# Galaxies in the Densest Environments through Cosmic Time

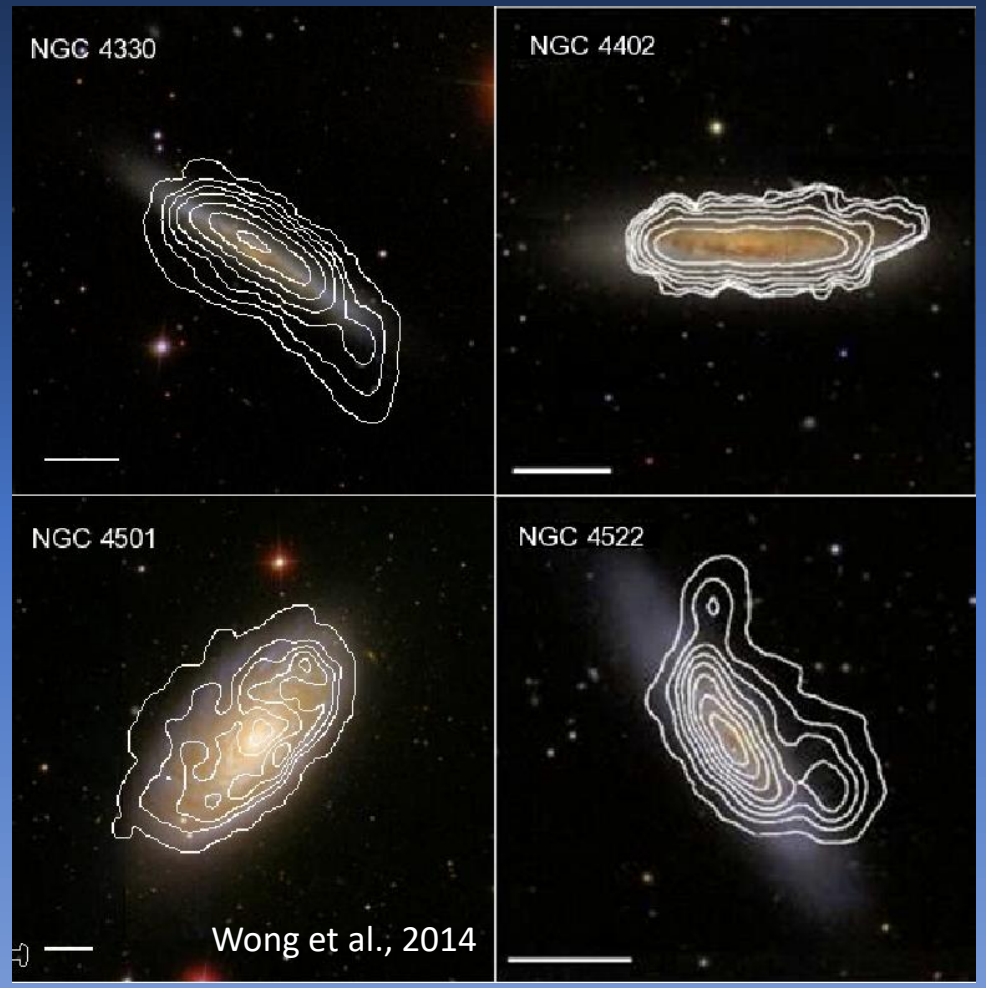
Rhea-Silvia Remus

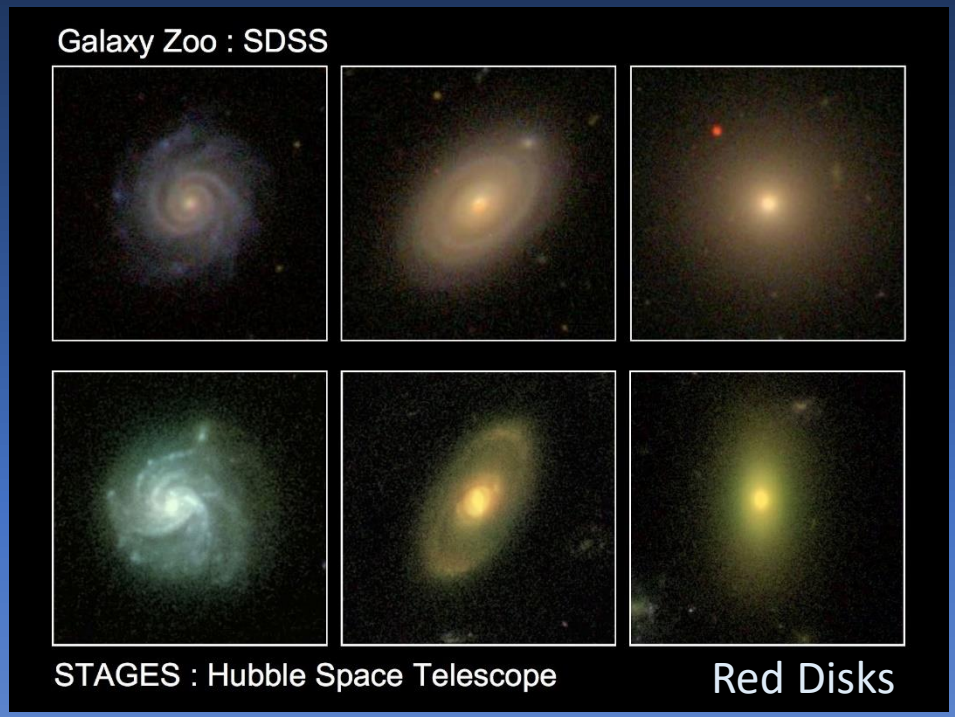
with Marcel Lotz, Klaus Dolag, Andreas Burkert

and the Magneticum Pathfinder Team

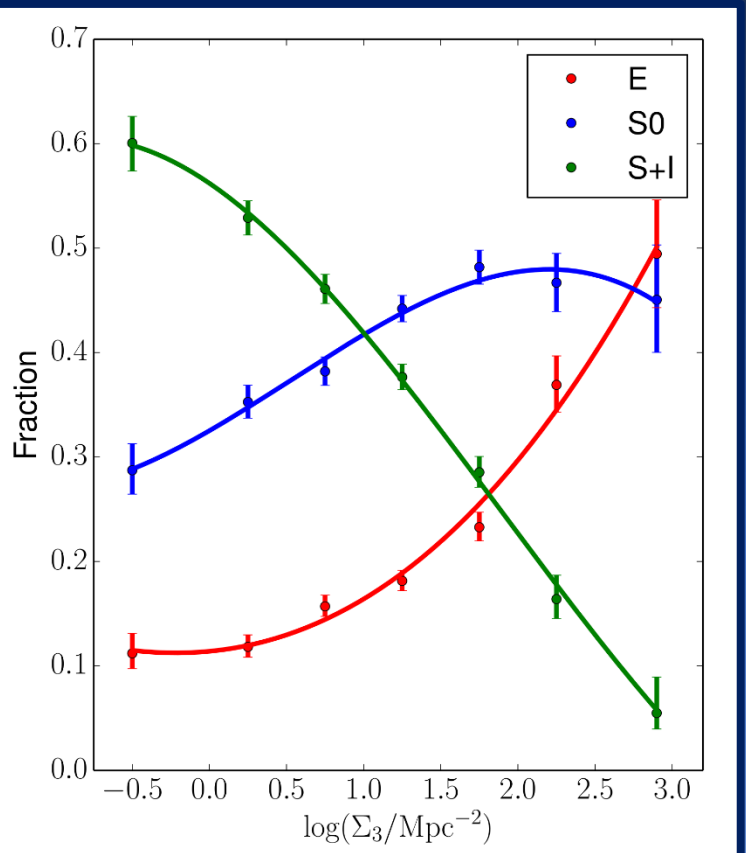
EAS 2020, S14, 30.06.2020

# Environment and Galaxies

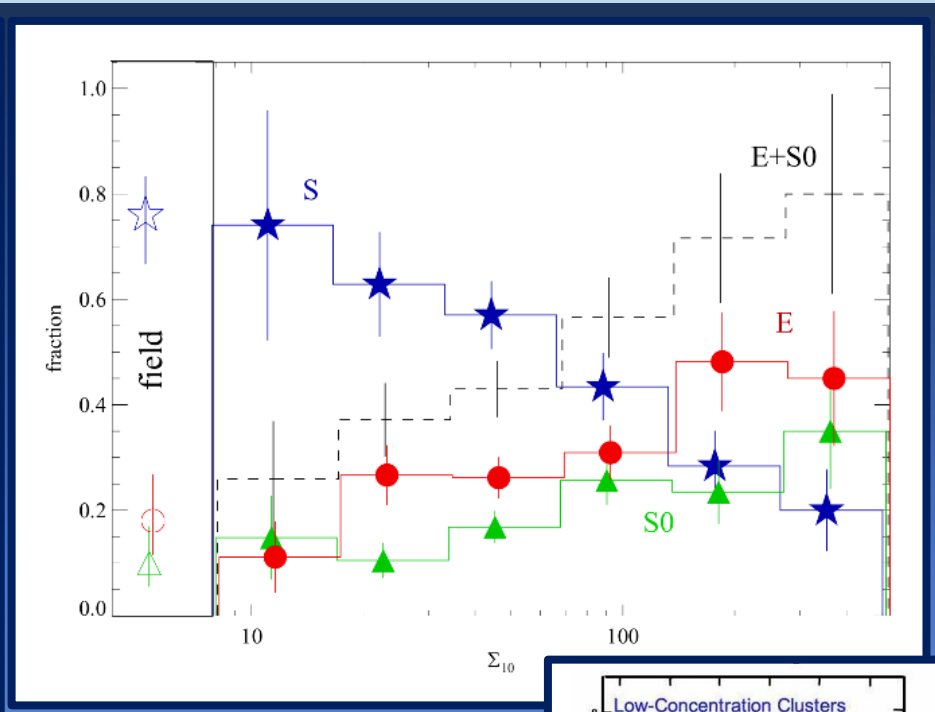


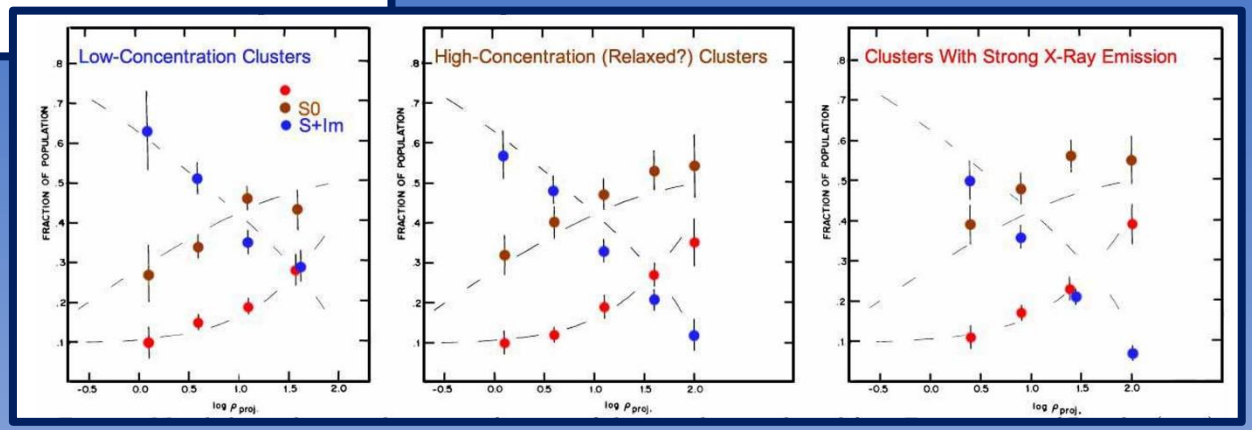
# Environment and Galaxies: Morphology Density




Houghton 2015, redone from data from Dressler 1980




Ma & Ebeling, 2010




Kormendy & Bender, 2012

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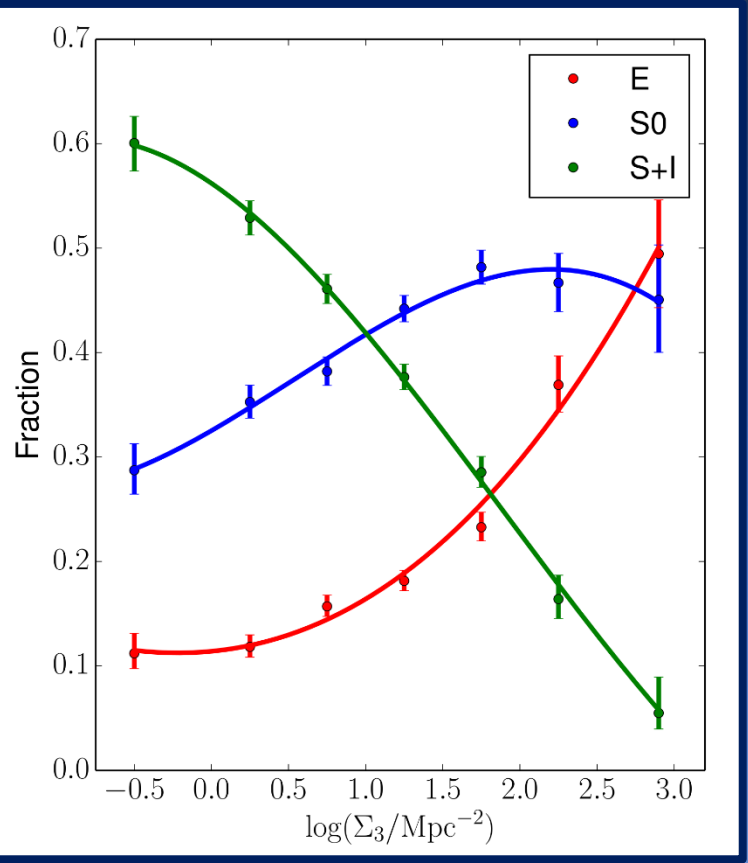


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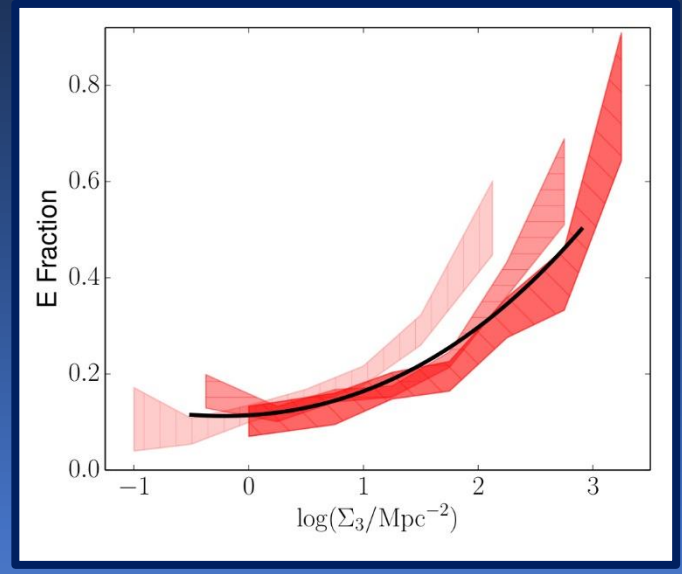
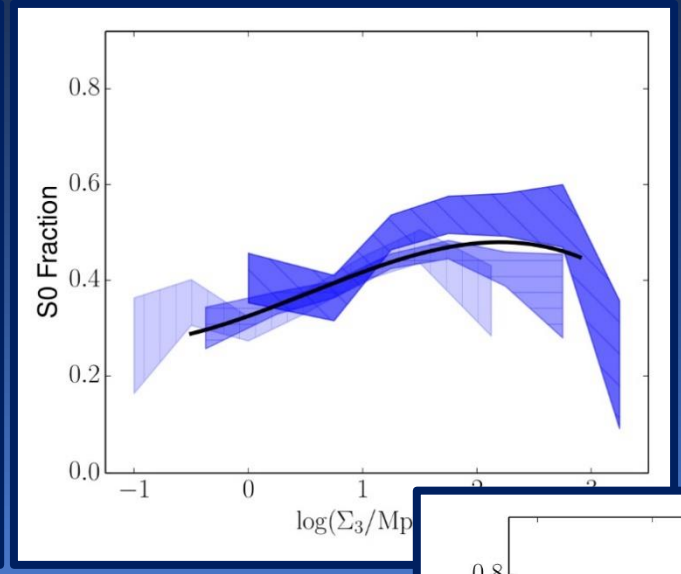
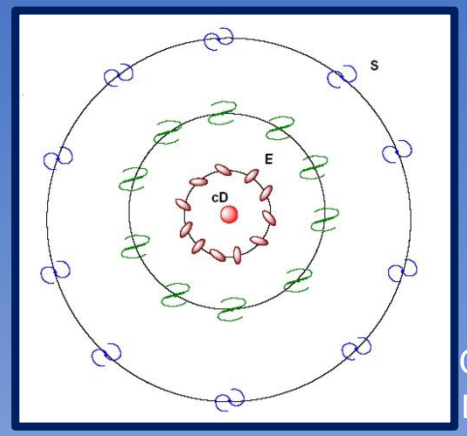
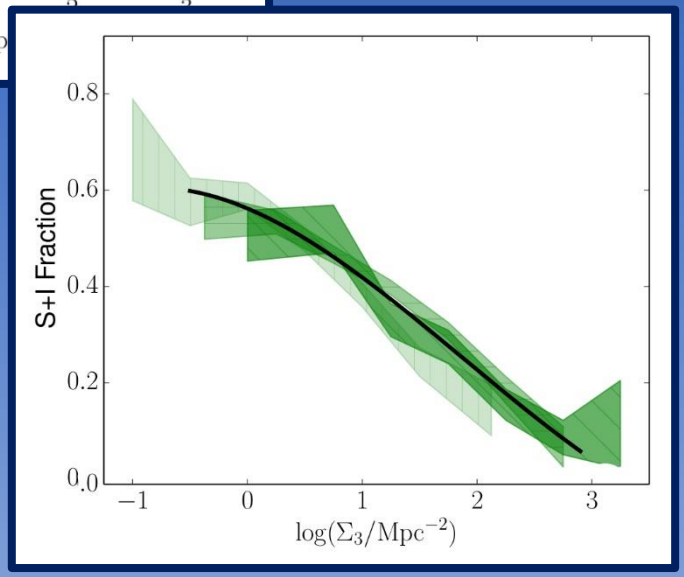



