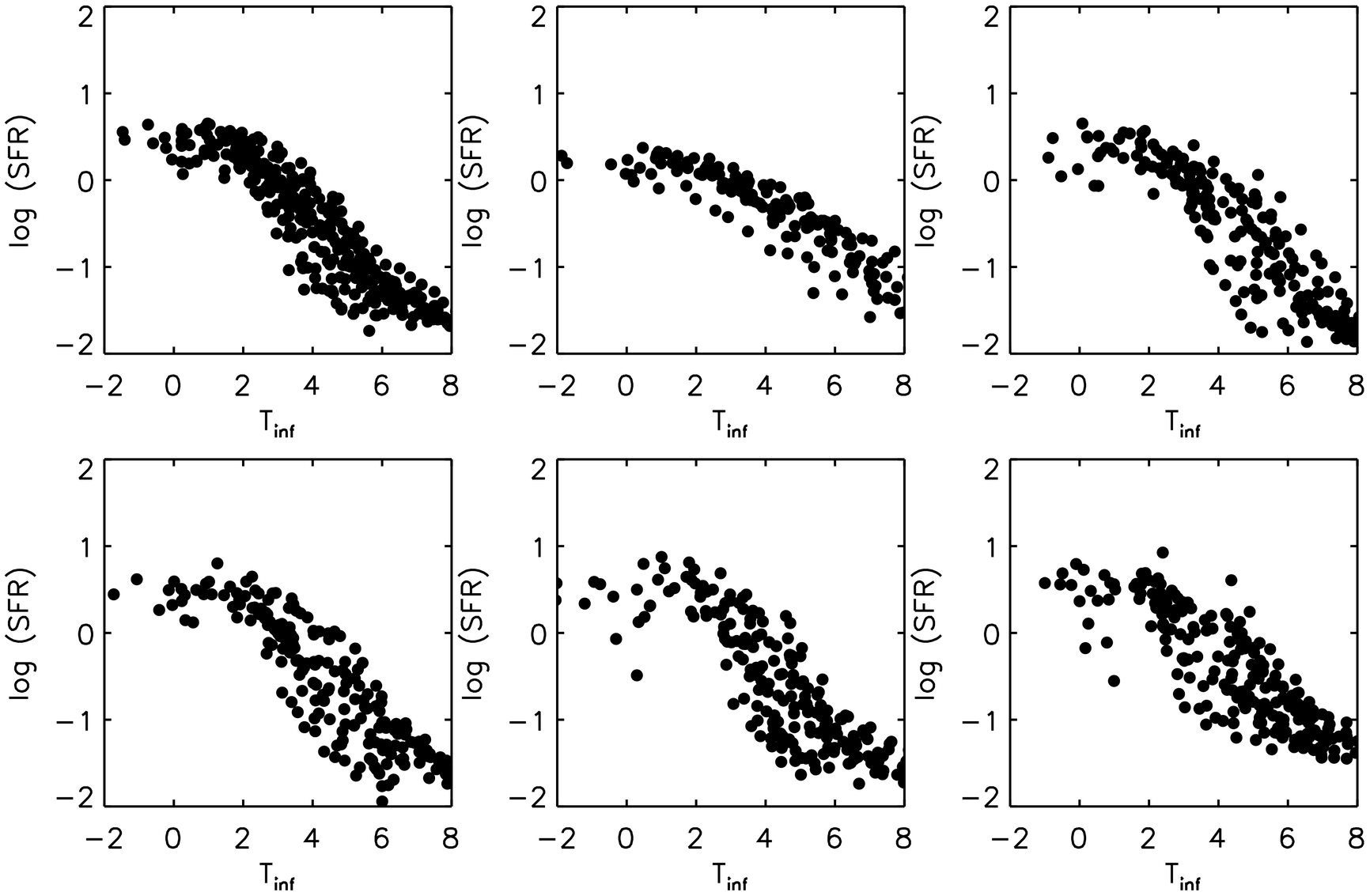
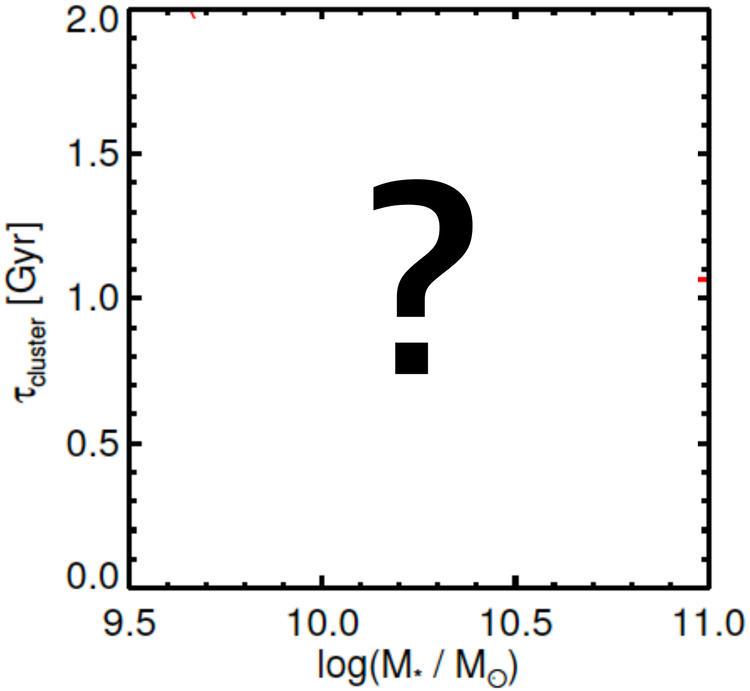




Future Work II - Case Study

