

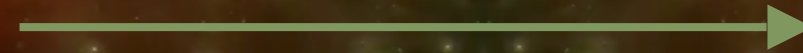
Groups, clusters, and the cosmic web

Meghan Gray, University of Nottingham

 @emeegrays

Jake Arthur, Robert Mostoghui, Agustín Rost, Roan Haggard, Ulrike Kuchner

The Three Hundred



WEAVE Wide-Field Cluster Survey

Frazer Pearce,

Alexandre Knebe, Weiguang Cui,

Gustavo Yepes, Chris Power, Federico Stasyszyn

Alfonso Aragón-Salamanca,

Alfonso Aguerri, Russell Smith

Why are clusters dominated by 'red and dead' galaxies?

Which galaxies have their star formation quenched?

How do galaxies lose their gas?

Where do they lose their gas?

When do they lose their gas?

How long does it take?

What else is going on?

Why are clusters dominated by 'red and dead' galaxies?

Which galaxies have their star formation quenched?

e.g. stellar mass dependence?

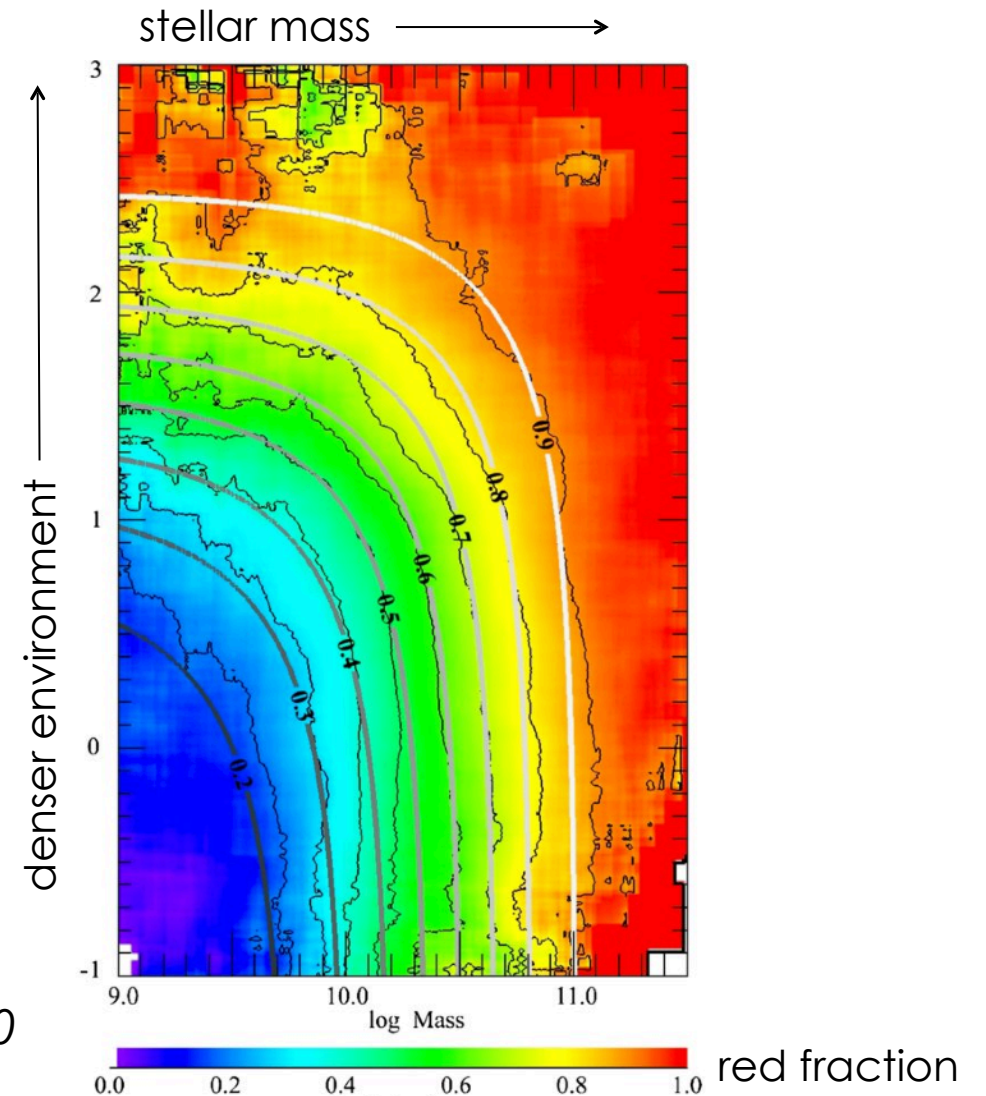
How do galaxies lose their gas?

Where do they lose their gas?

When do they lose their gas?

How long does it take?

What else is going on?



Peng et al. 2010

Why are clusters dominated by 'red and dead' galaxies?

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How do galaxies lose their gas?

Where do they lose their gas?

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How long does it take?

What else is going on?

physical mechanism – interactions with...
...cluster/group/filament gas?
...cluster/group potential?
...galaxies?

Boselli 2006 review



HST/Chandra

[see McCarthy review talk]



HST

Why are clusters dominated by 'red and dead' galaxies?

Which galaxies have their star formation quenched?

How do galaxies lose their gas?