Capozziello & Lattanzi 2005



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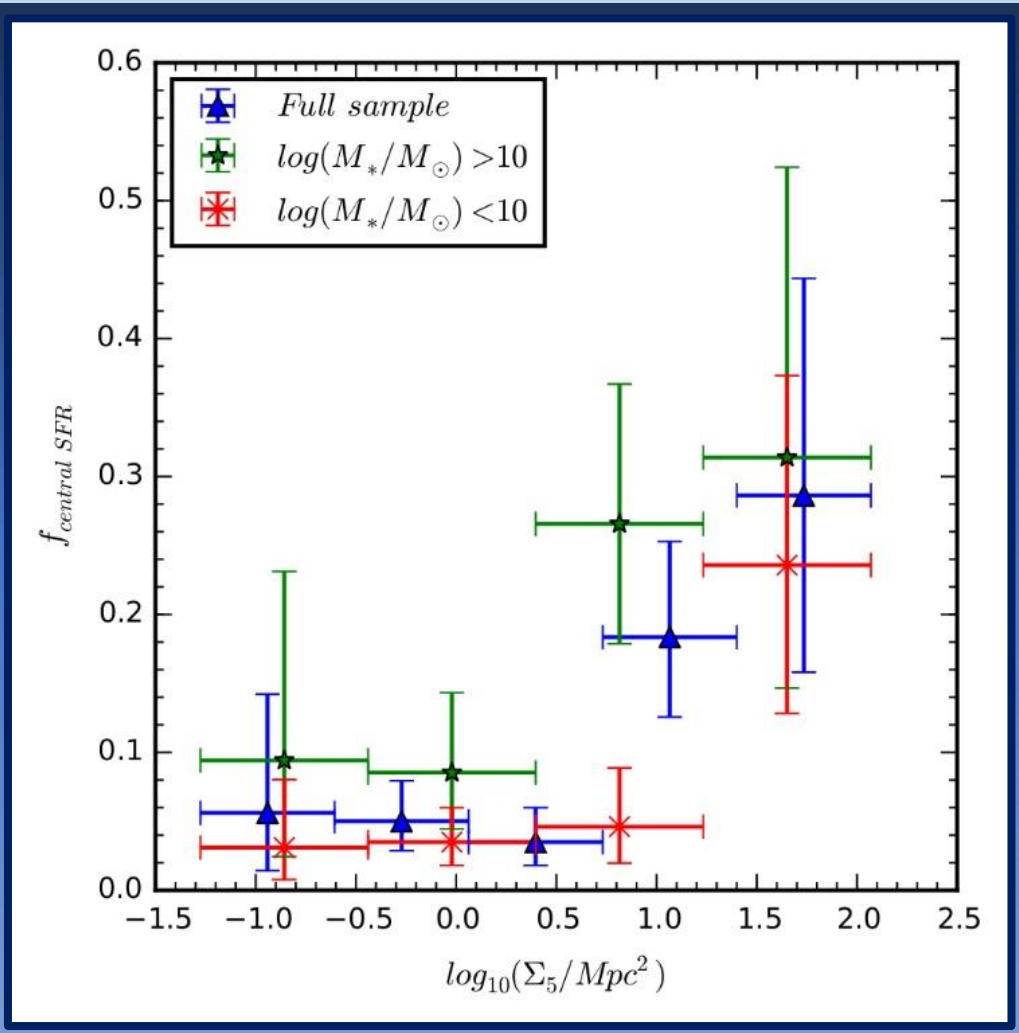
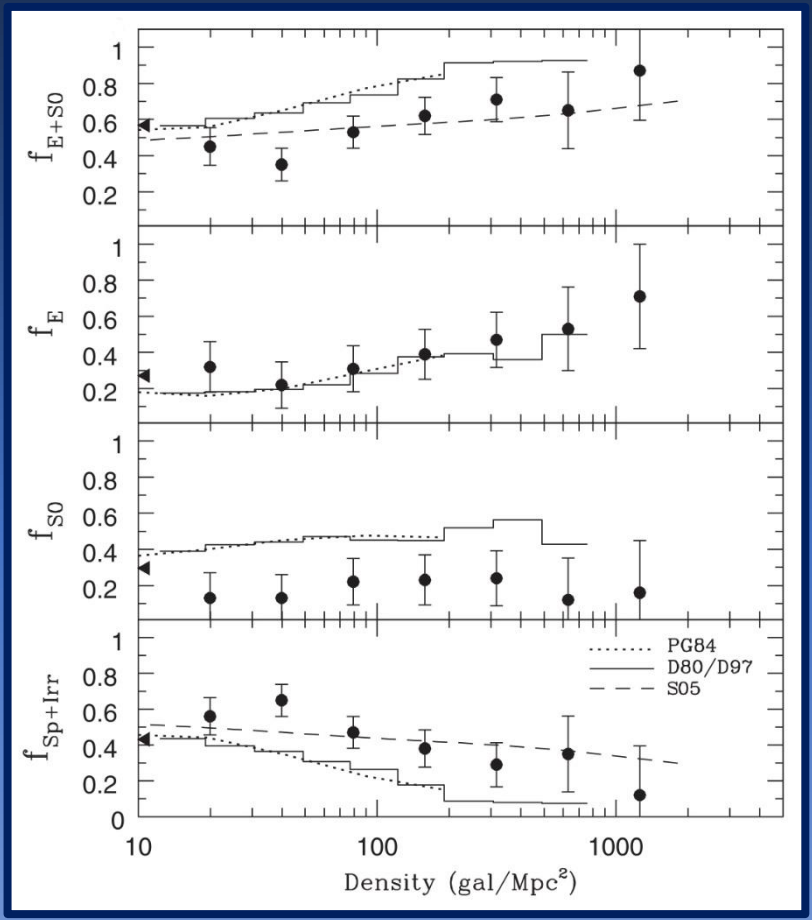
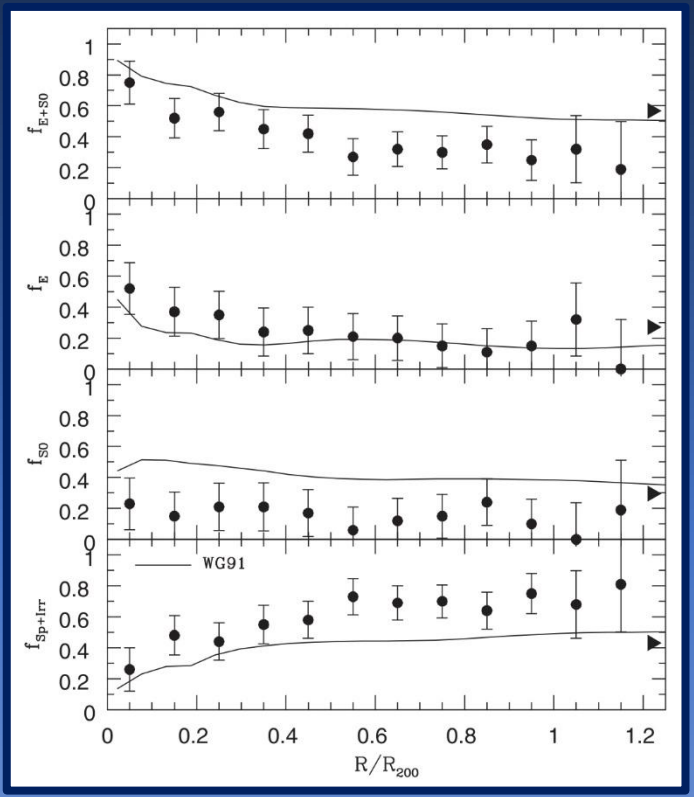


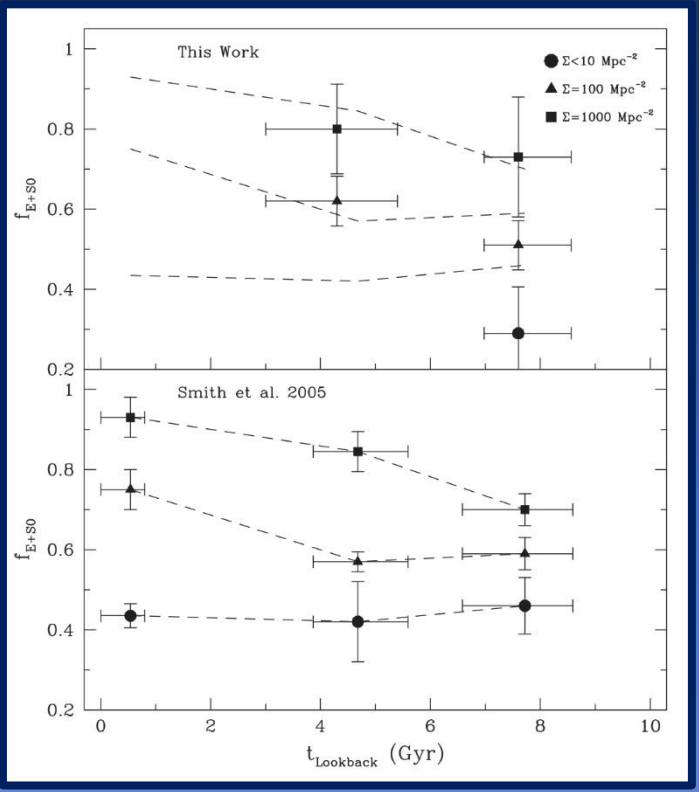

Schaefer+ 2016

# Morphology Density Relation with Redshift

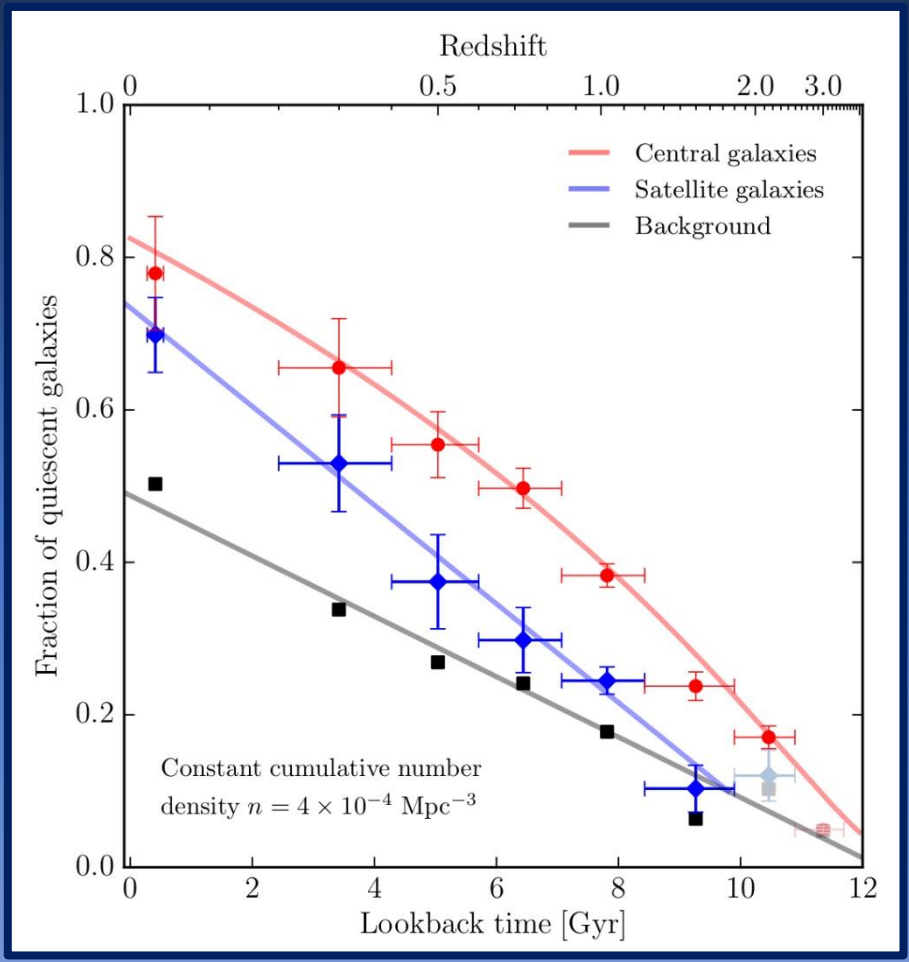



Postman+ 2005



# Mass vs Environment Quenching




Tal+ 2014

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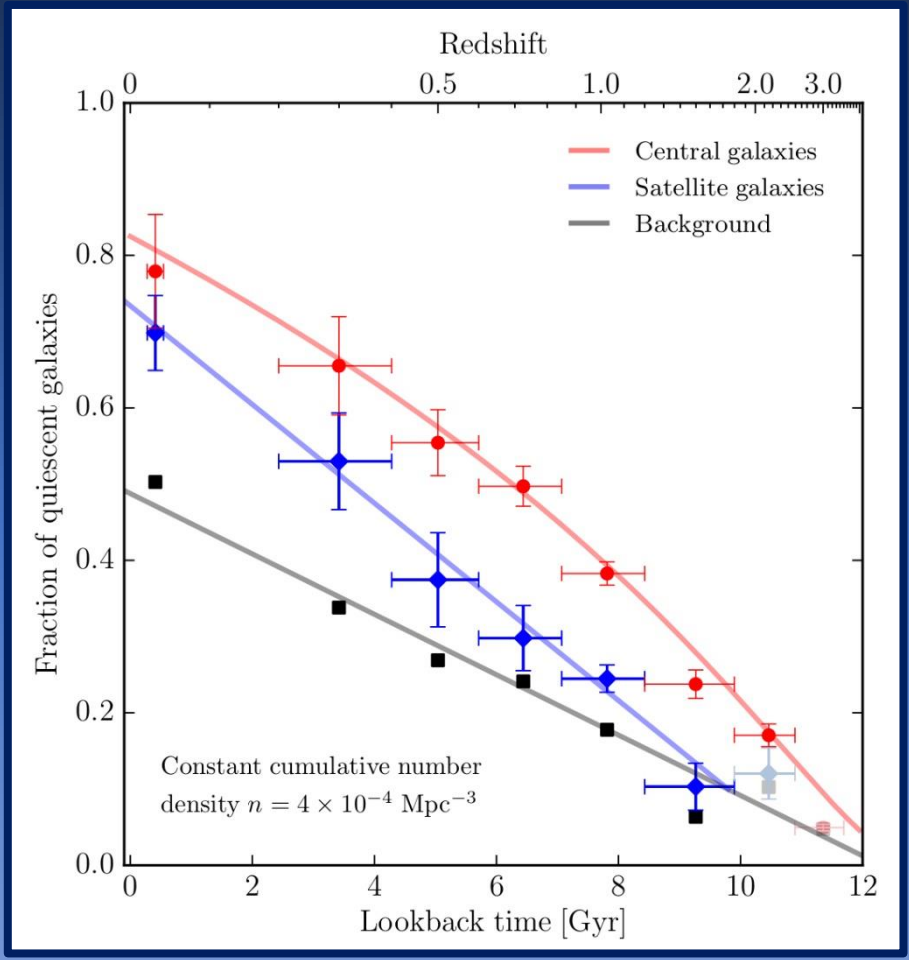
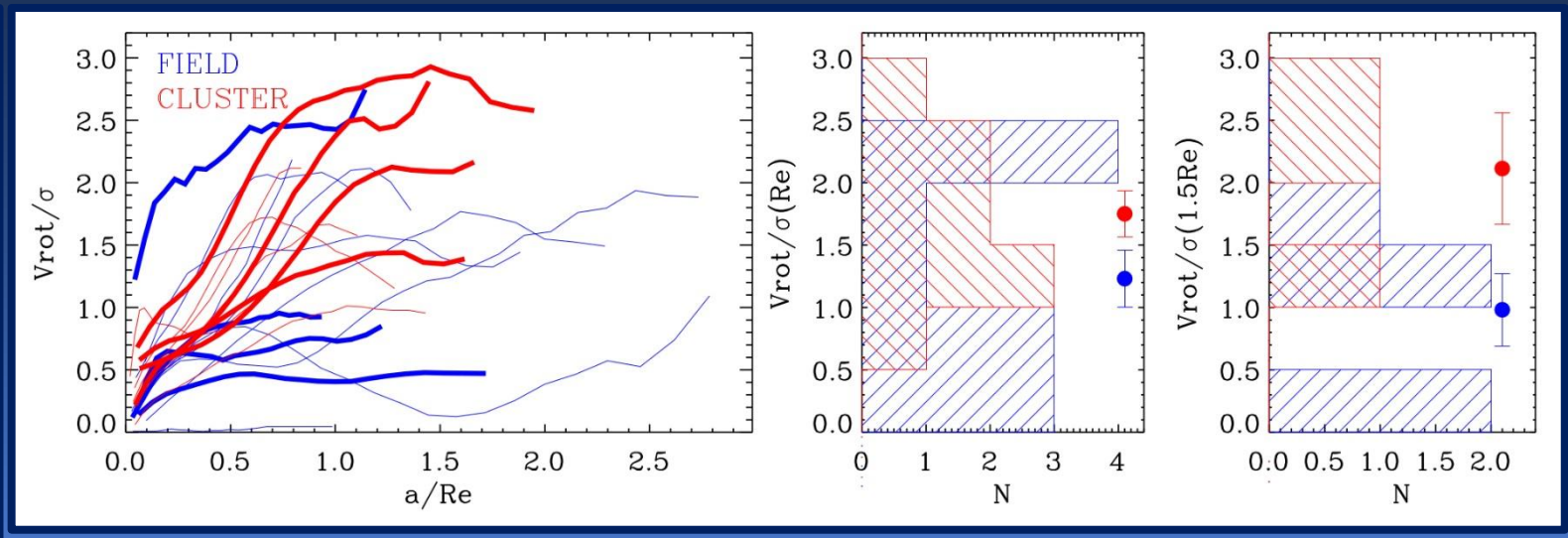
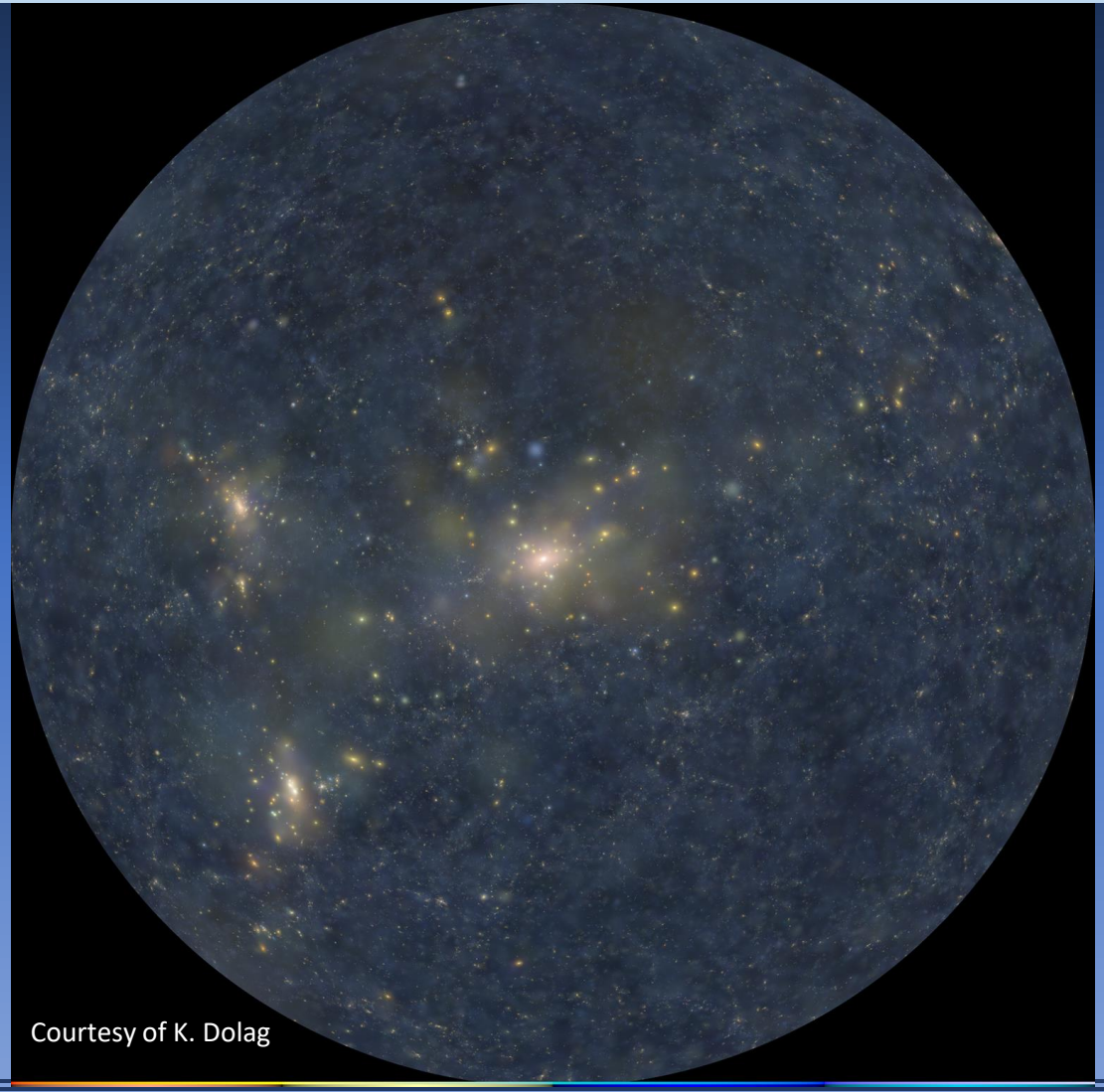



Tal+ 2014




Coccato+ 2019

# The Simulations: Magneticum


Courtesy of K. Dolag

## www.magneticum.org

| Box | Mpc/h | mr | hr | uhr |
|---|---|---|---|---|
| 0 | 2688 | y | | |
| 1 | 896 | y | | |
| 2b | 640 | y | y | |
| 3 | 128 | y | y | (z=2) |
| 4 | 48 | y | y | y |

| | mr | hr | uhr |
|---|---|---|---|
| $m_{DM}\ (M_\odot/h)$ | $1.3 \cdot 10^{10}$ | $6.9 \cdot 10^{8}$ | $3.7 \cdot 10^{7}$ |
| $m_{Gas}\ (M_\odot/h)$ | $2.6 \cdot 10^{9}$ | $1.4 \cdot 10^{7}$ | $7.3 \cdot 10^{6}$ |

One gas particle can spawn up to 4 stellar particles.