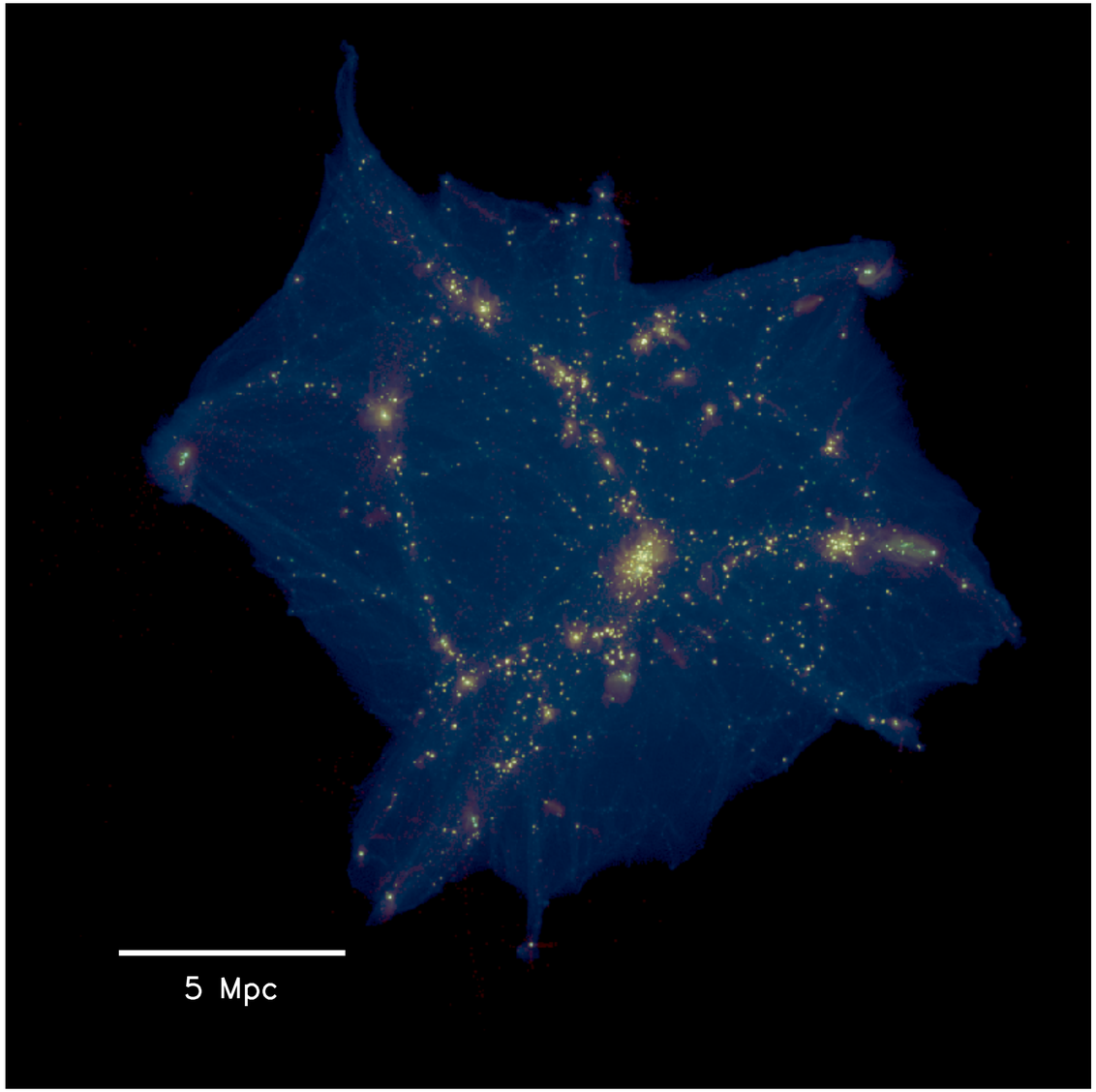
NewHorizon

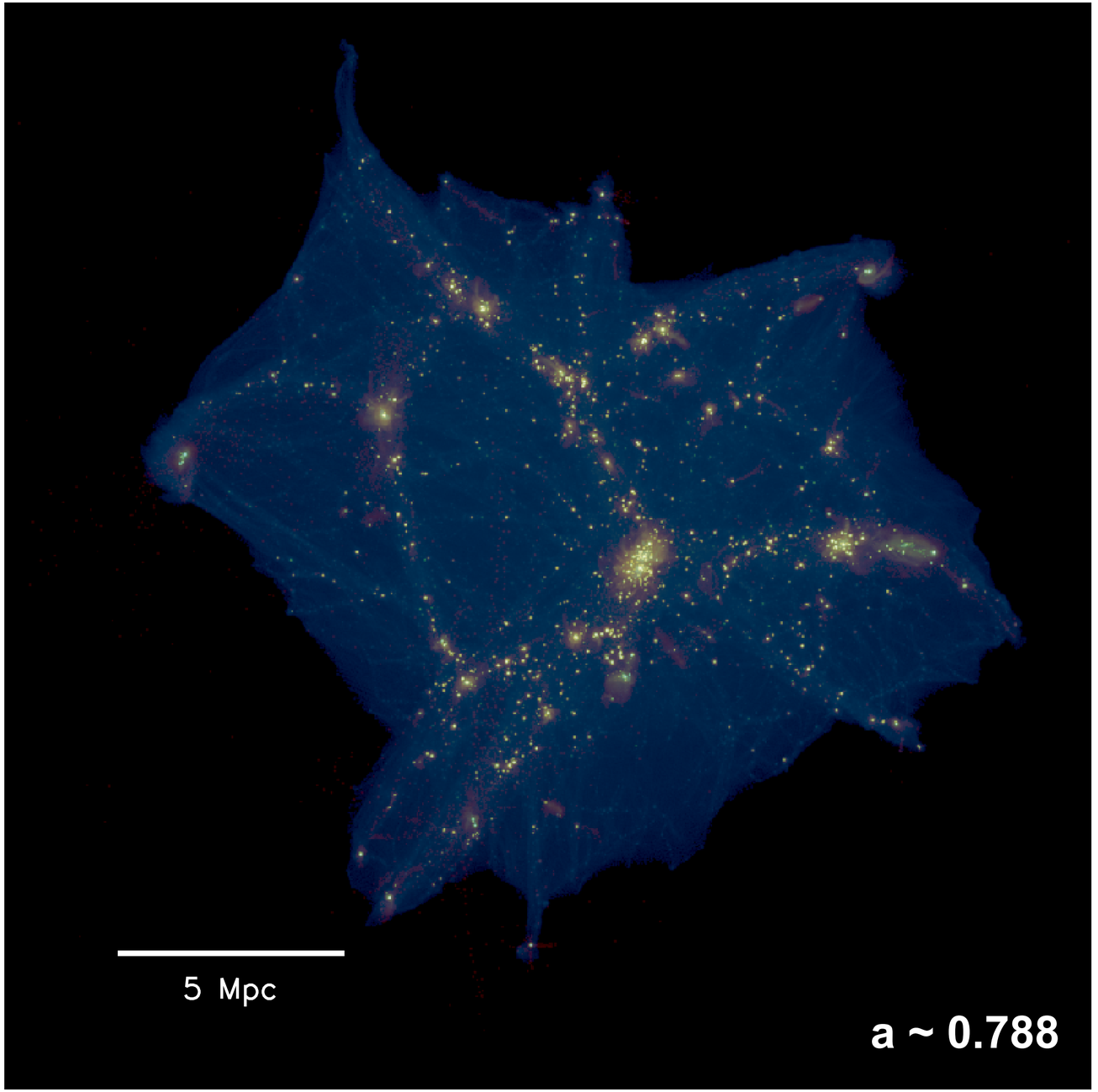