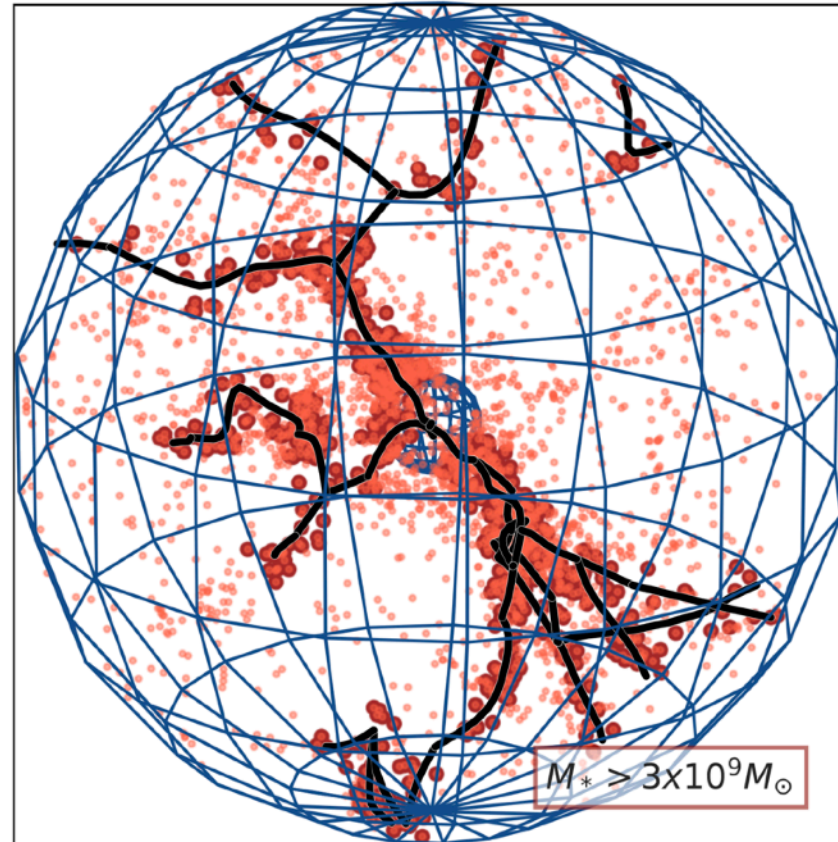
Where do they lose their gas?

When do they lose their gas?

How long does it take?

What else is going on?

groups, filaments, cluster cores:
orbital history? preprocessing?



[see this talk]

Kuchnert+, in prep

Why are clusters dominated by 'red and dead' galaxies?

Which galaxies have their star formation quenched?

How do galaxies lose their gas?

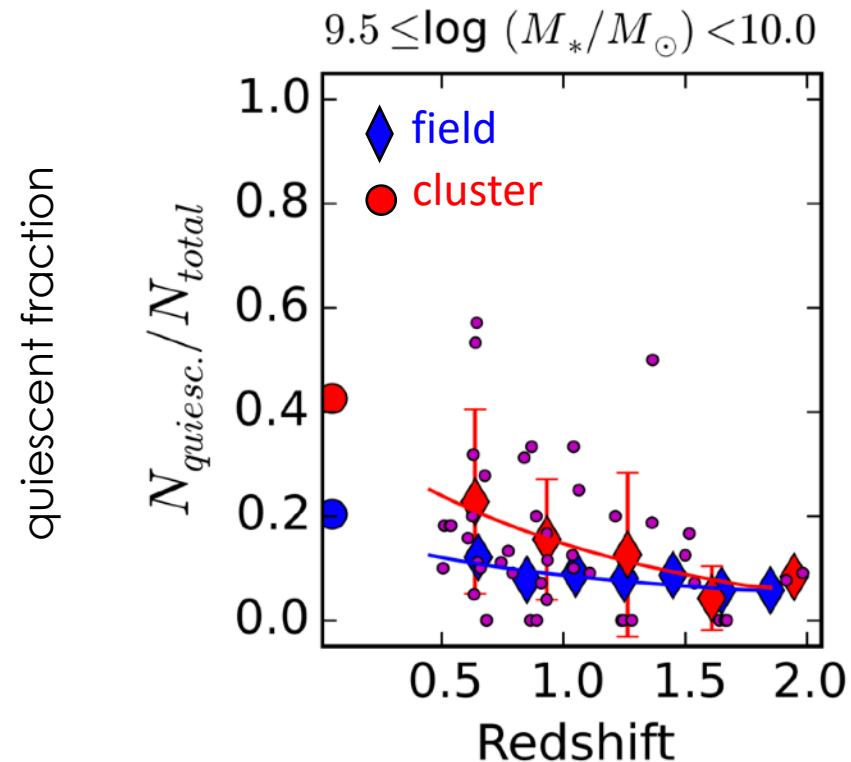
Where do they lose their gas?

When do they lose their gas?

How long does it take?

What else is going on?

what's special about the cosmic middle ages?



[see Remus review talk]

Lee+, 2015

Why are clusters dominated by 'red and dead' galaxies?

Which galaxies have their star formation quenched?

How do galaxies lose their gas?