- Modified SPH version of GADGET-3 (incl. thermal conduction)
- Feedback from stellar winds
- Feedback from AGN
- Metal enrichment and star formation follow pattern of metal production from SNIa, SNII & AGB
- Gas cooling depends on local metallicity

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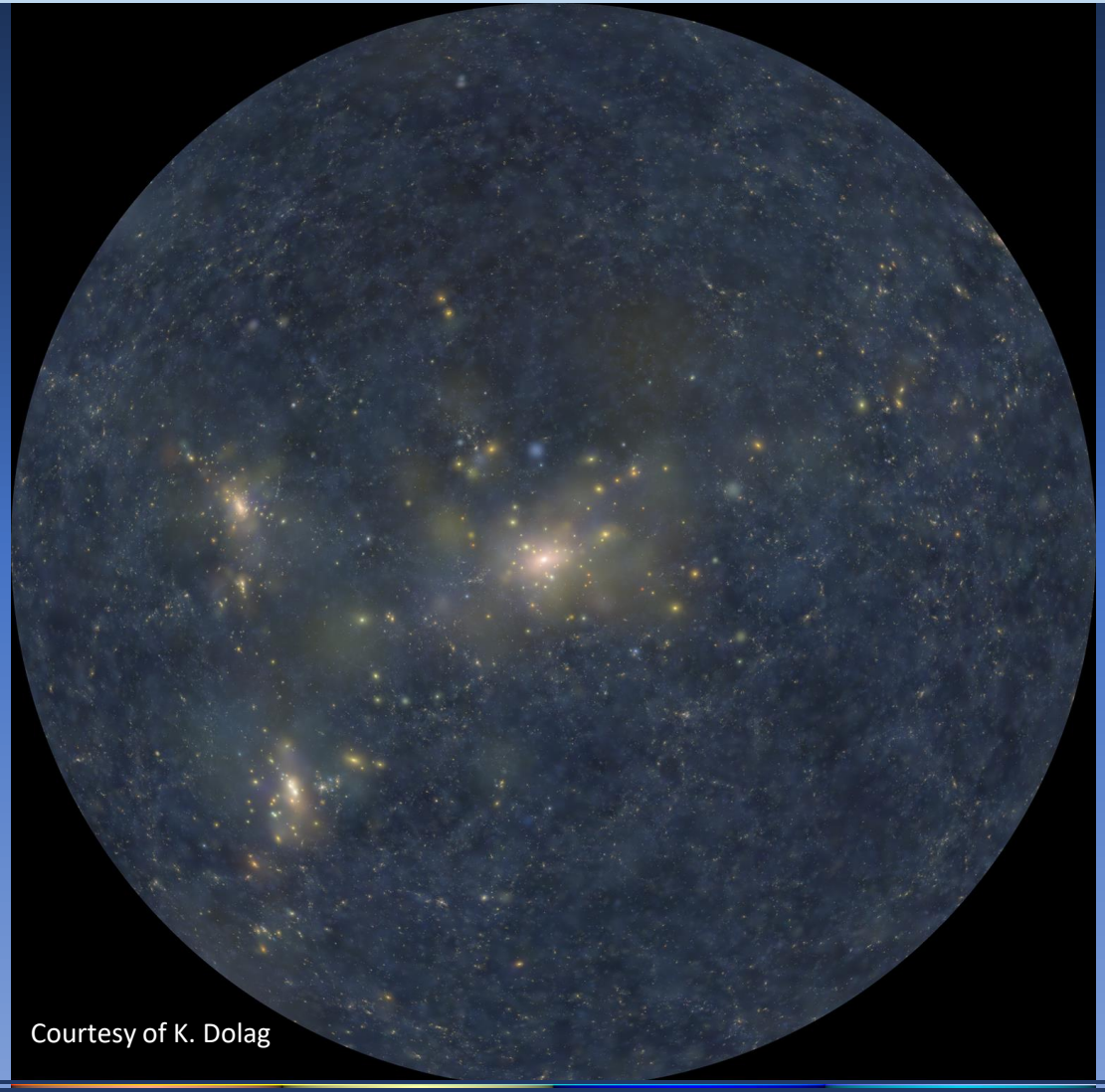
Courtesy of K. Dolag

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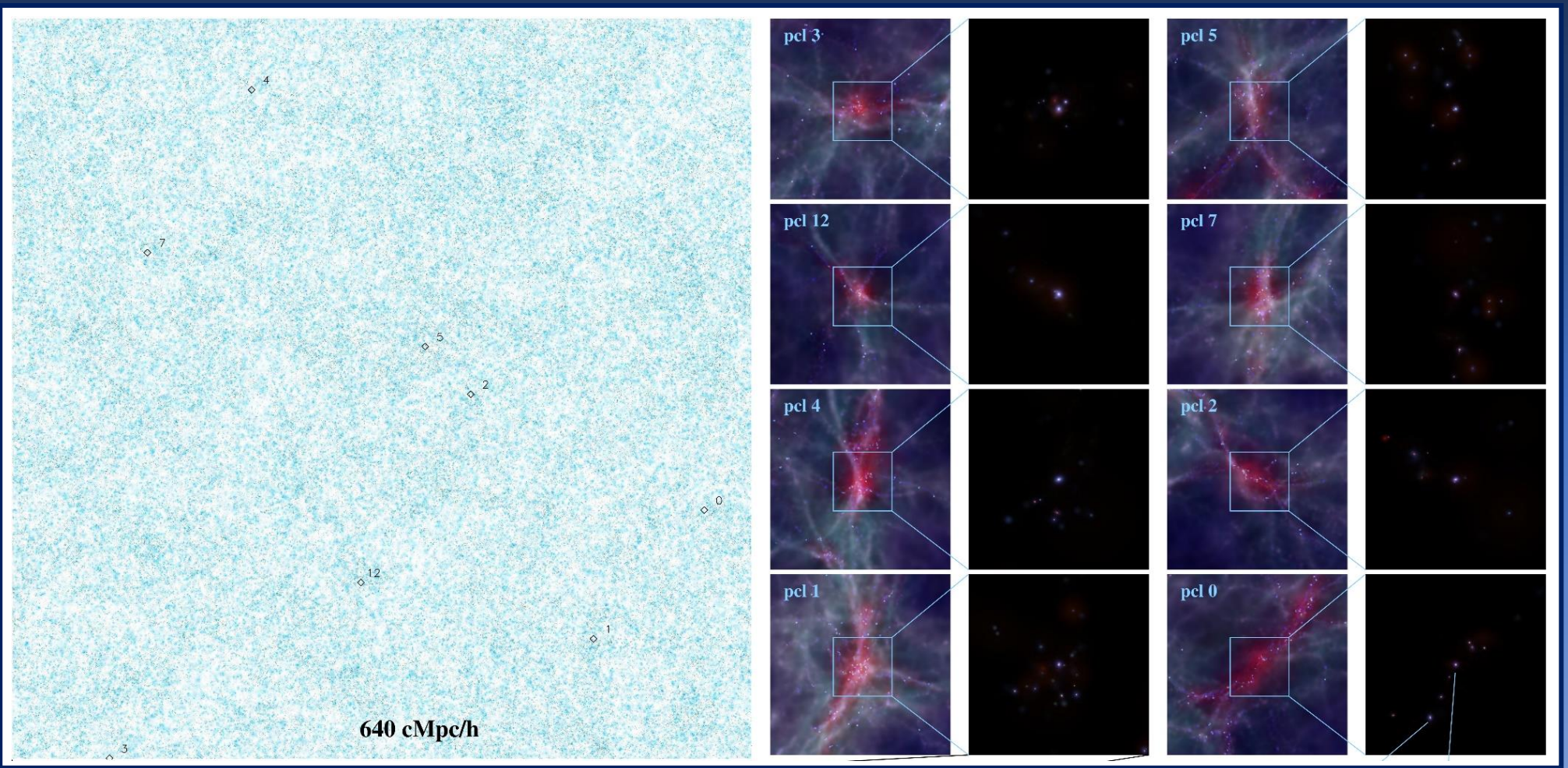
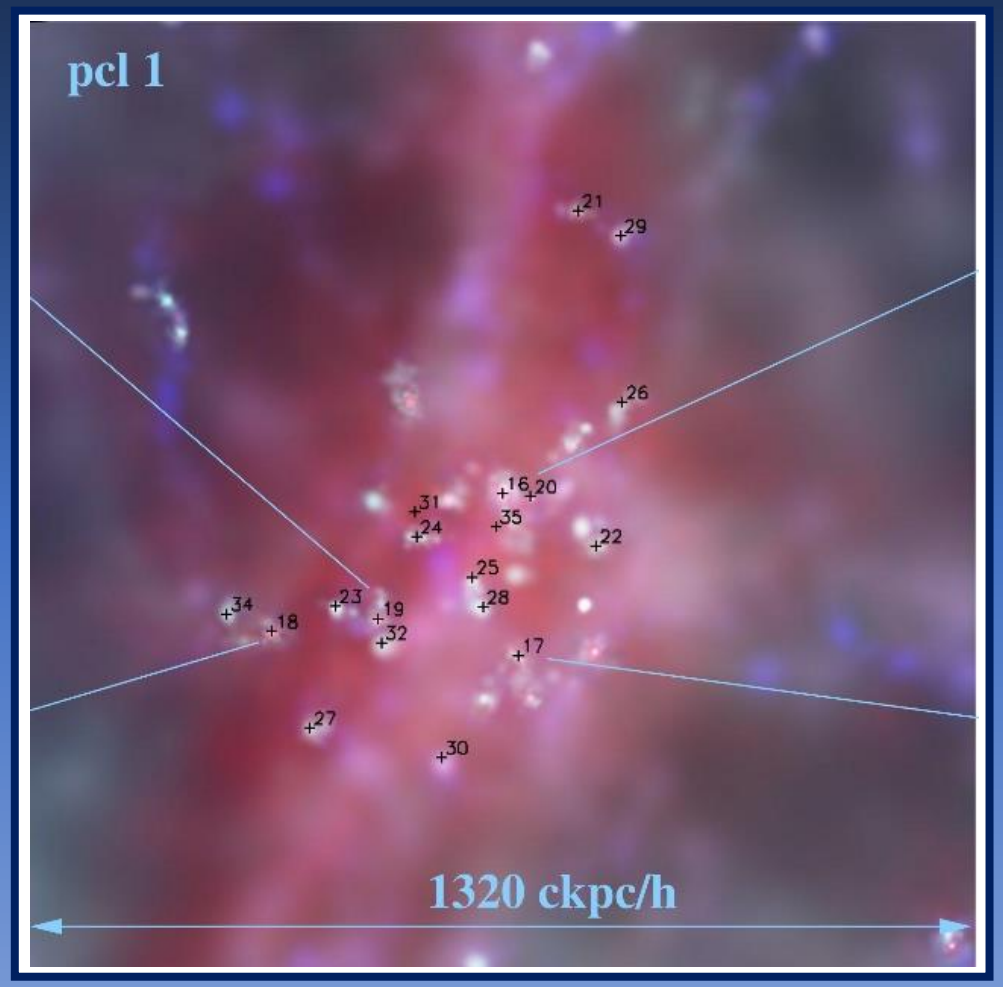
# Protocluster in Magneticum



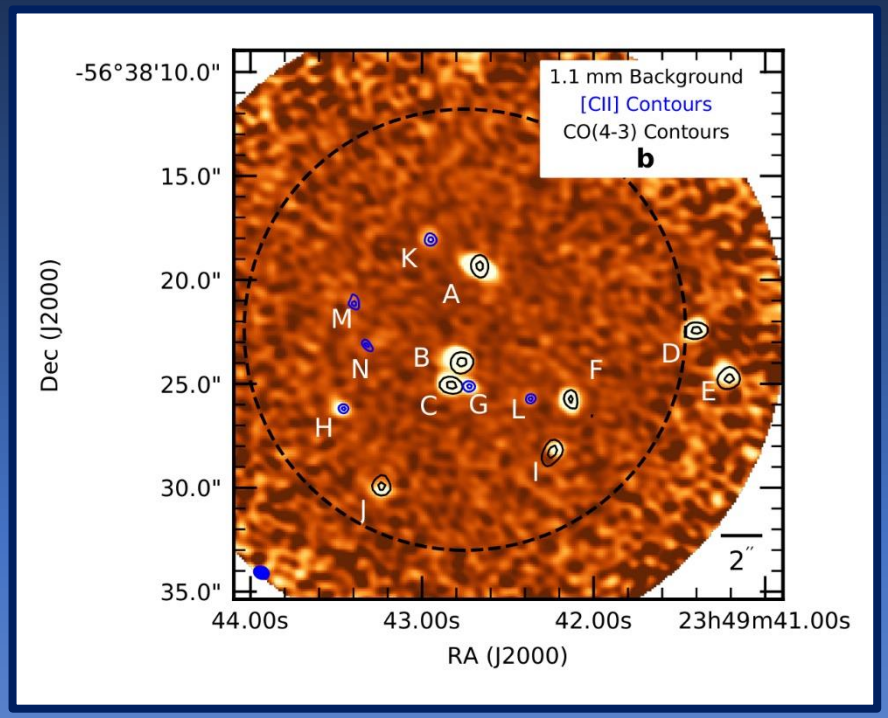

42 potential Protocluster with $M_{vir} > 10^{13} M_{\odot}$

Remus+ to be submitted

# Protocluster in Magneticum




Remus+ to be submitted




Miller et al., 2018

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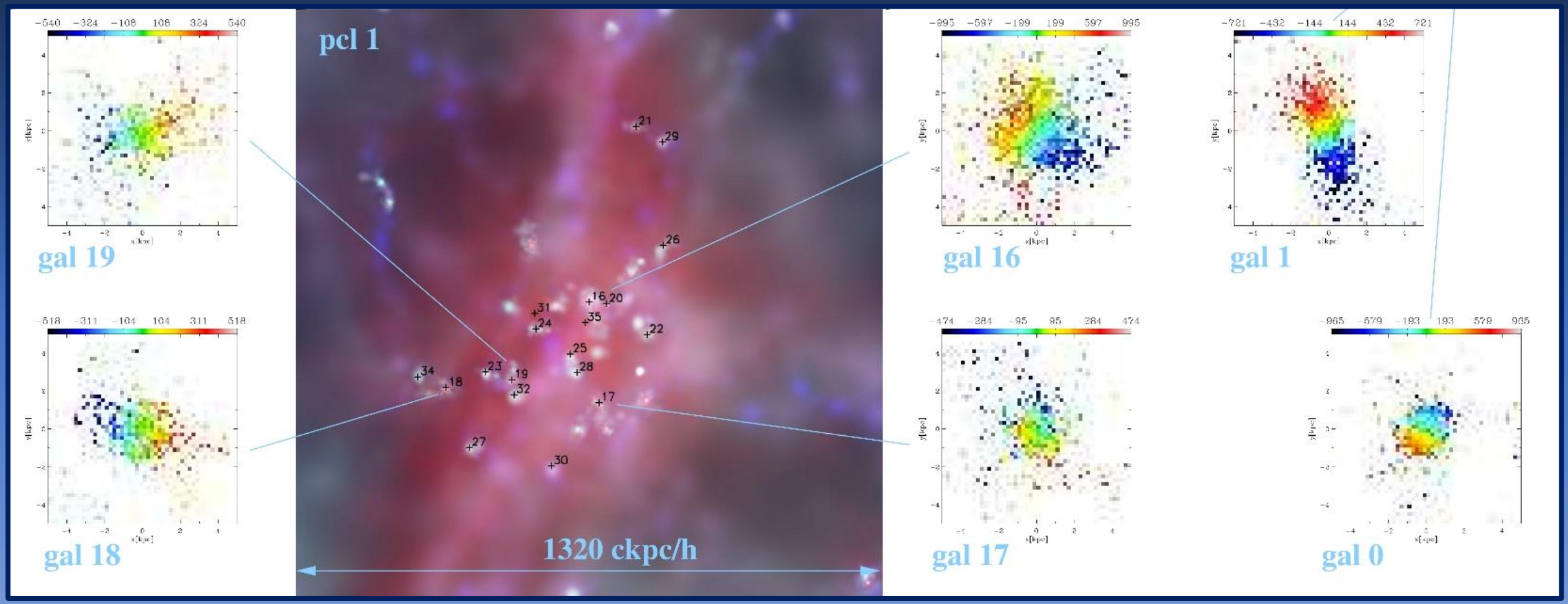