- Dubois et al. 2020 (in pres)
- RAMSES (AMR, Teyssier 2002)
- Cosmological Zoom in

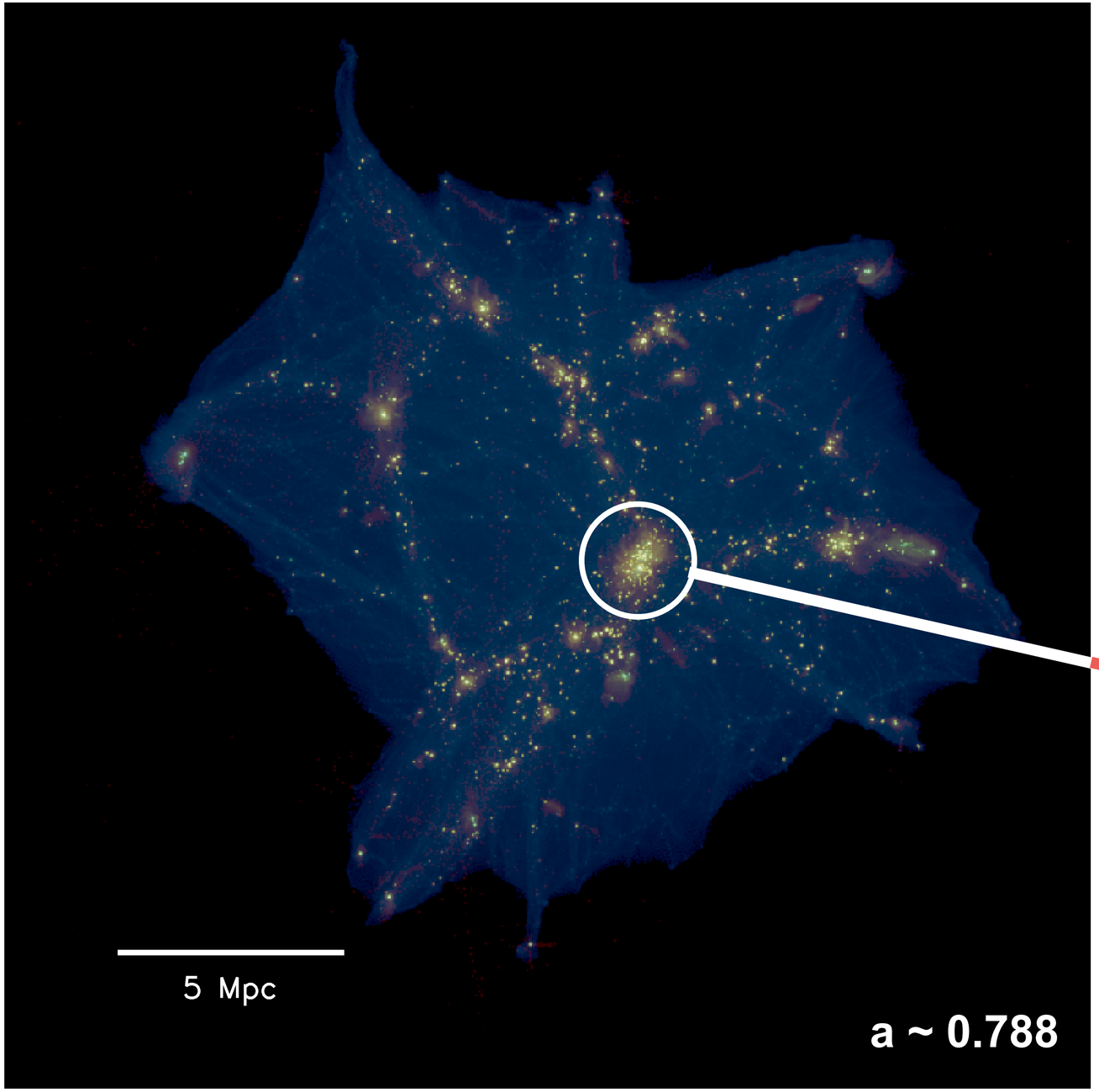