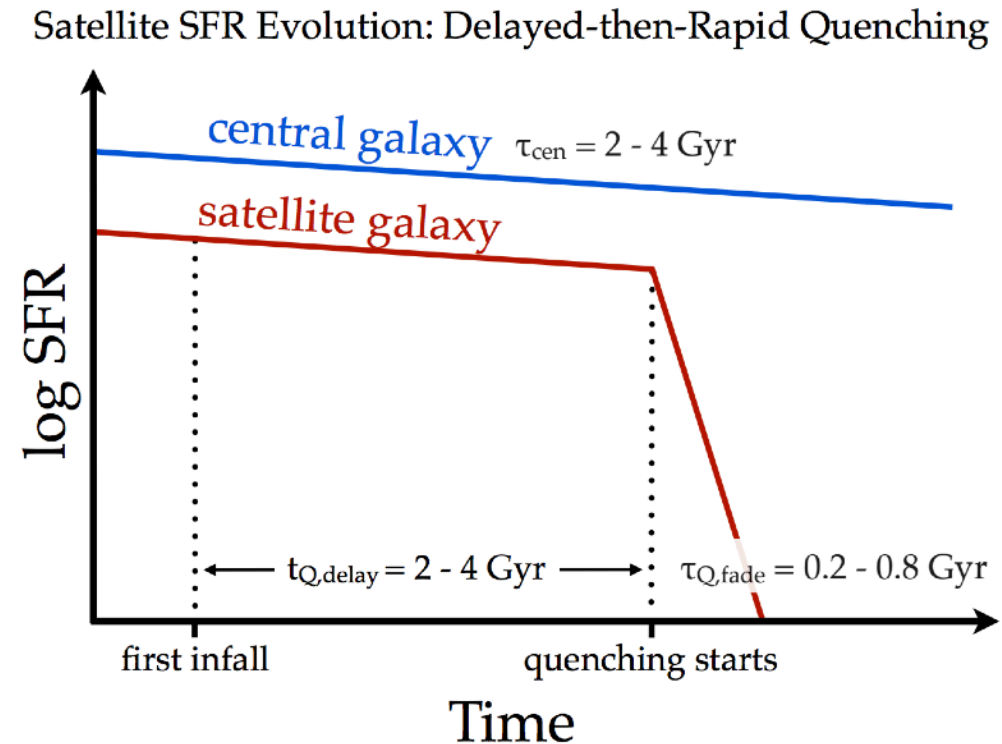
Where do they lose their gas?

When do they lose their gas?

How long does it take?

What else is going on?

timescales for quenching?



Wetzel+ 2013, also Bahé+ 2019, Lotz+ 2019

Why are clusters dominated by 'red and dead' galaxies?

Which galaxies have their star formation quenched?

How do galaxies lose their gas?

Where do they lose their gas?

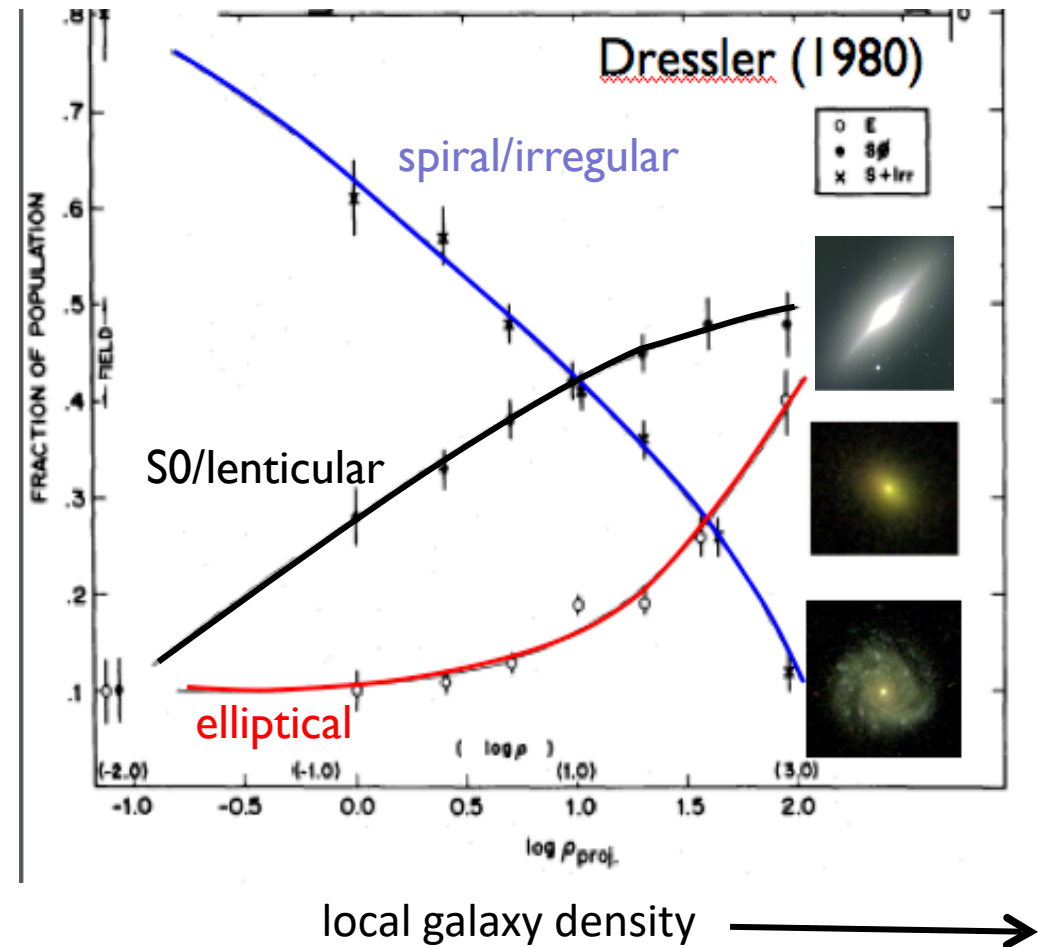
When do they lose their gas?