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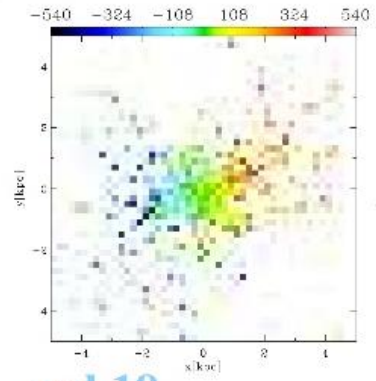
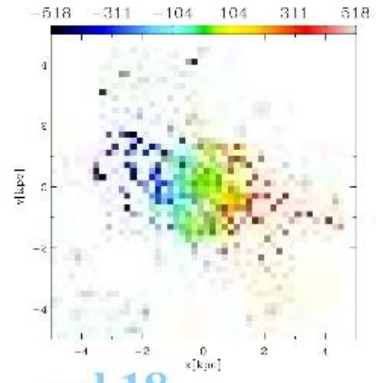
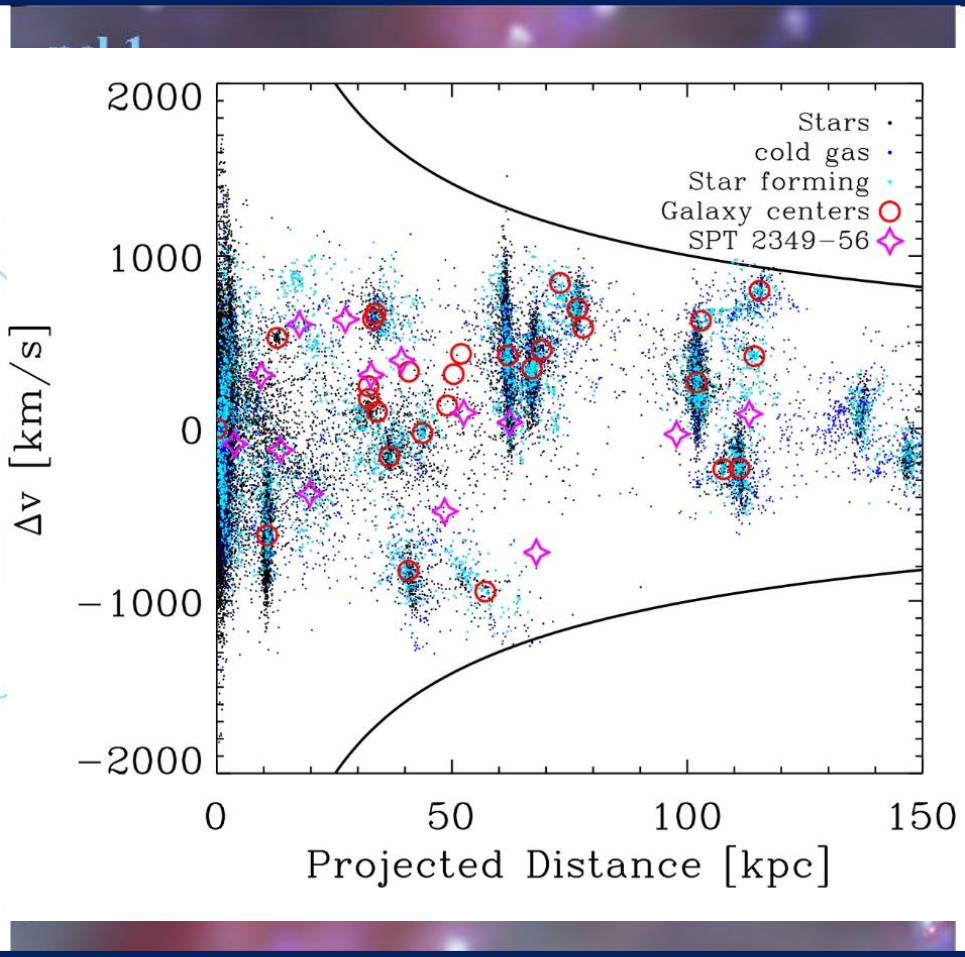
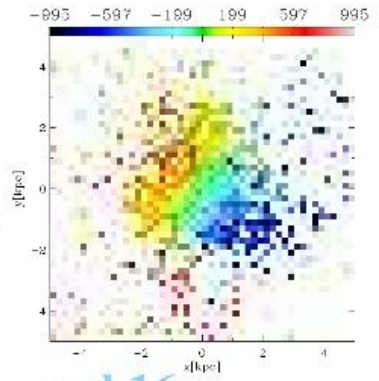
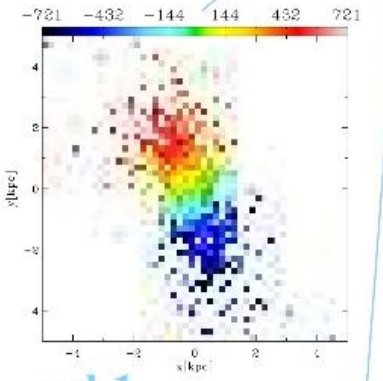
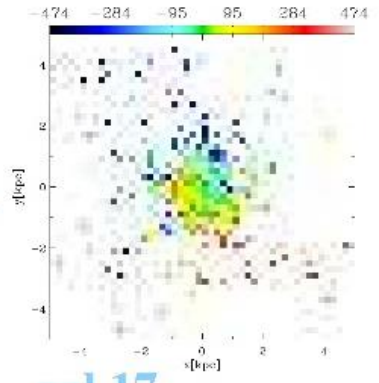


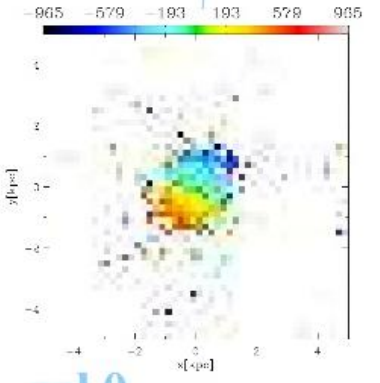



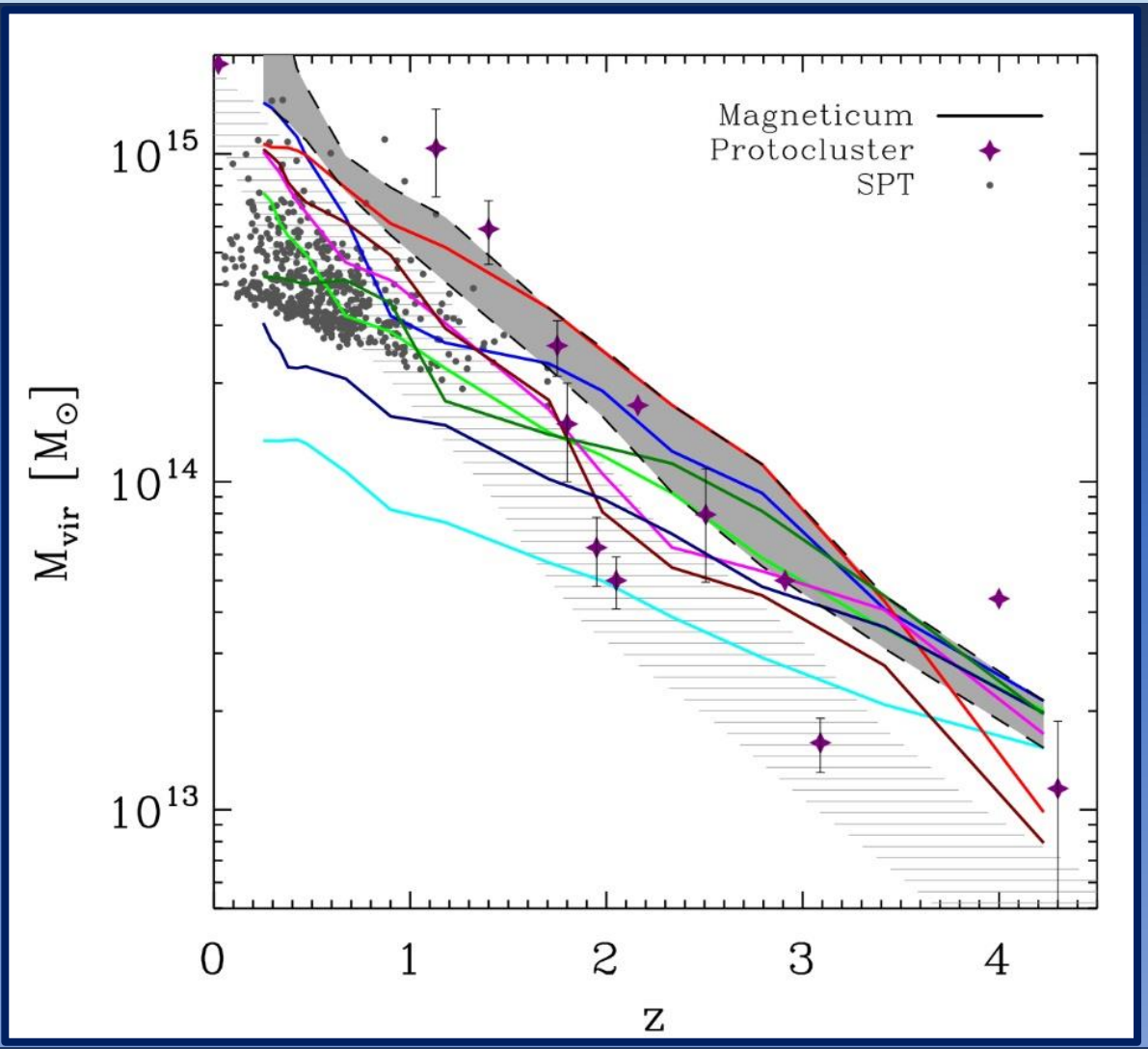




Remus+ to be submitted

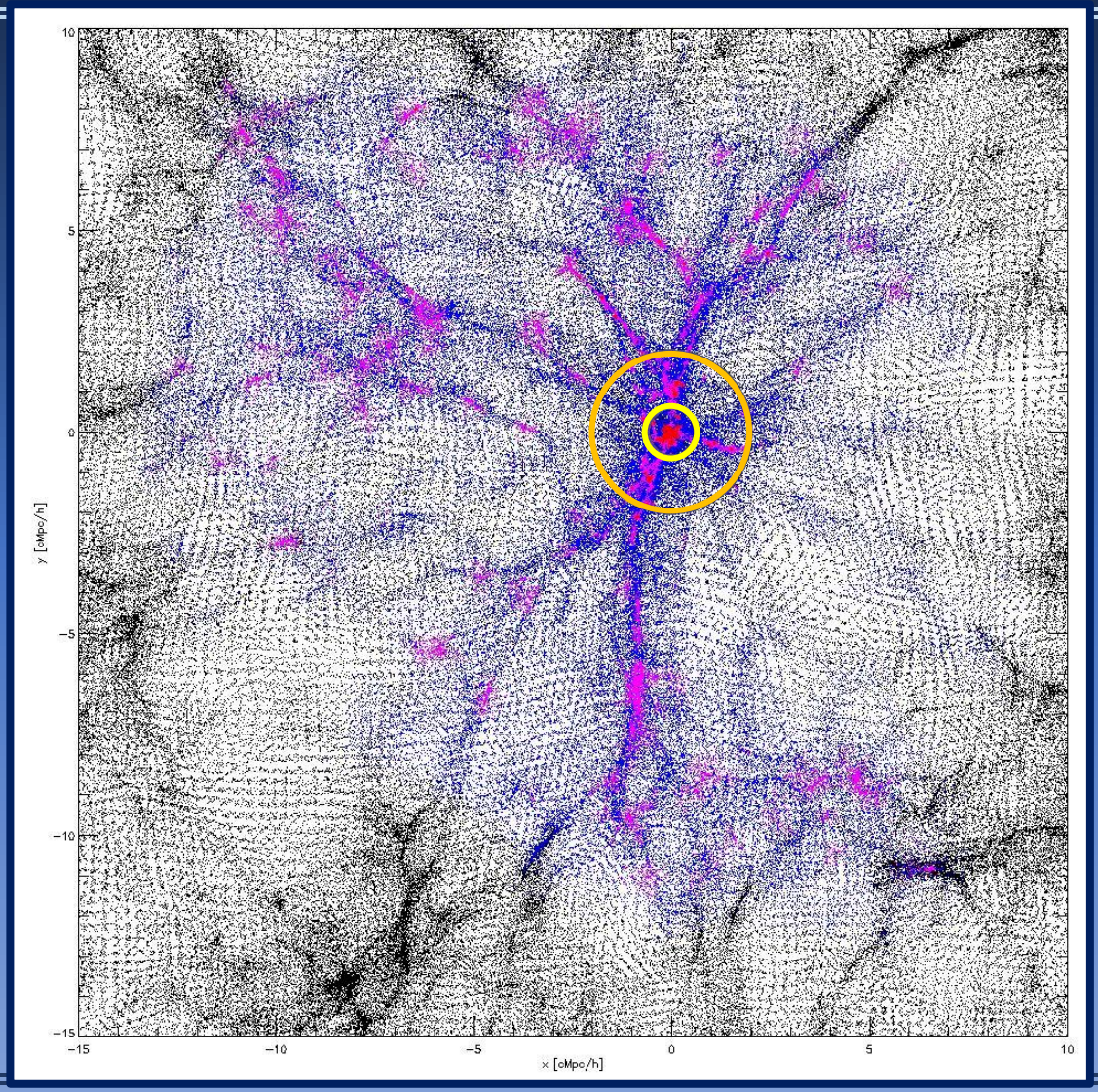
# Protocluster in Magneticum: Evolution




Colored lines: Magneticum Protoclusters
Shade: Magneticum Most Massive at each redshift
Striped: Millenium prediction, Chiang et al., 2013