  10 Mpc Sphere (from HorizonAGN)
- DM+hydro
- 6D Galaxy Finder (VELOCIRaptor)
- dx=40 pc/h

  dm=1e6 $M_\odot$

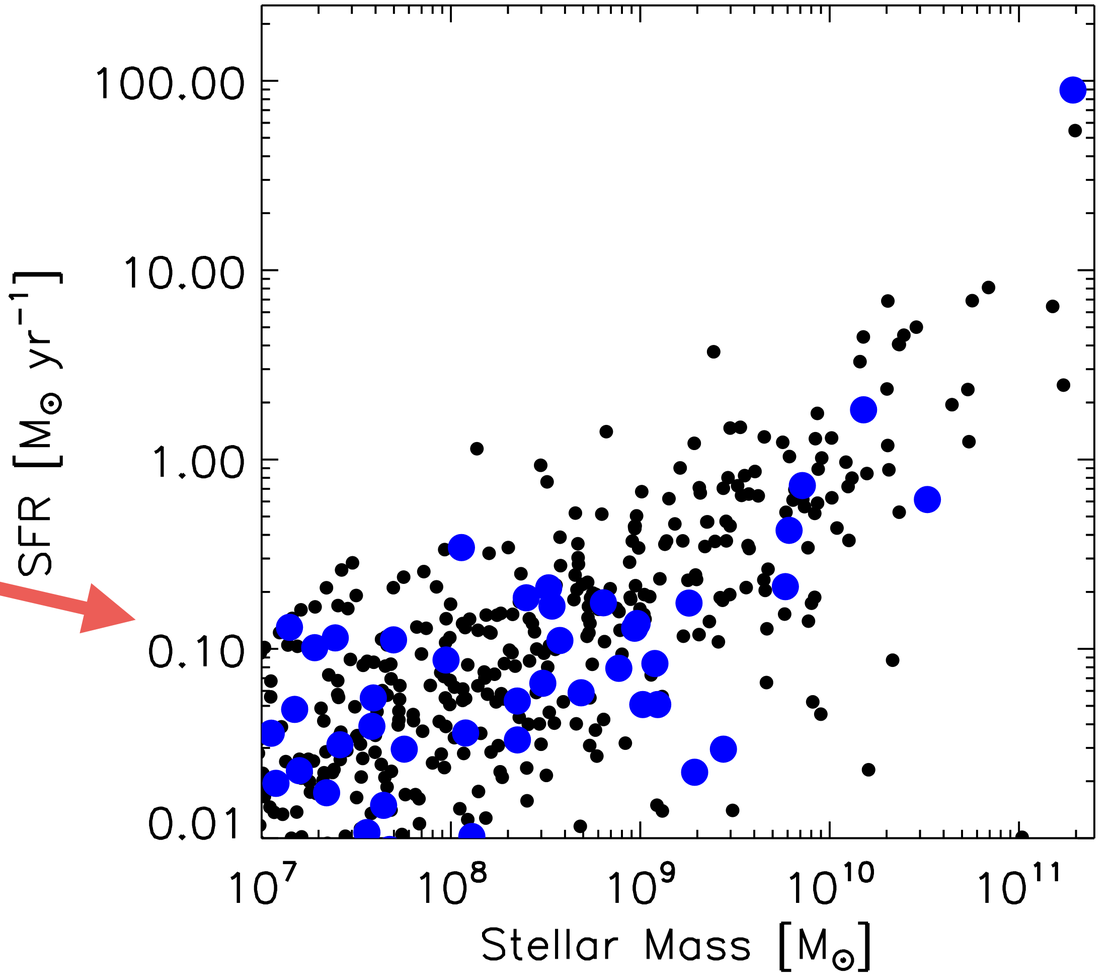
  dm_*=1e4 $M_\odot$

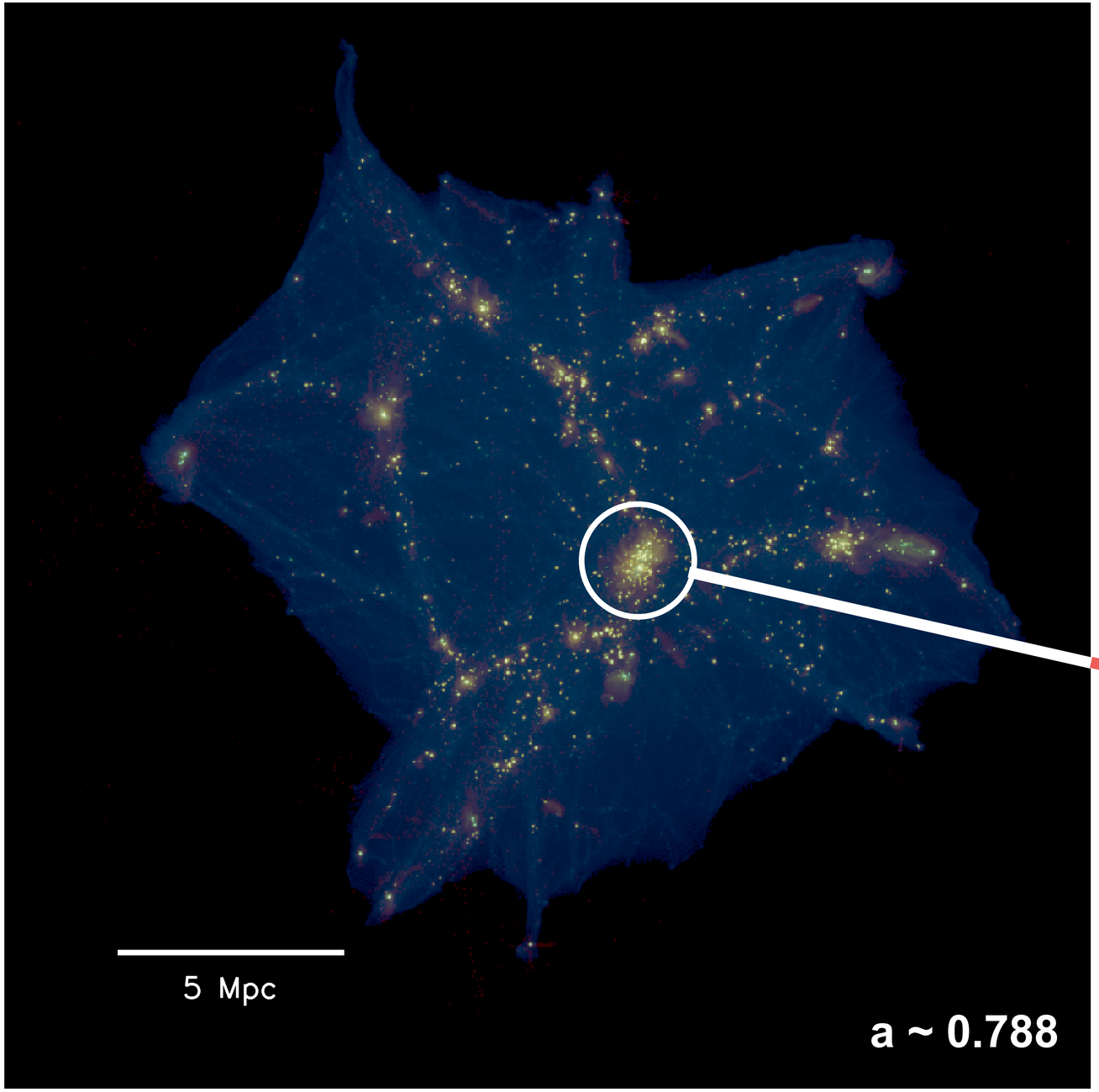