How long does it take?

What else is going on?

[see McGee review talk]

changes in morphology, size, kinematics, metallicity, AGN activity...



“The 300” cluster simulations



See mockingastrophysics.org, Cui et al. 2018

- zoom resimulations of **324 most massive clusters** from MDPL2 $1 h^{-1}\text{Gpc}$ volume
- **mass complete:** $M_{200} > 6.42 \times 10^{14} h^{-1} M_{\odot}$ at $z = 0$
- **6 physics engines:** 3 hydro codes + 3 SAMs
- infall region probed out to **15 $h^{-1}\text{Mpc}$ radius**
- mass resolution (gas: $2.4 \times 10^8 M_{\odot}$; DM: $1.3 \times 10^9 M_{\odot}$)

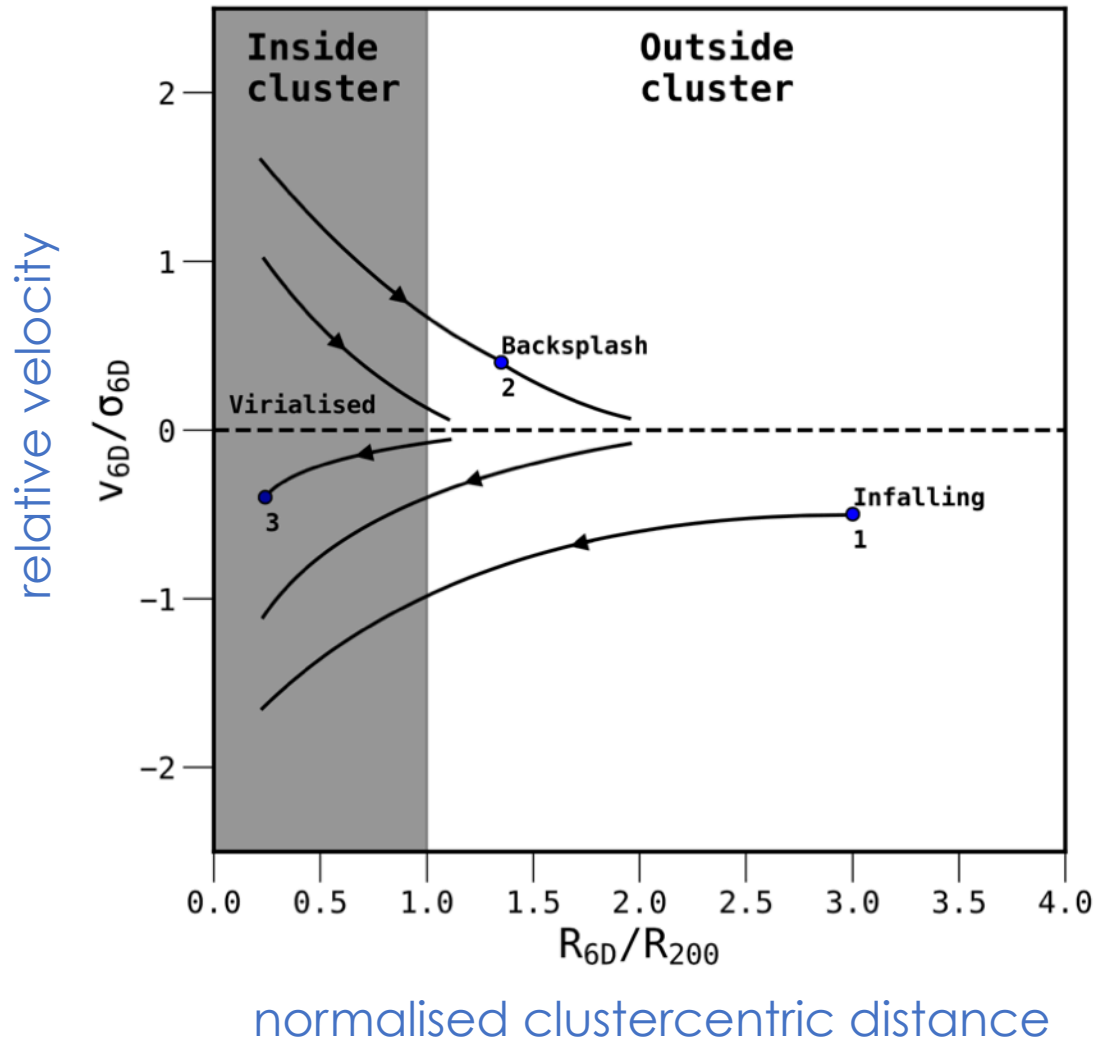
For complementary approaches see e.g.