Remus+ to be submitted

# Protocluster in Magneticum: Evolution

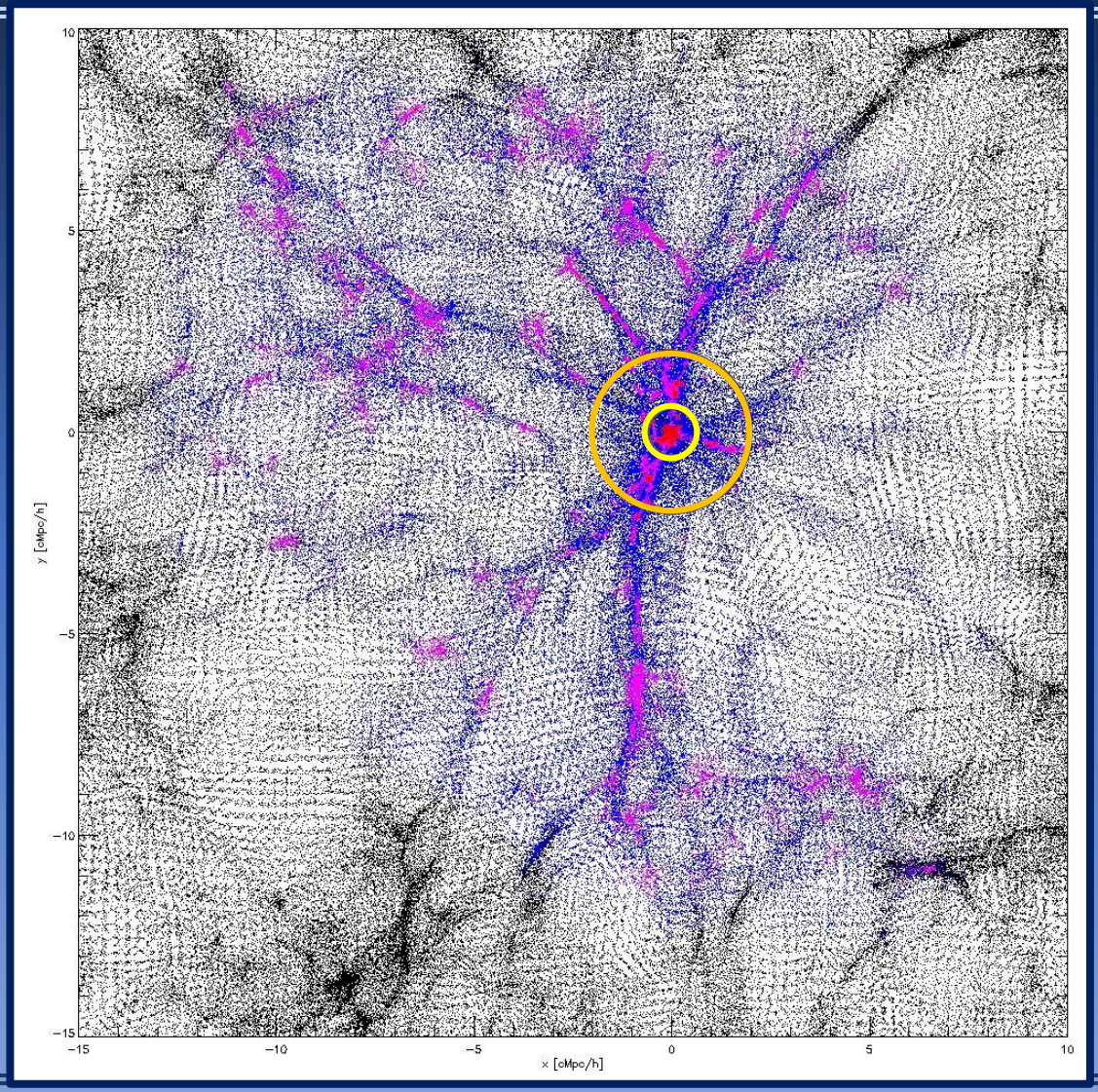


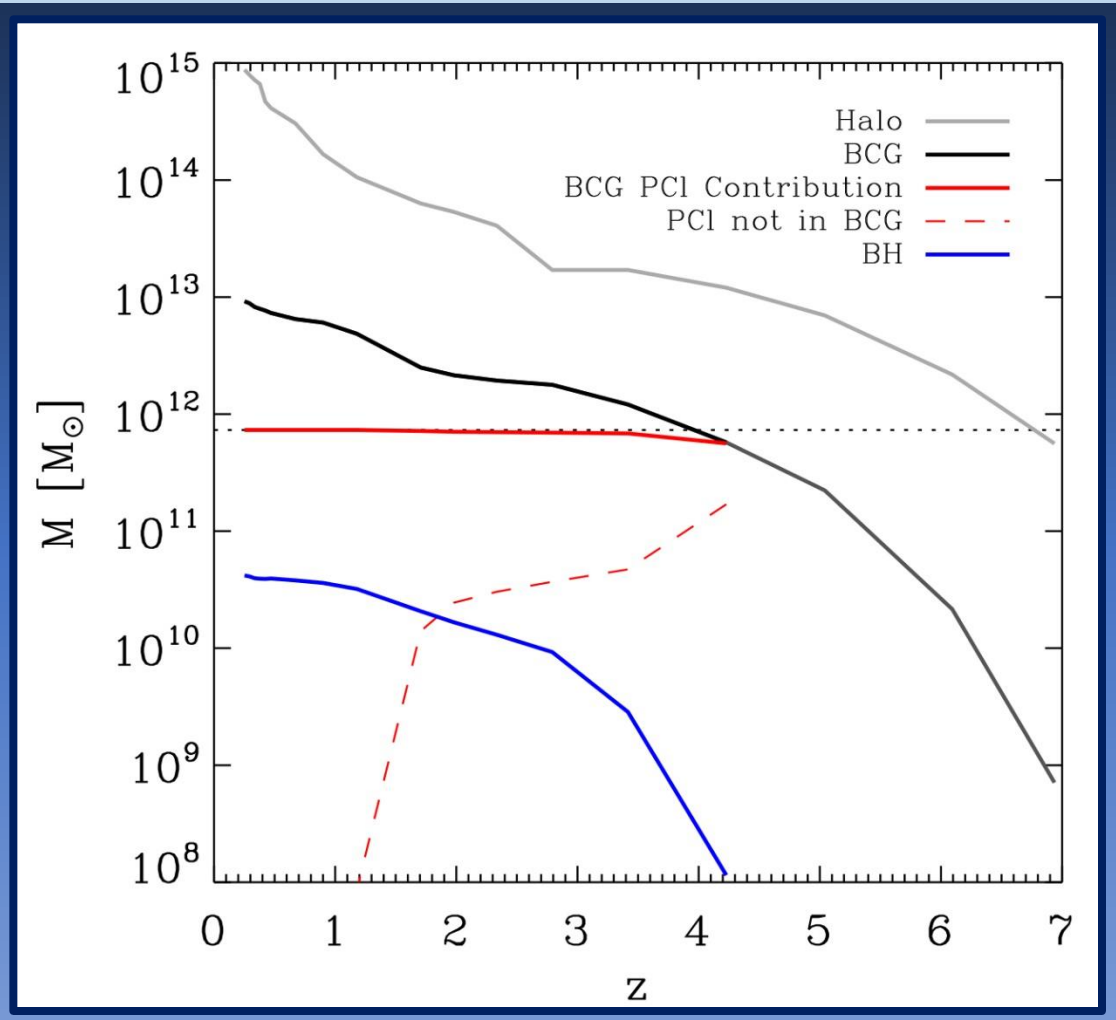

$R_{vir}$ @ z = 4.3

$R_{vir}$ @ z = 0

Remus+ to be submitted

# Protocluster in Magneticum: BCG Assembly

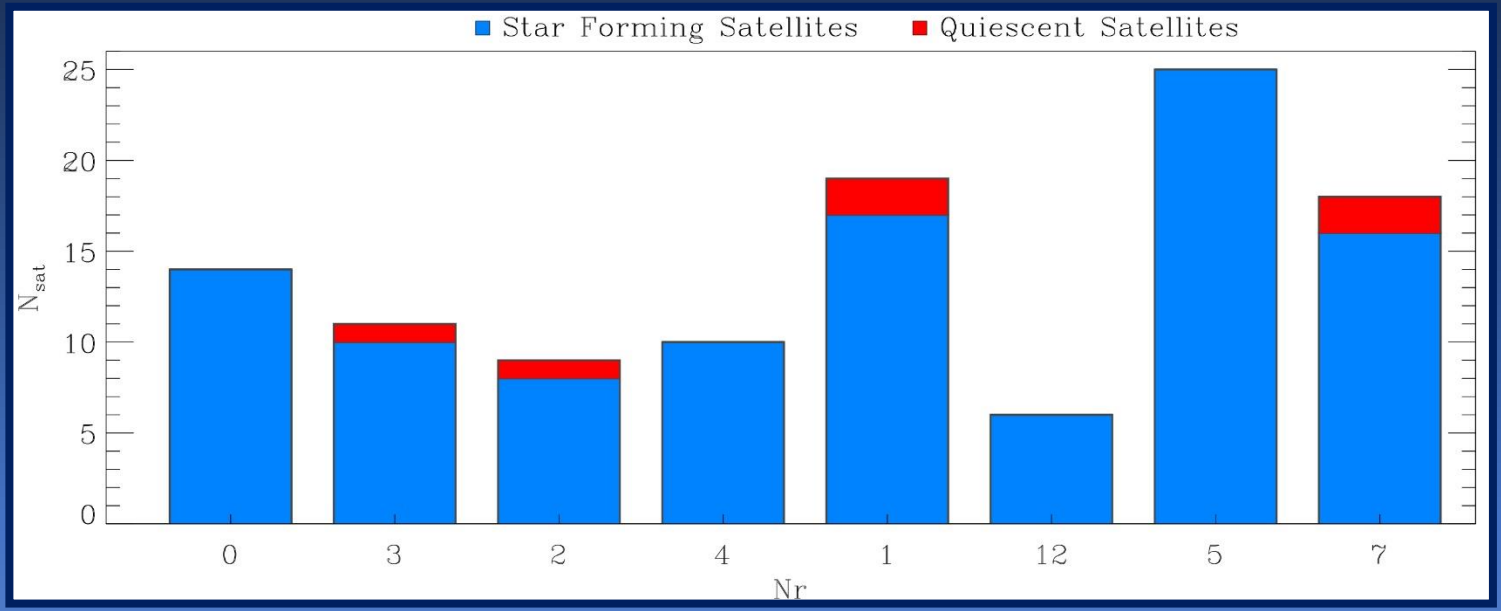



Remus+ to be submitted

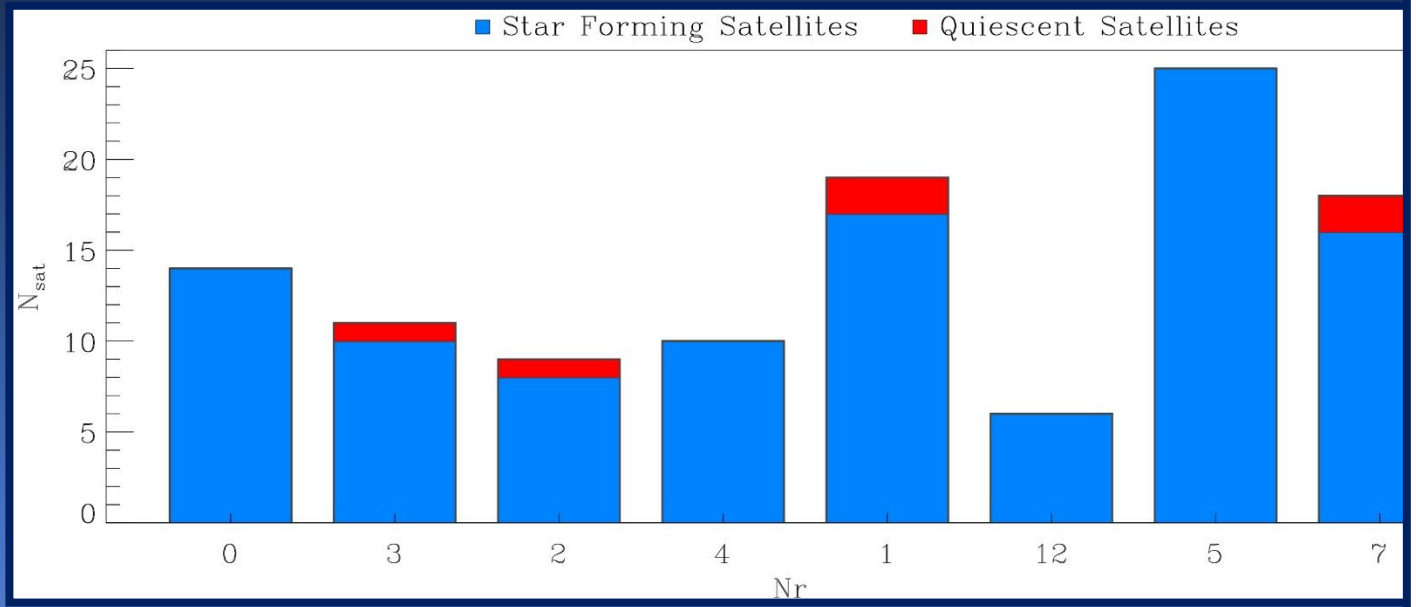
See also Rennehan+2019

# Protocluster in Magneticum: Quiescent fraction

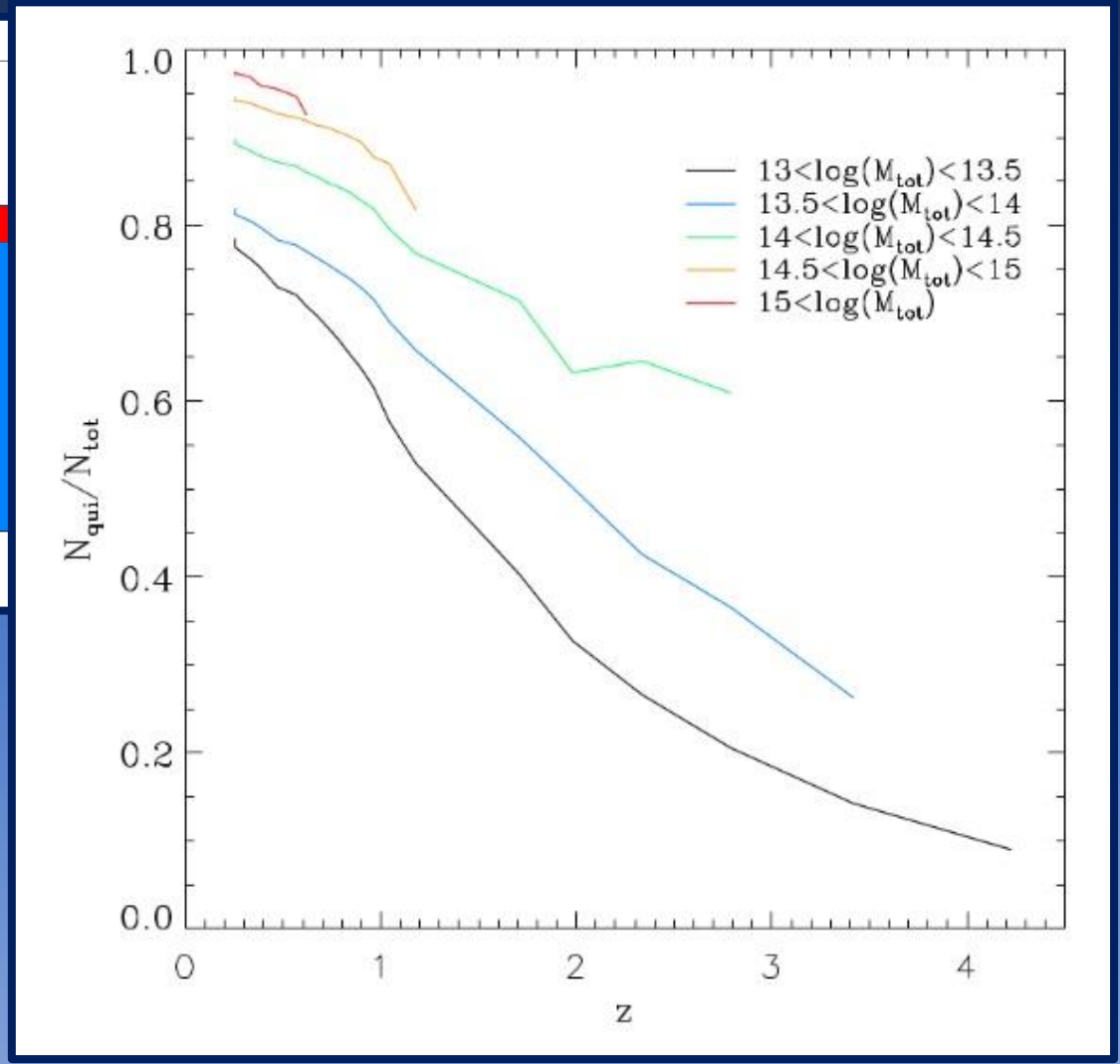



Remus+ to be submitted

# Quiescent fraction with redshift

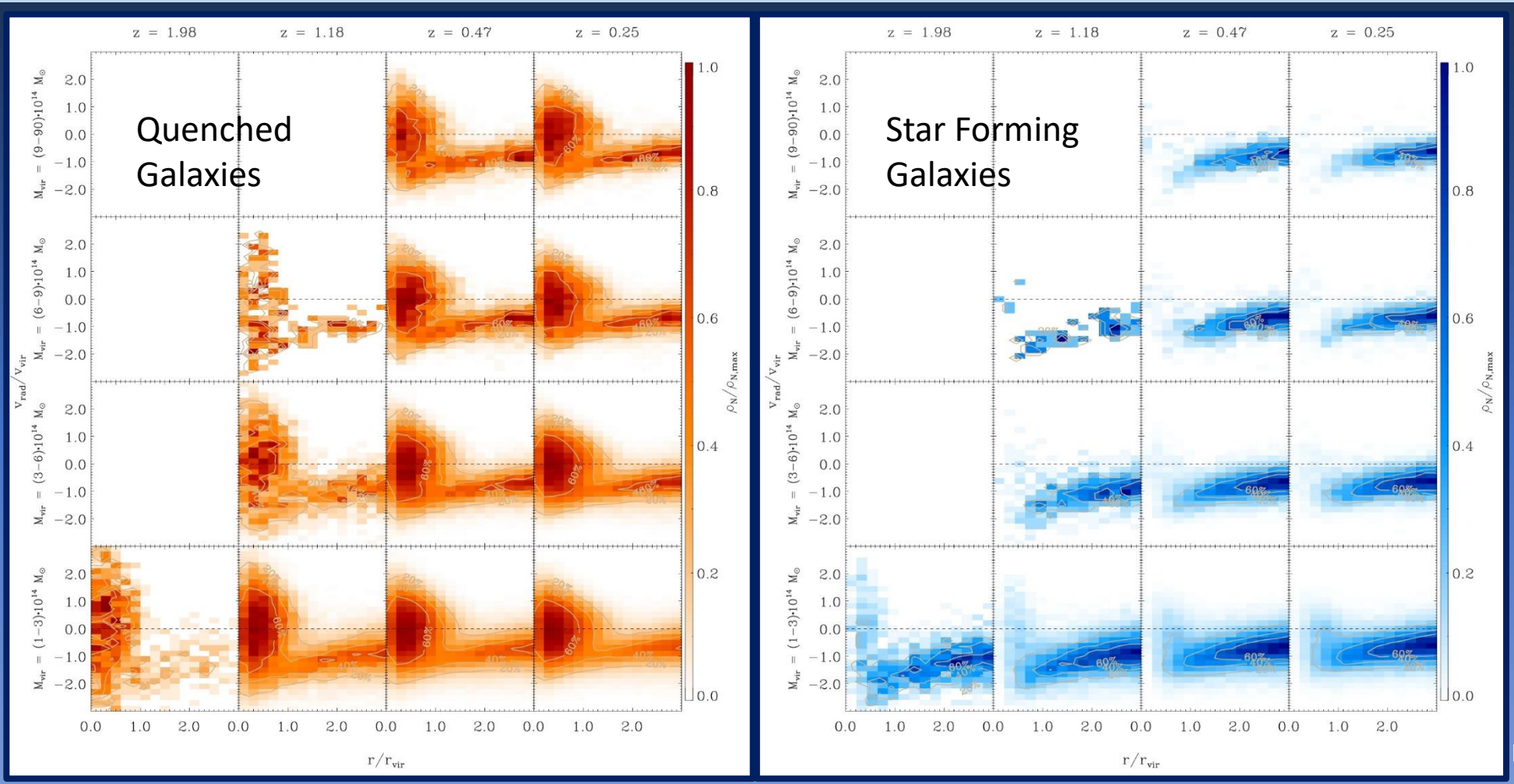



Remus+ to be submitted




See also Teklu et al., 2017 for more details on the build-up of the Morphology Density Relation

# Quenching in Clusters




Lotz+ 2019

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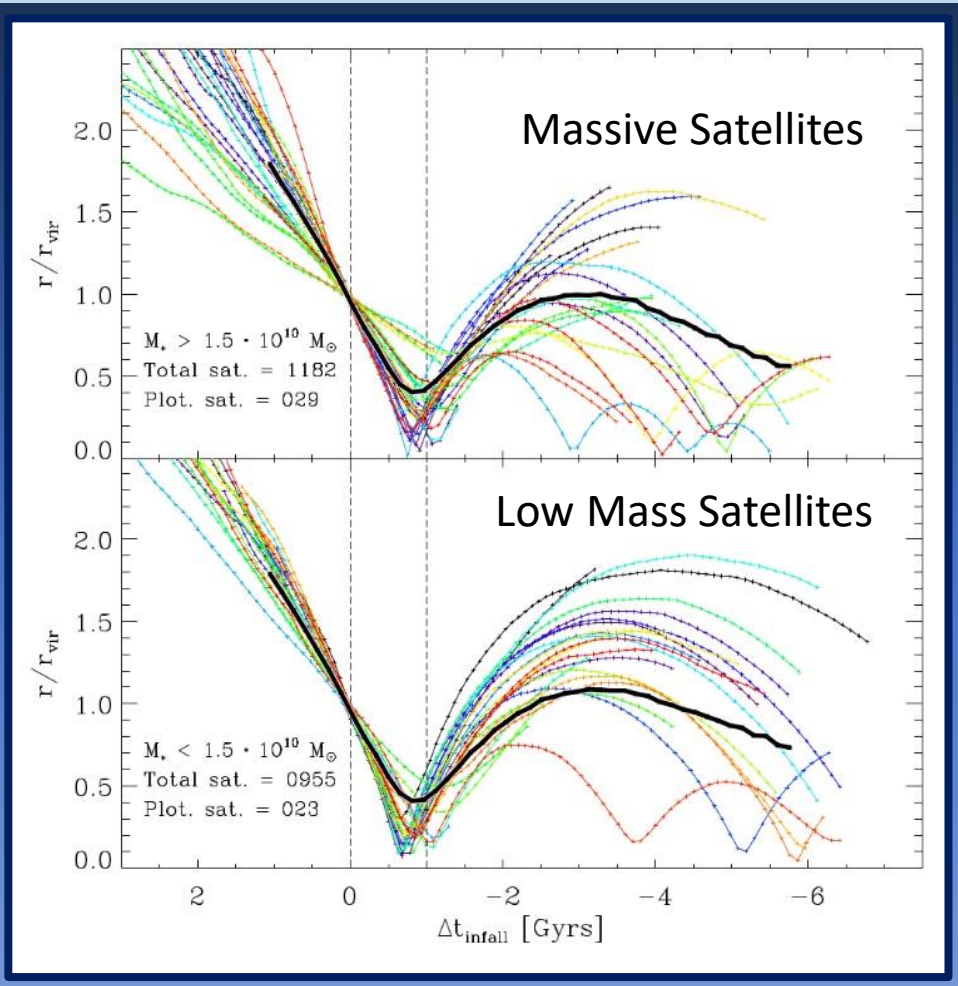