5 Mpc
a ~ 0.788



- **A Group with M_{halo} = 8e12 M_{sun}**
- **~100 Galaxies in the group**





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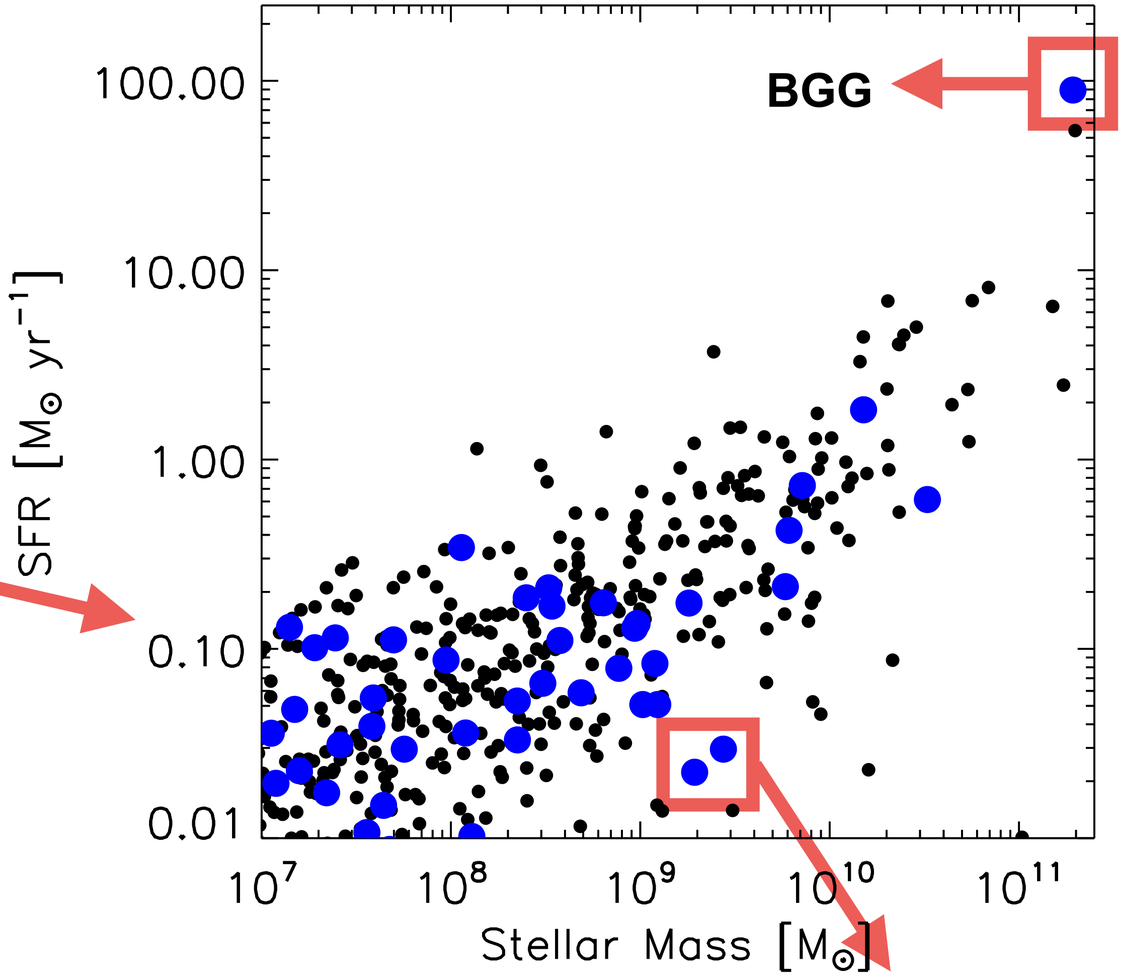

Quenched in Group?