MUSIC (Sembolini+13)
Hydrangea (Bahé+17)
C-EAGLE (Barnes+17)

Cosmo-OWLS (Le Brun+14)
BAHAMAS (McCarthy+17)

The phase-space diagram: position and velocity

Arthur+ 2019



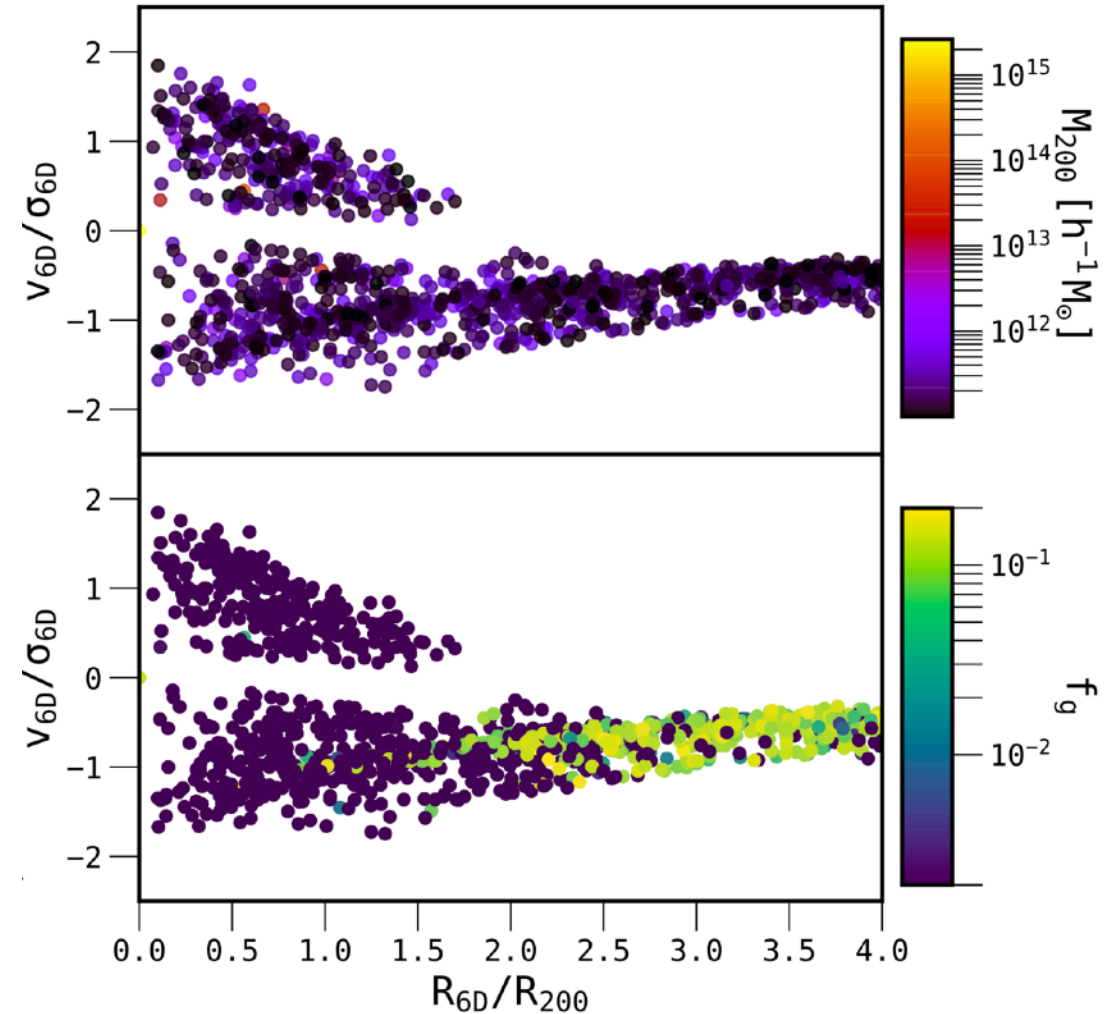
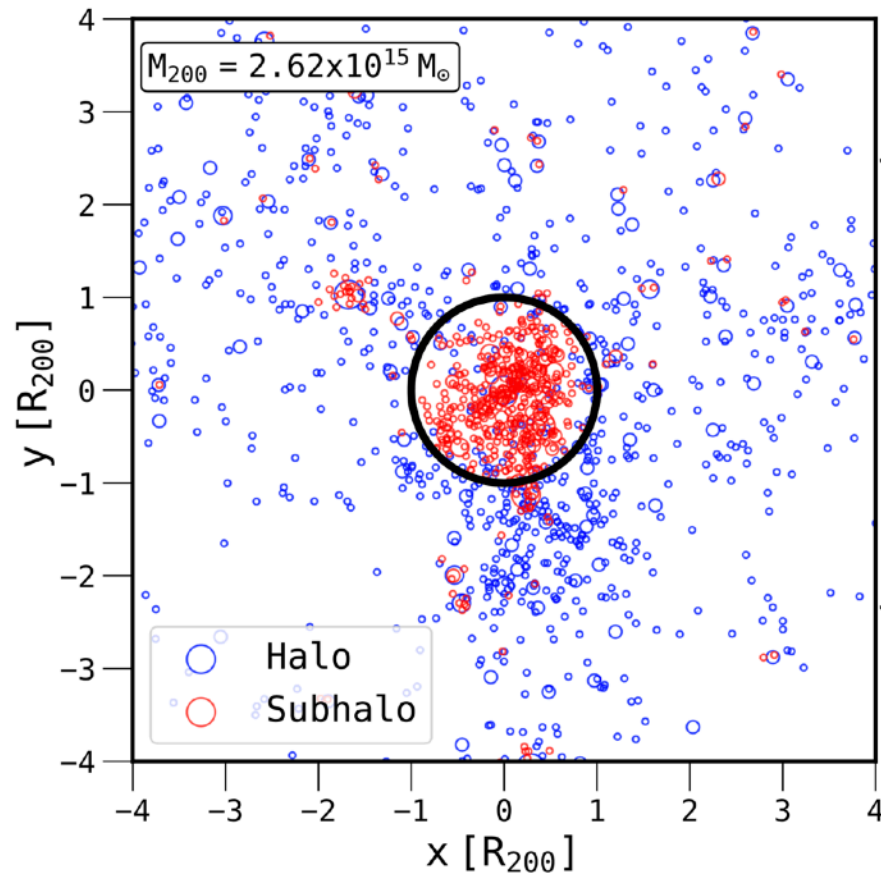
6D view
(x, y, z, v_x, v_y, v_z)