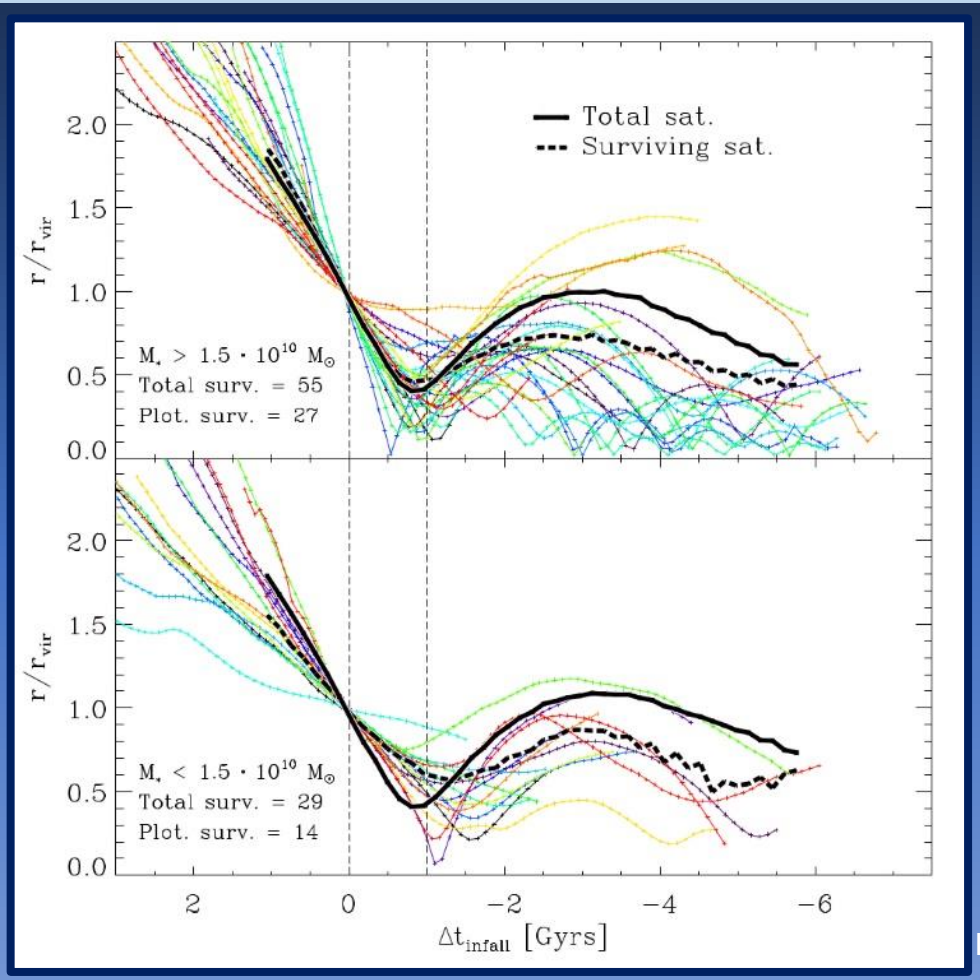


Lotz+ 2019

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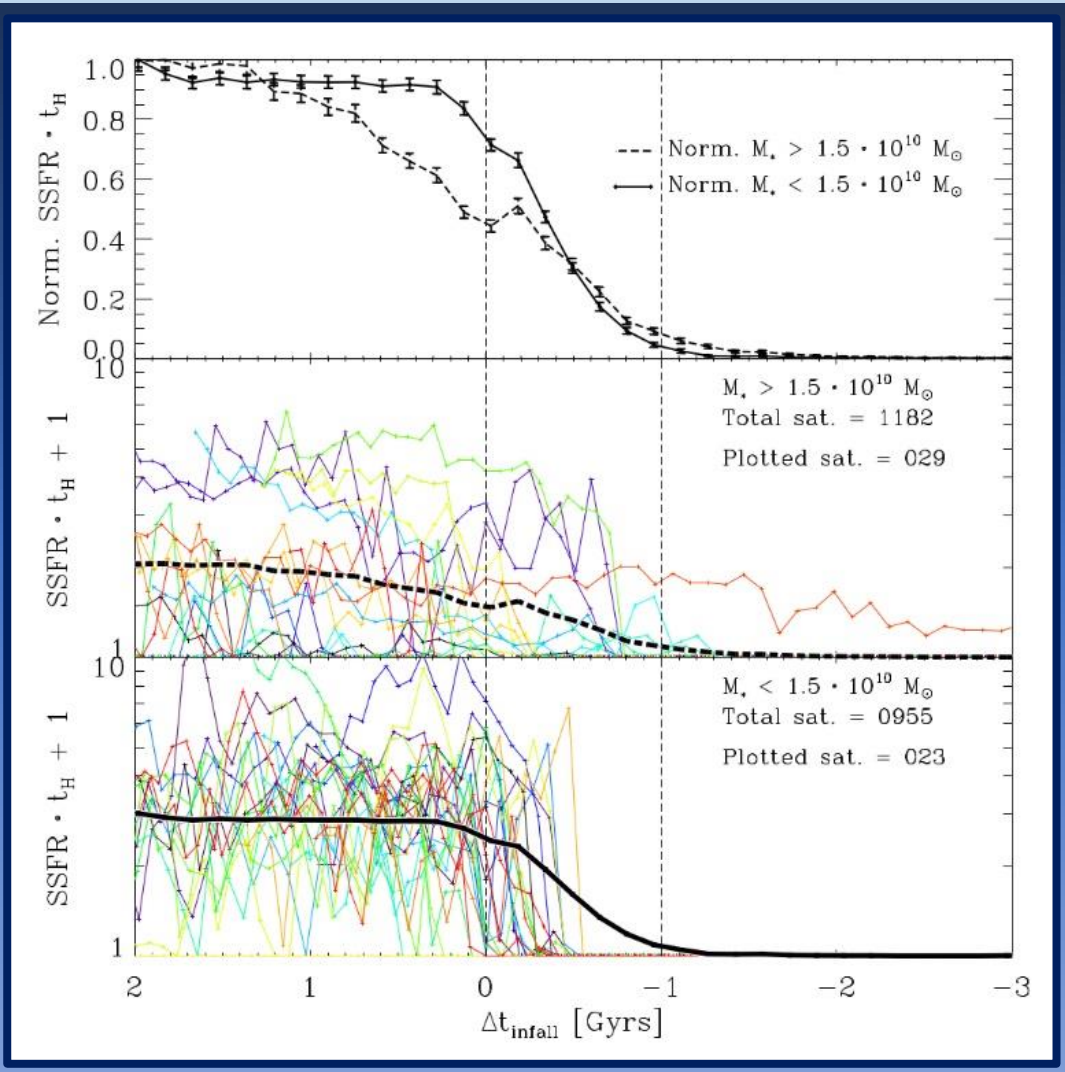
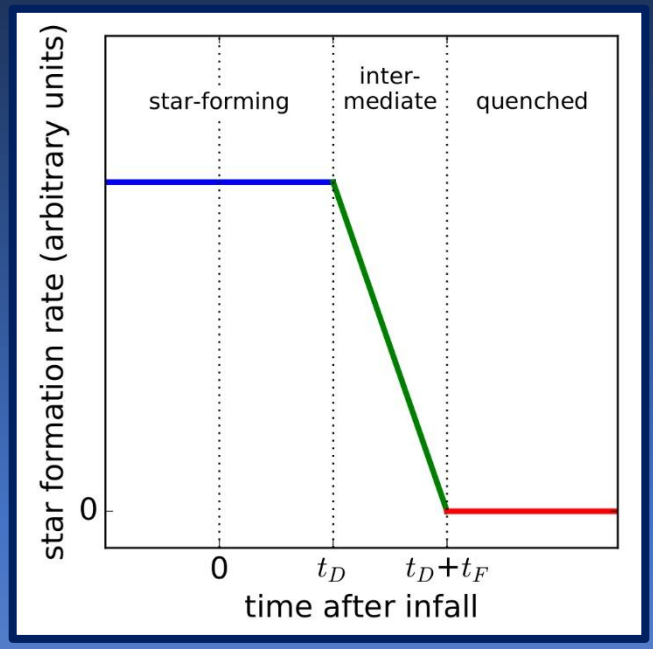



Lotz+ 2019




Foltz+ 2018

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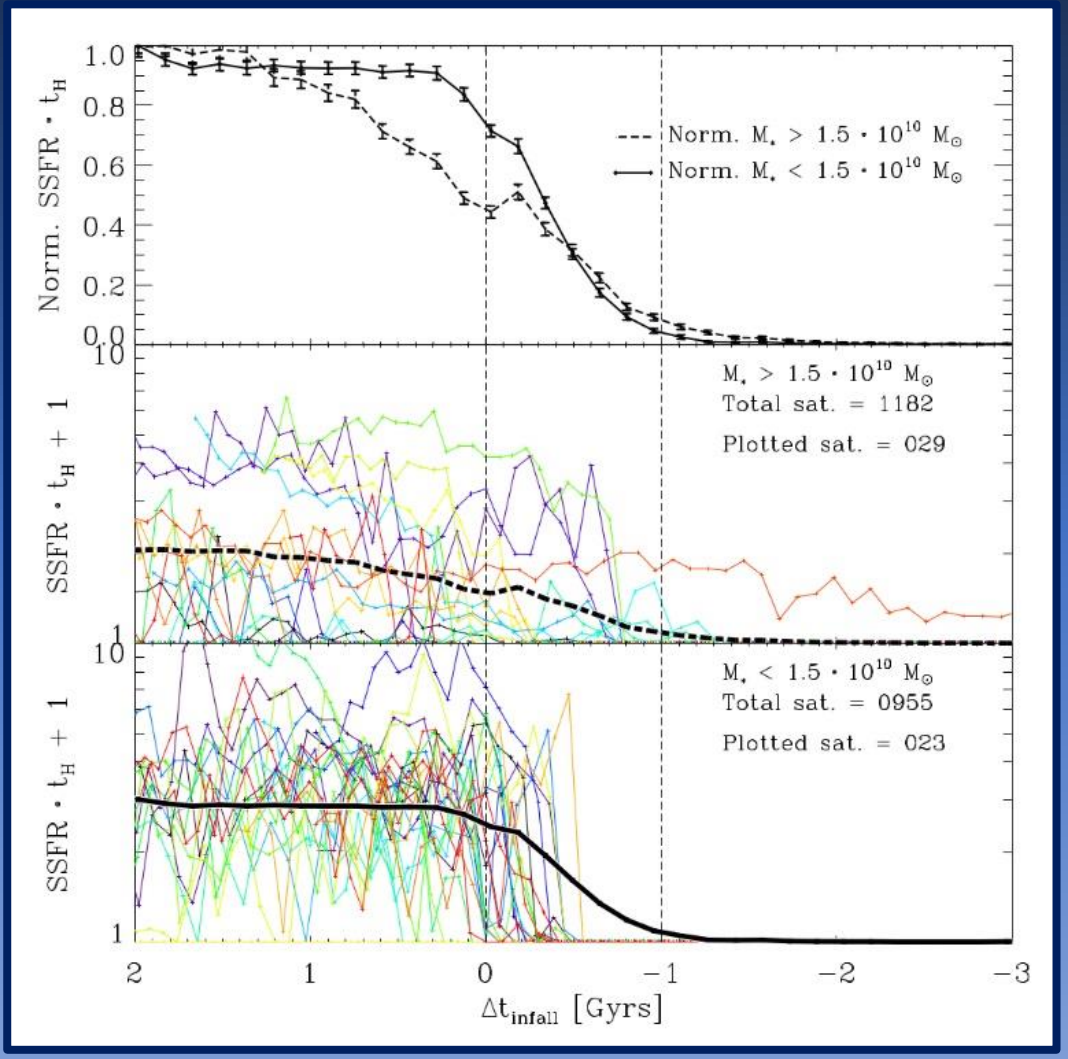


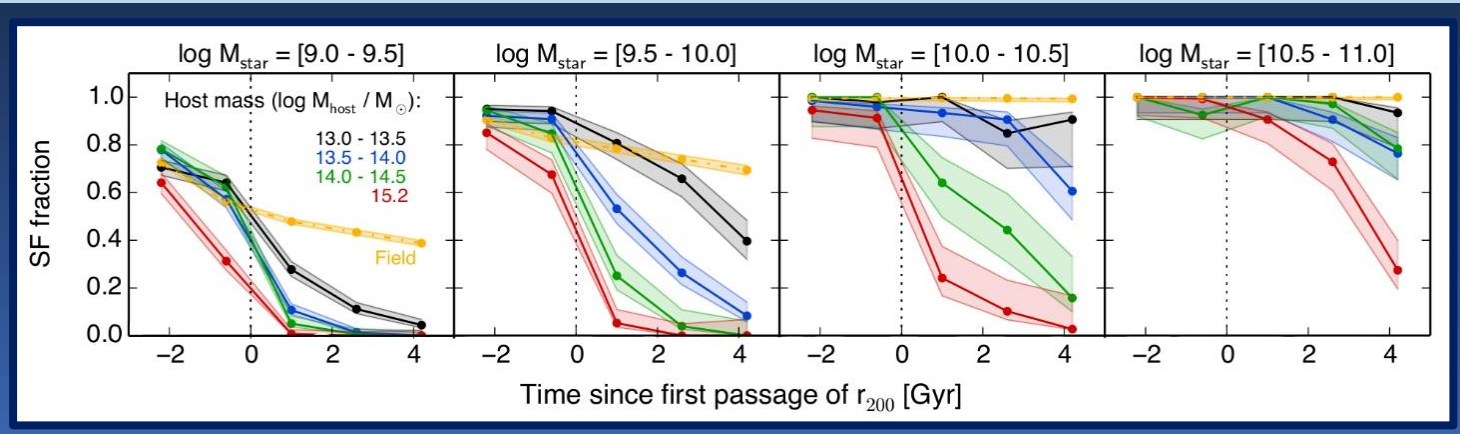


Bahe+ 2015

Lotz+ 2019

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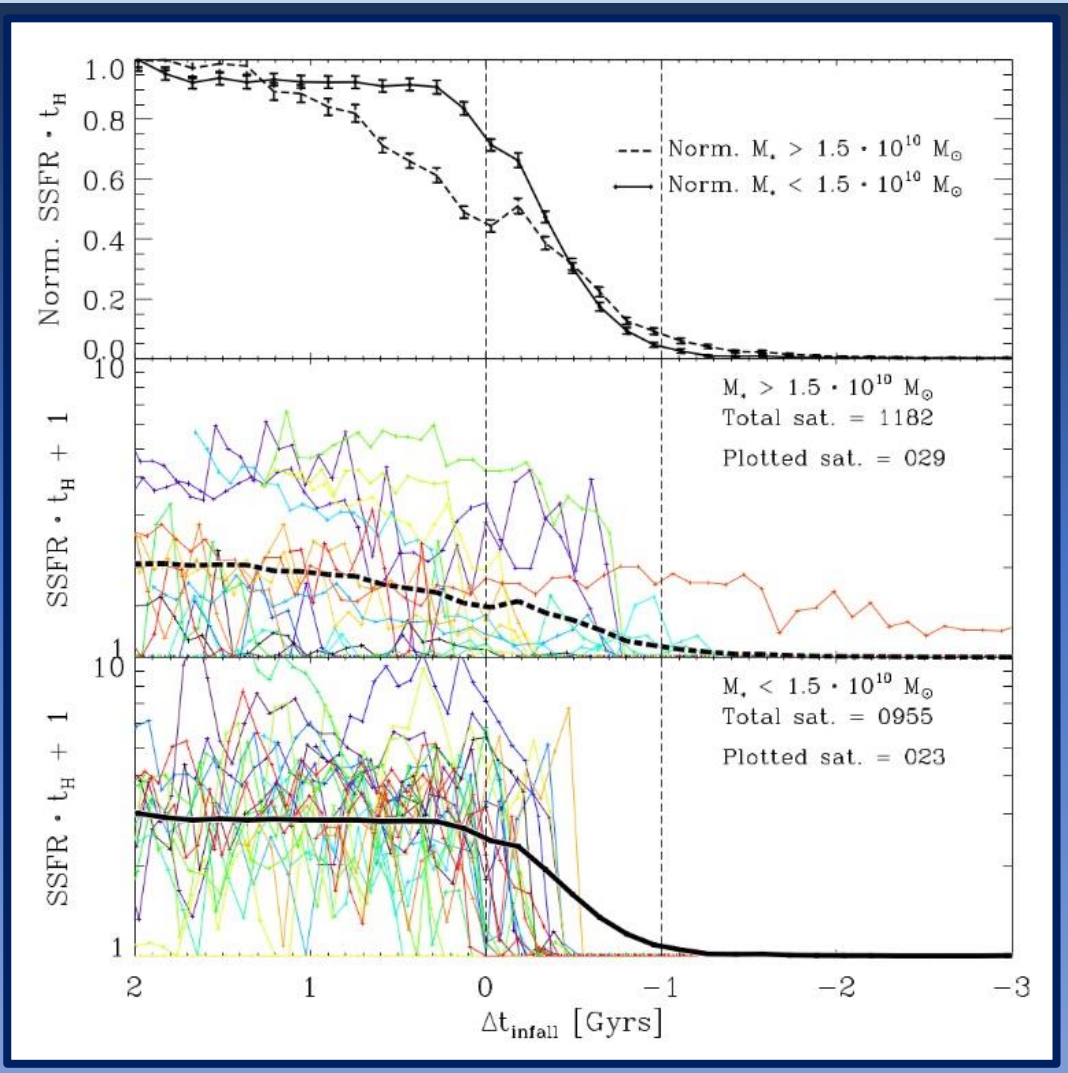
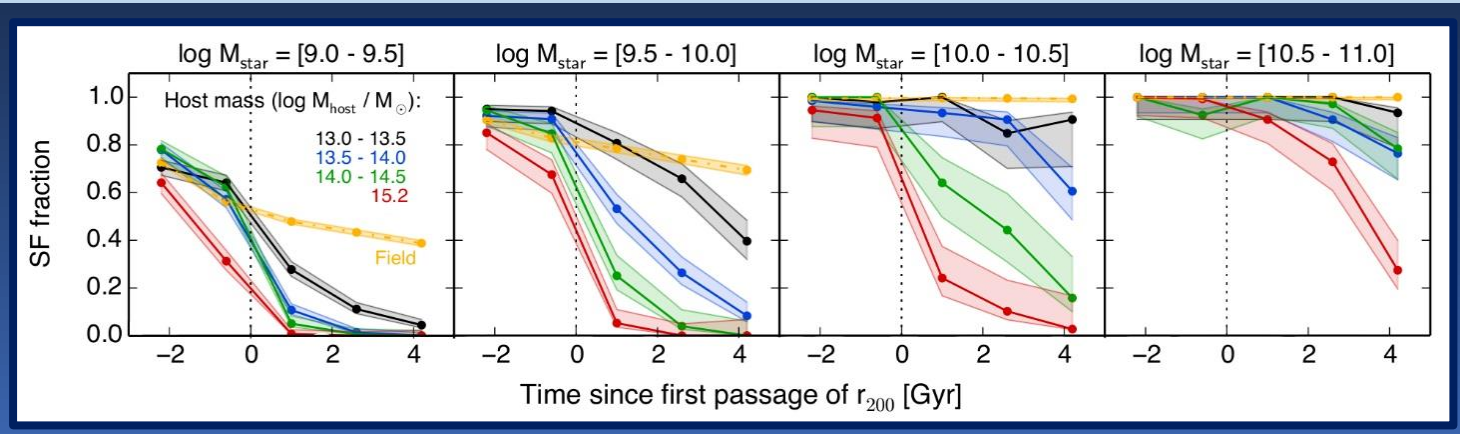
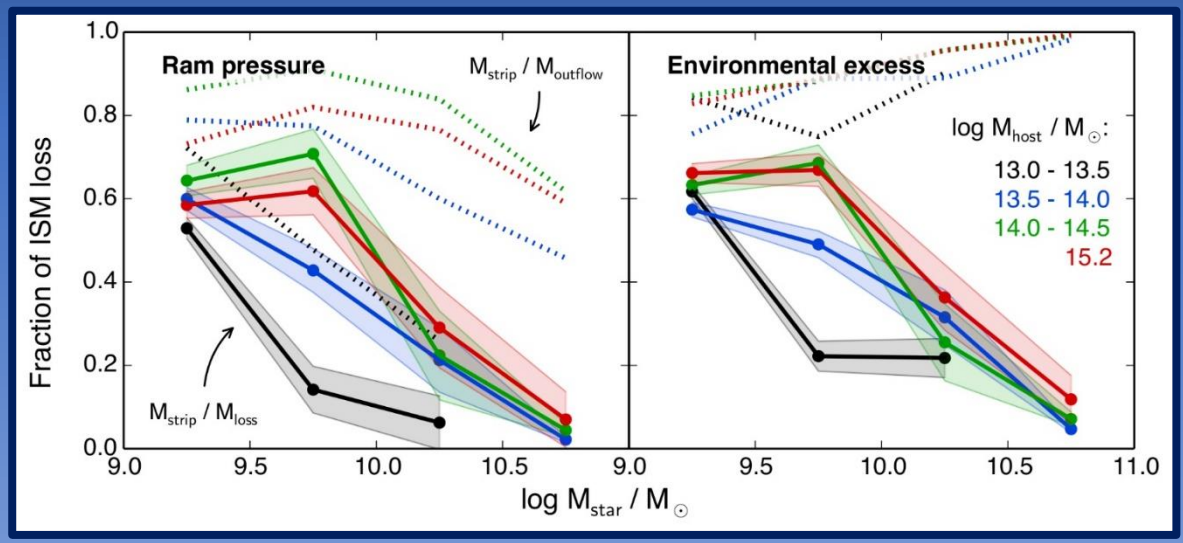


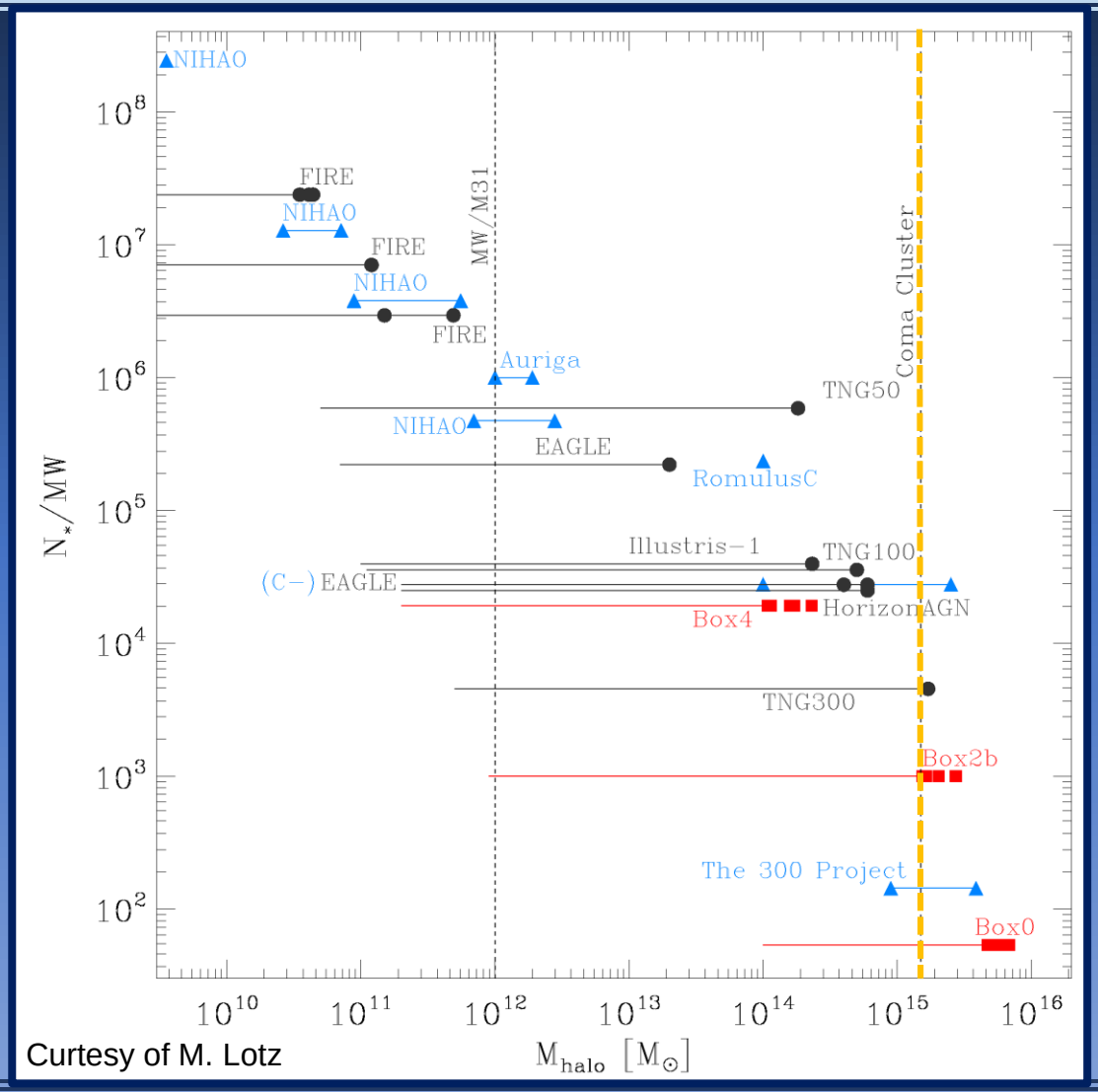




Bahe+ 2015




Lotz+ 2019

# Simulations: Current state




Curtesy of M. Lotz

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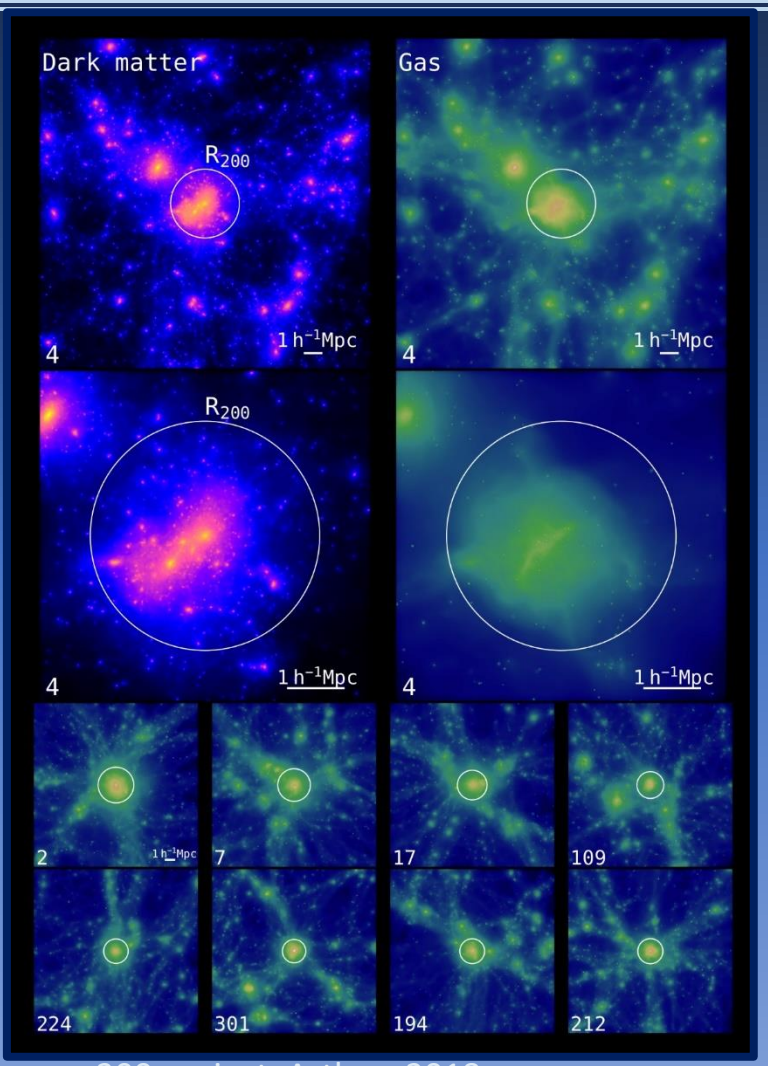
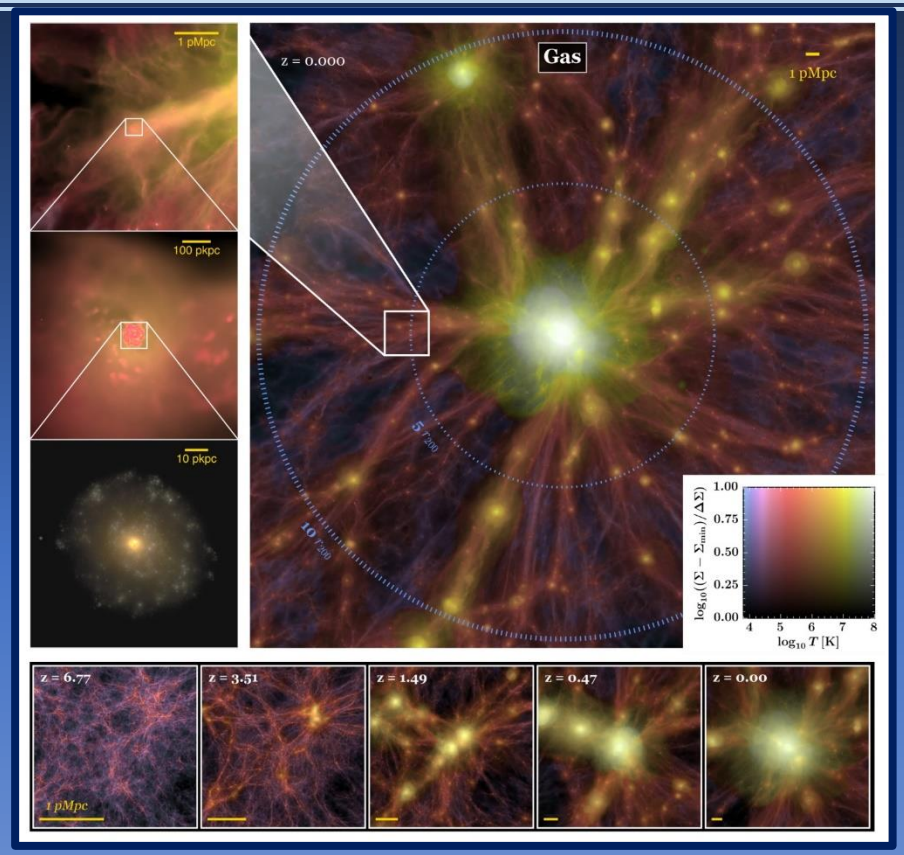
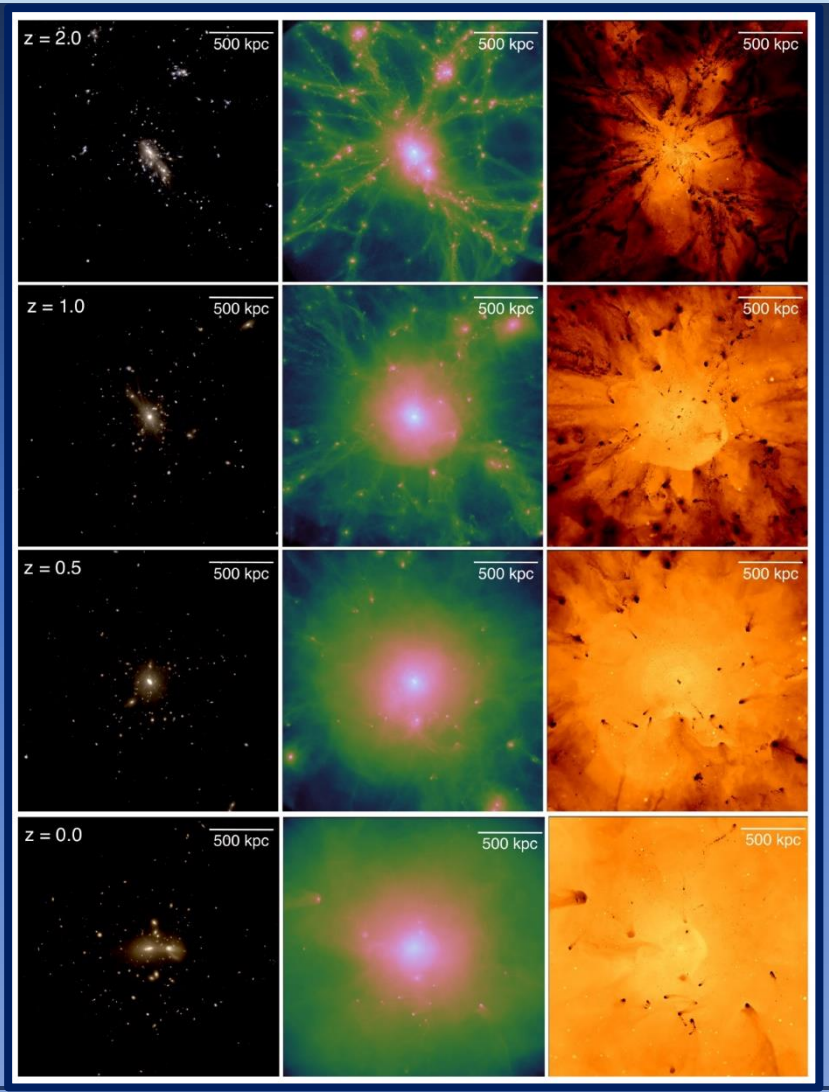



300 project, Arthur+2018




Hydrangea, Bahe+2017




RomulusC, Tremmel+2015

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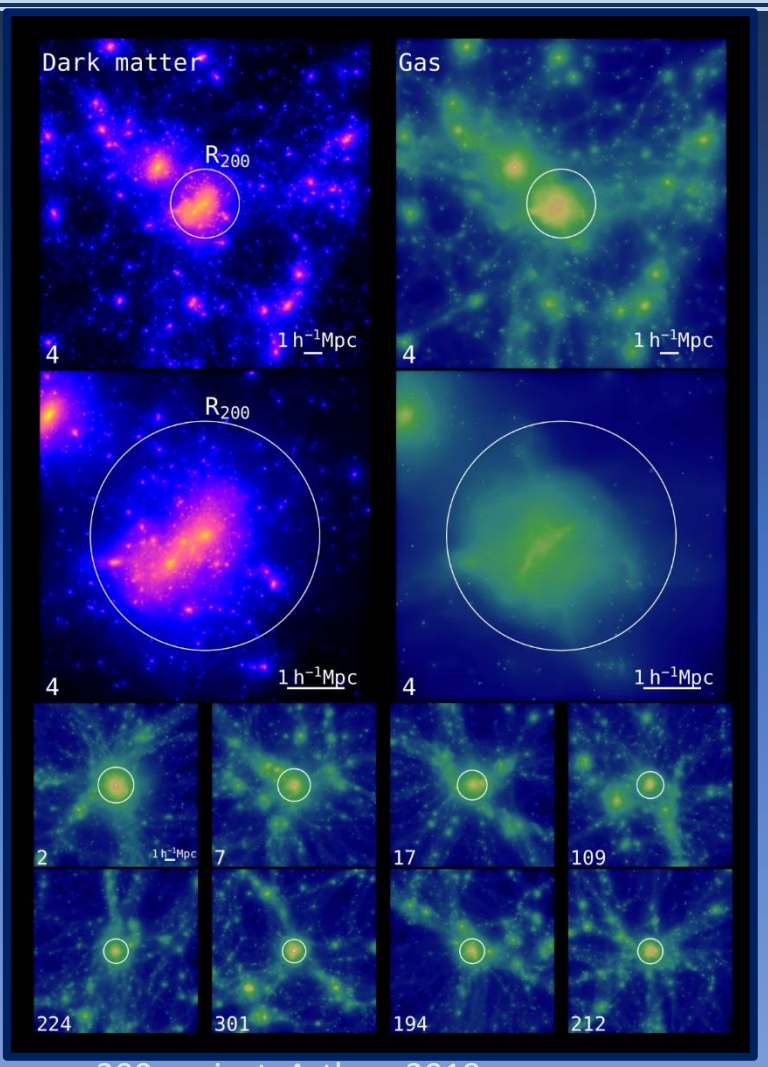


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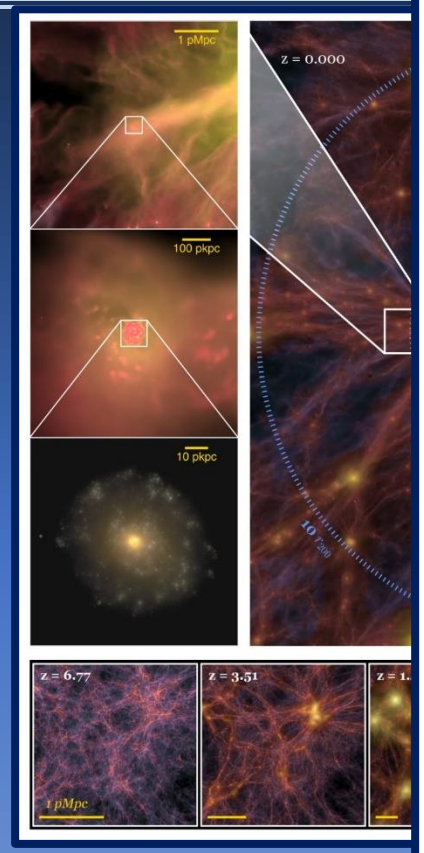
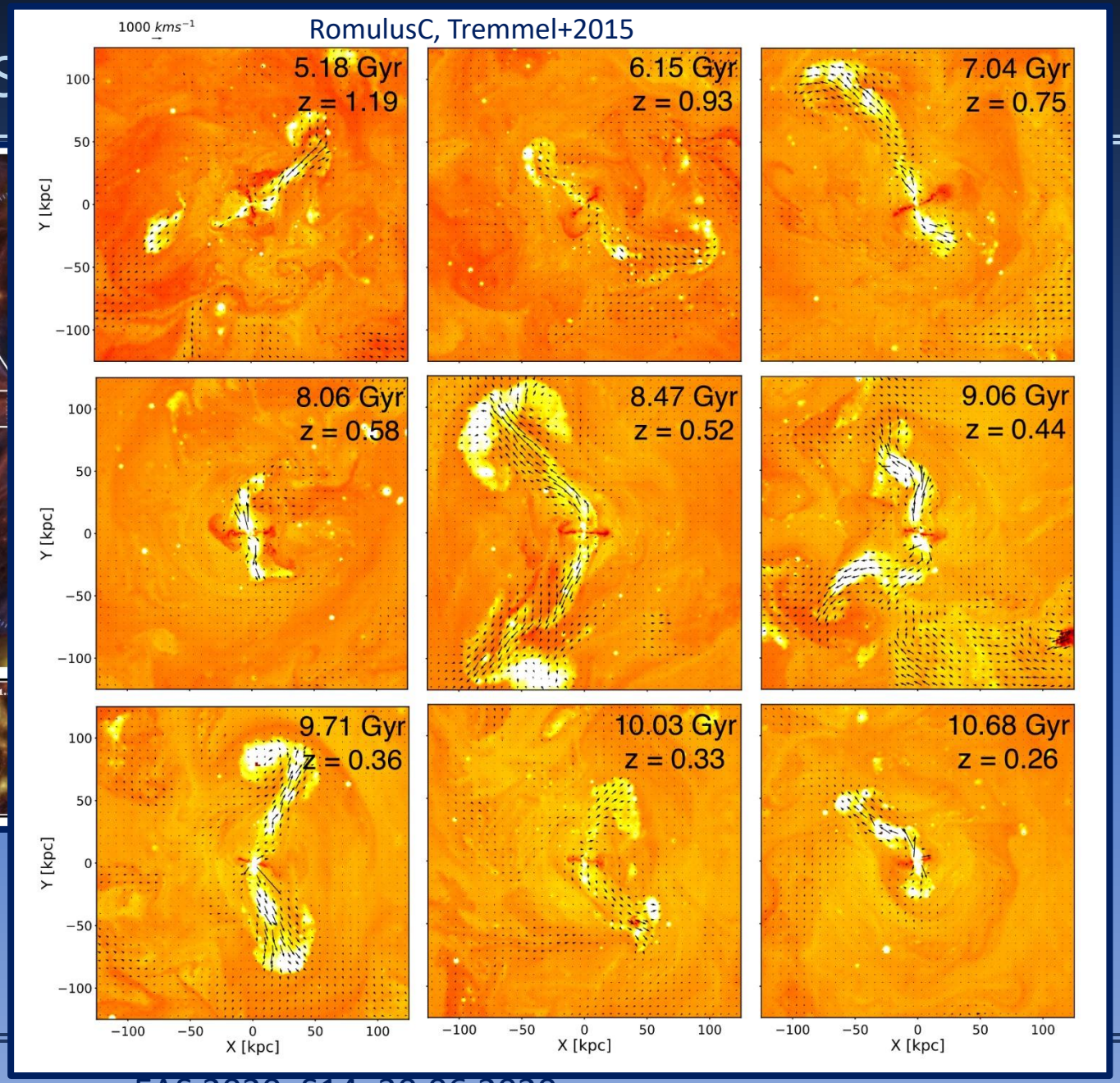
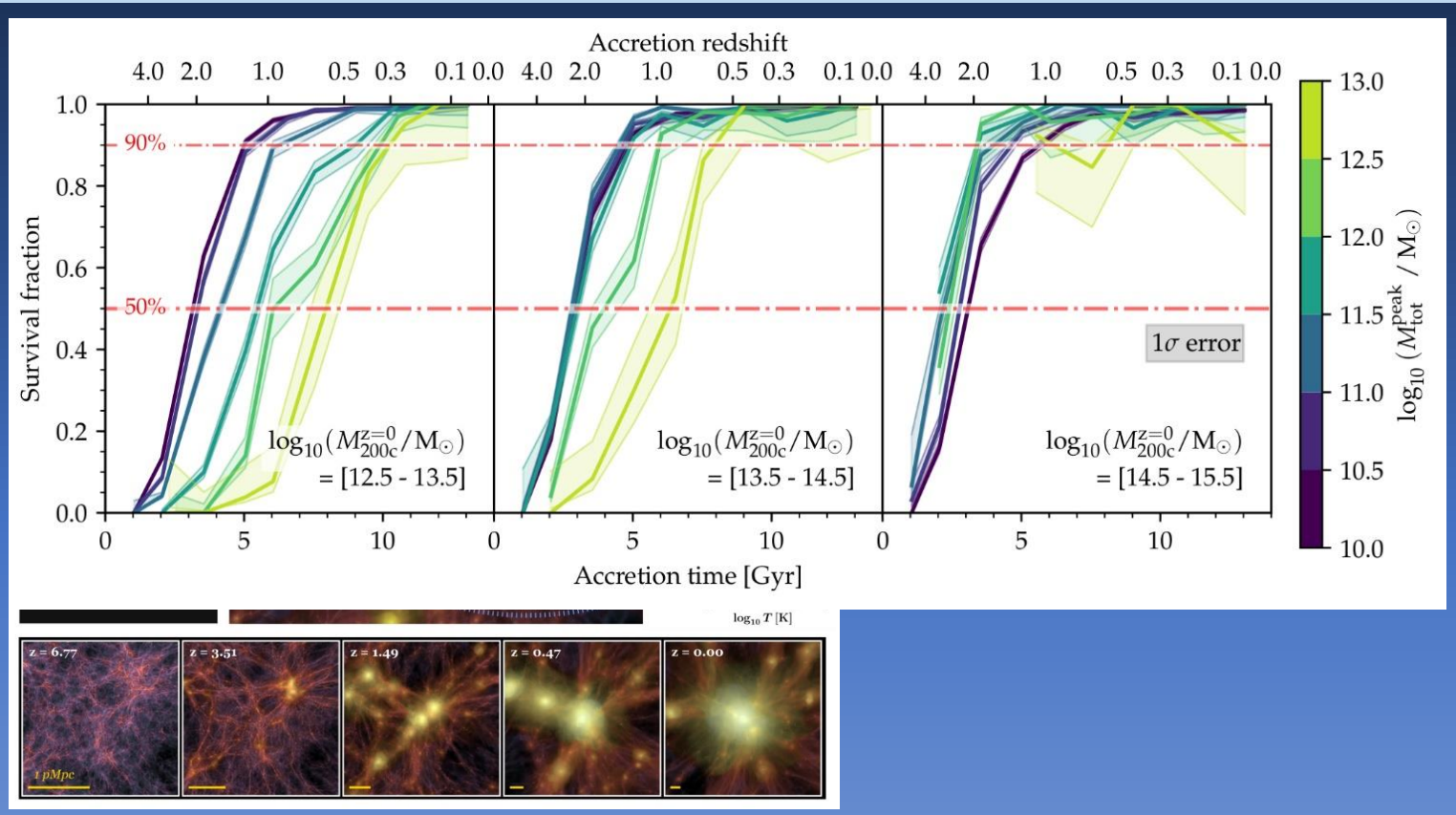