Dr. Jake Arthur

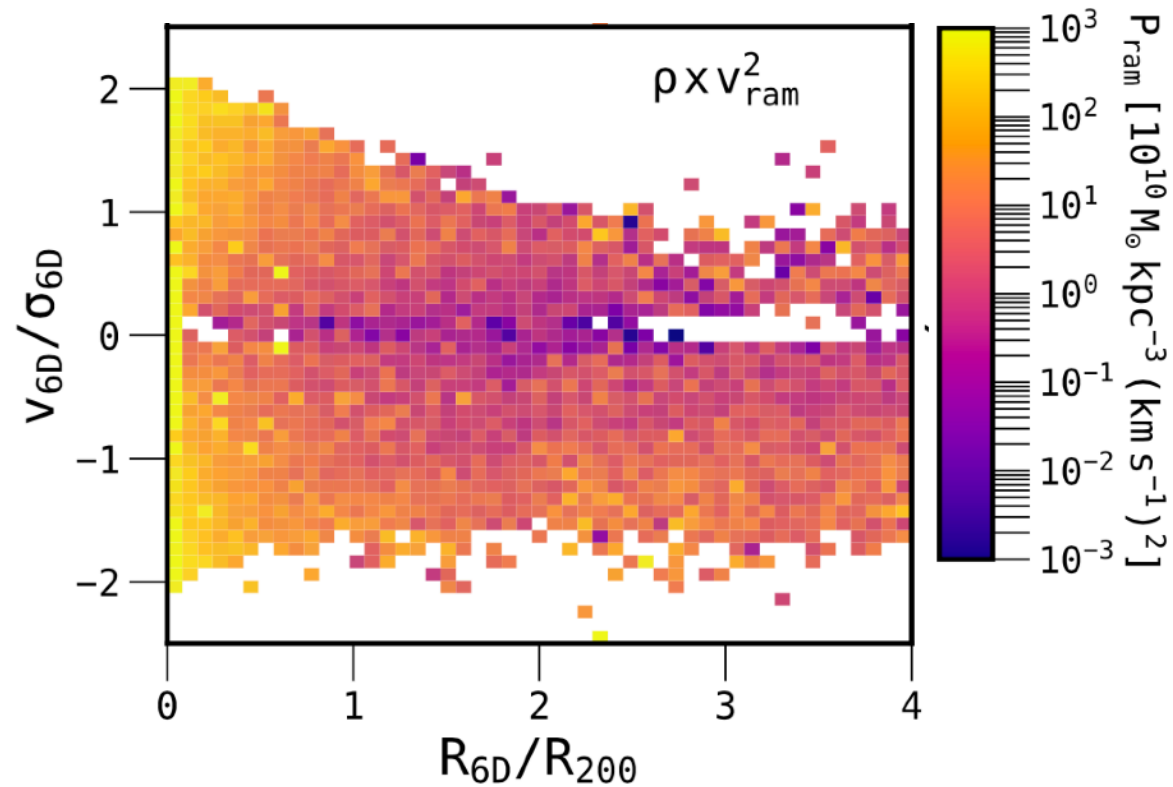
Case study: haloes are “gas poor” on first infall

Arthur+ 2019



Instantaneous ram pressure / low gas content

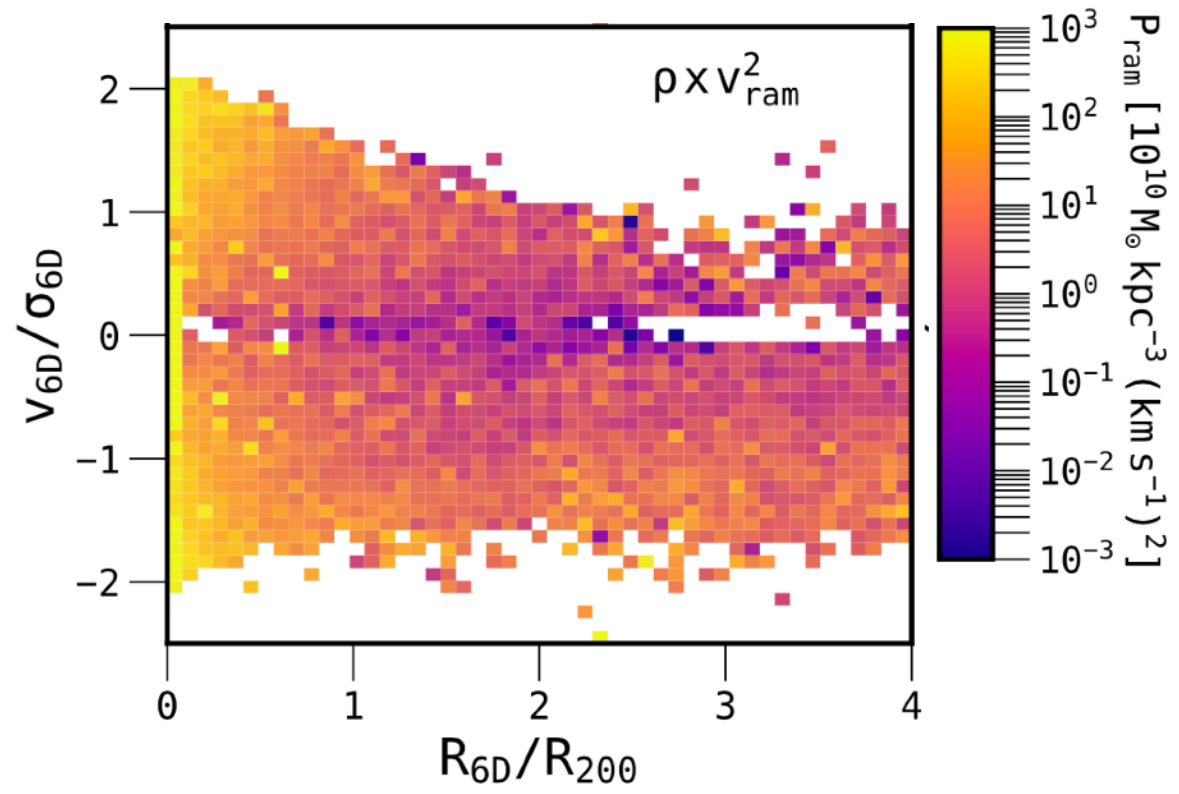
stacked phase-space
diagram for 324 clusters