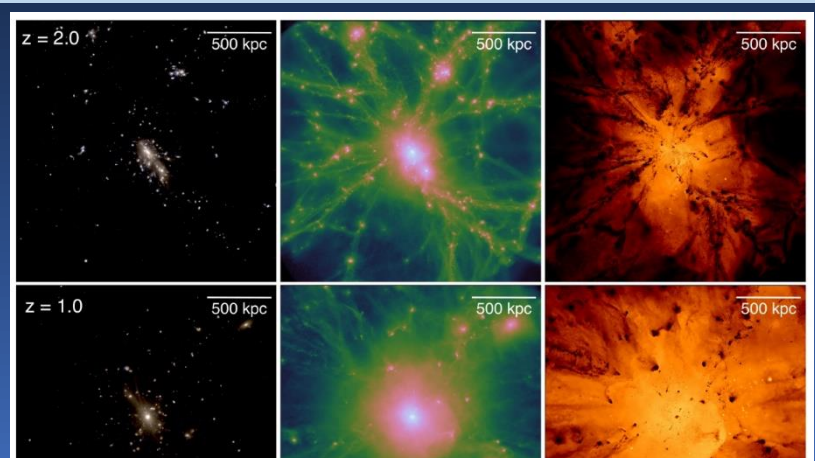

Hydrangea, Bahe+2017

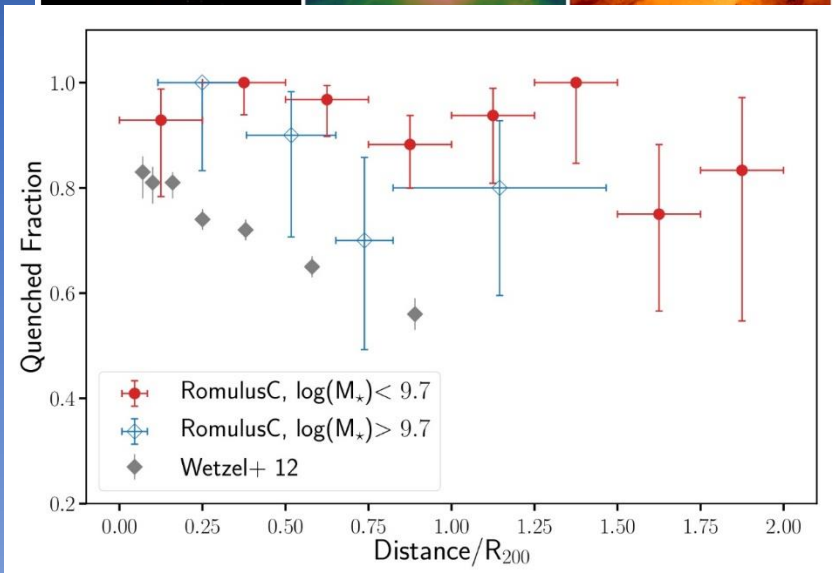


# Simulations: Current state



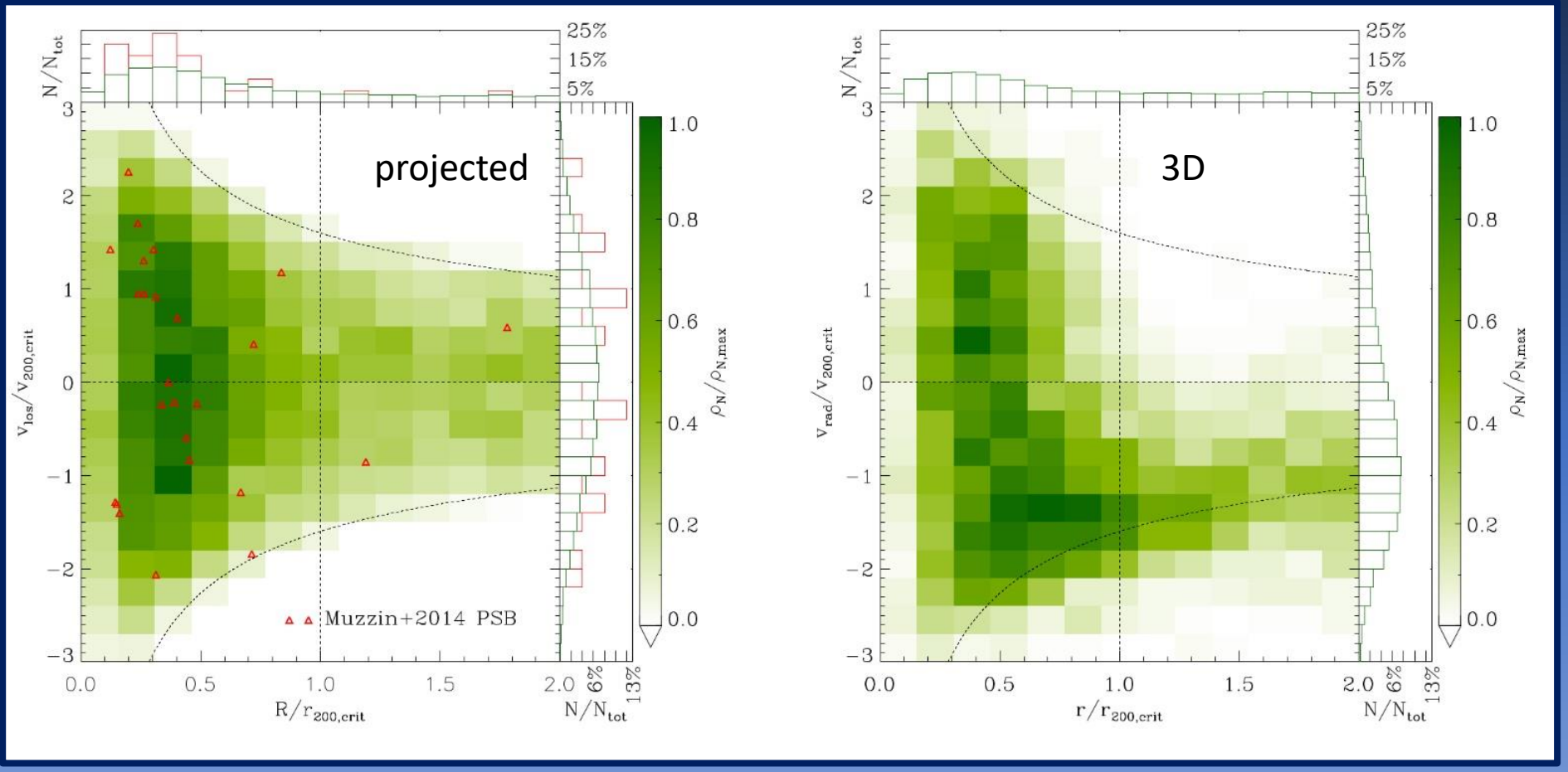

Hydrangea, Bahe+2017

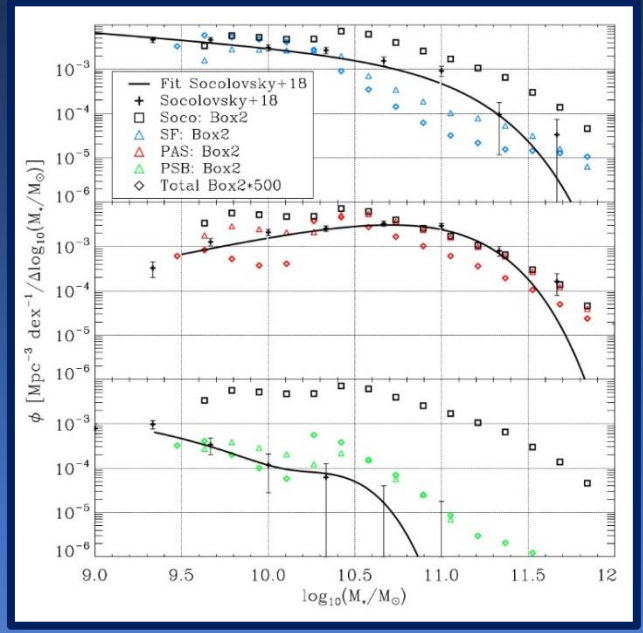



RomulusC, Tremmel+2015

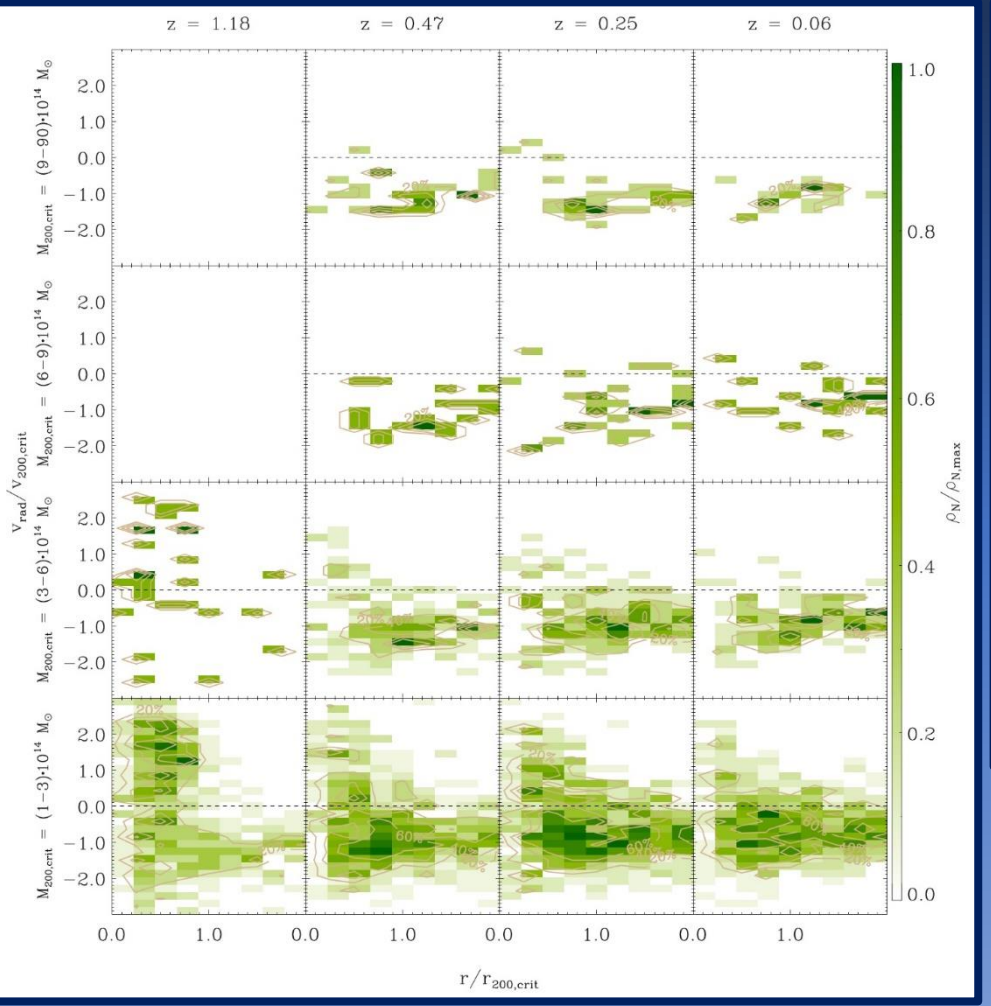
# Simulations: PSBs




Lotz+,to be submitted

# Simulations: PSBs

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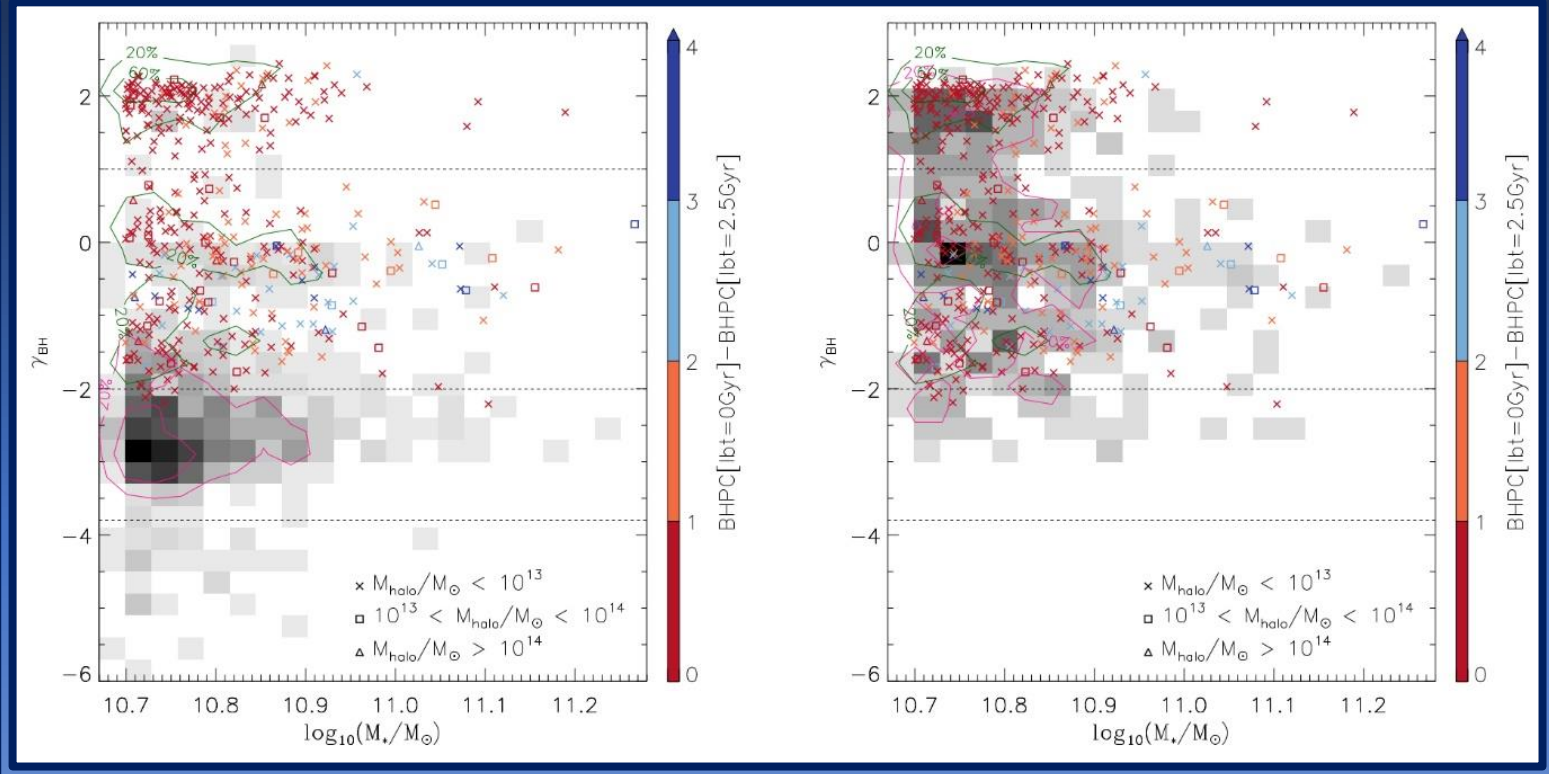

# Summary & Conclusions

- Environmental quenching through the cluster environment is observed, albeit it is not clear how frequent which mechanism contributes to the quenching
- Quenching exists already at redshifts as high as z=4, but for environmental quenching evidence only exists yet up to z=2
- Cosmological simulations large enough to study quenching in clusters are not yet resolved enough to study the internal galaxy details of the quenching mechanisms
- Simulations resolved enough are rare, and usually target only a few galaxy clusters
- Magenticum finds protoclusters at z=4 as massive as the currently most massive protoclusters observed, with similar mass, membership, and kinematic properties, but these protoclusters are not the progenitors of todays most massive galaxy clusters
- PSBs in Magneticum identified in accordance to simulations are all made by mergers and thus are preprocessed in galaxy groups with which they fall in

# Life is good if you are an assembling cluster!