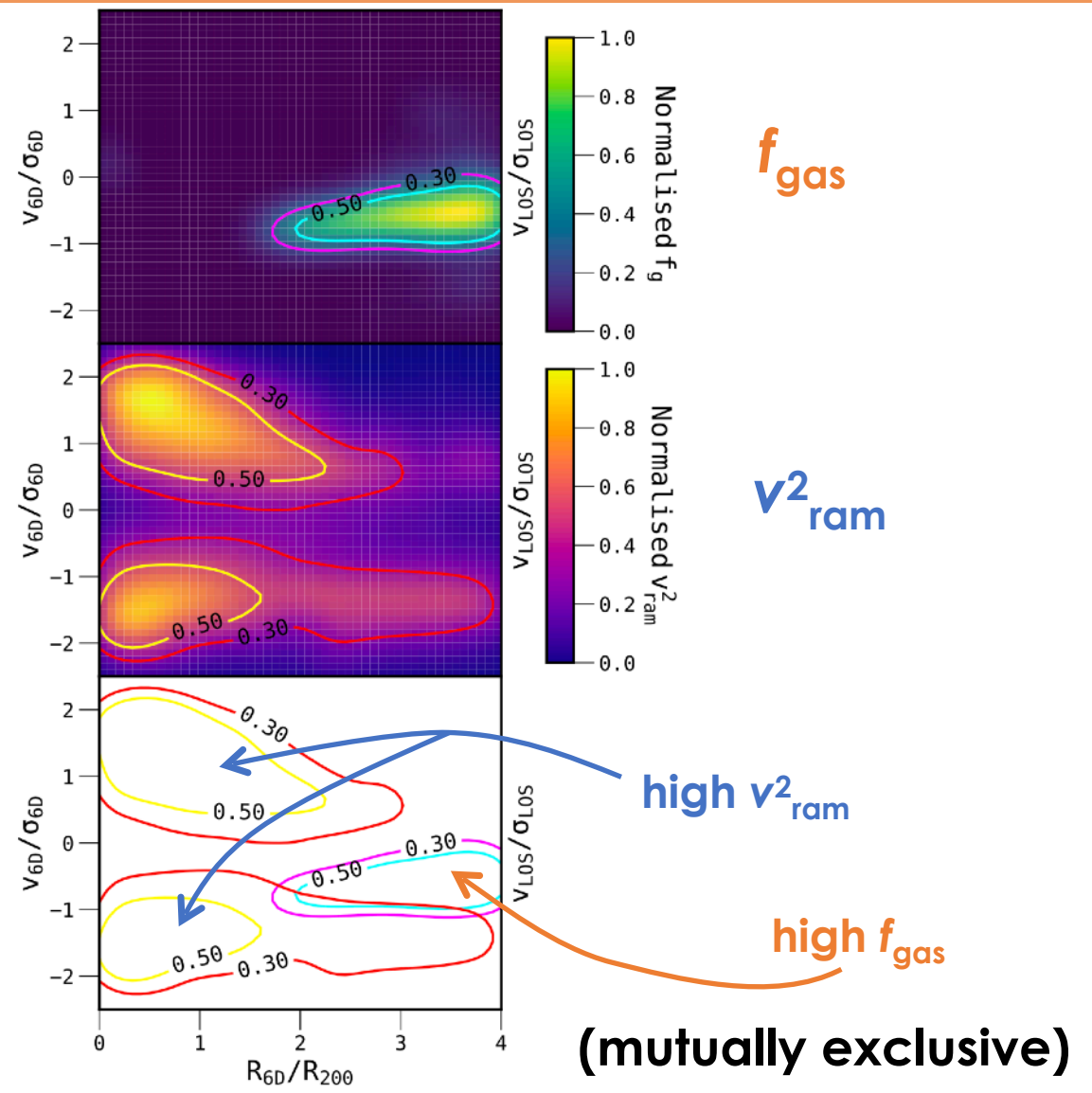
Arthur+ 2019

Instantaneous ram pressure / low gas content

stacked phase-space diagram for 324 clusters

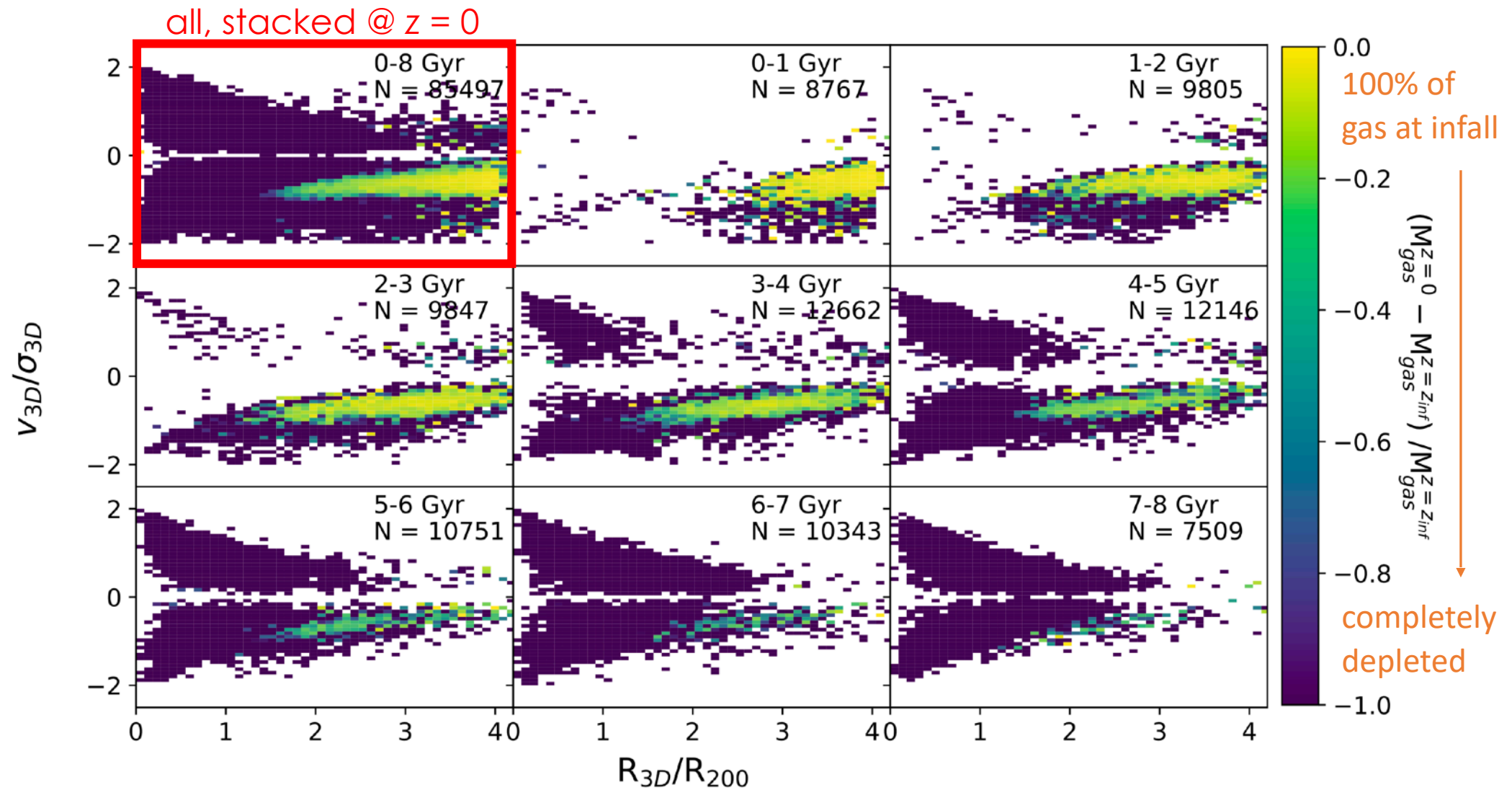


Arthur+ 2019



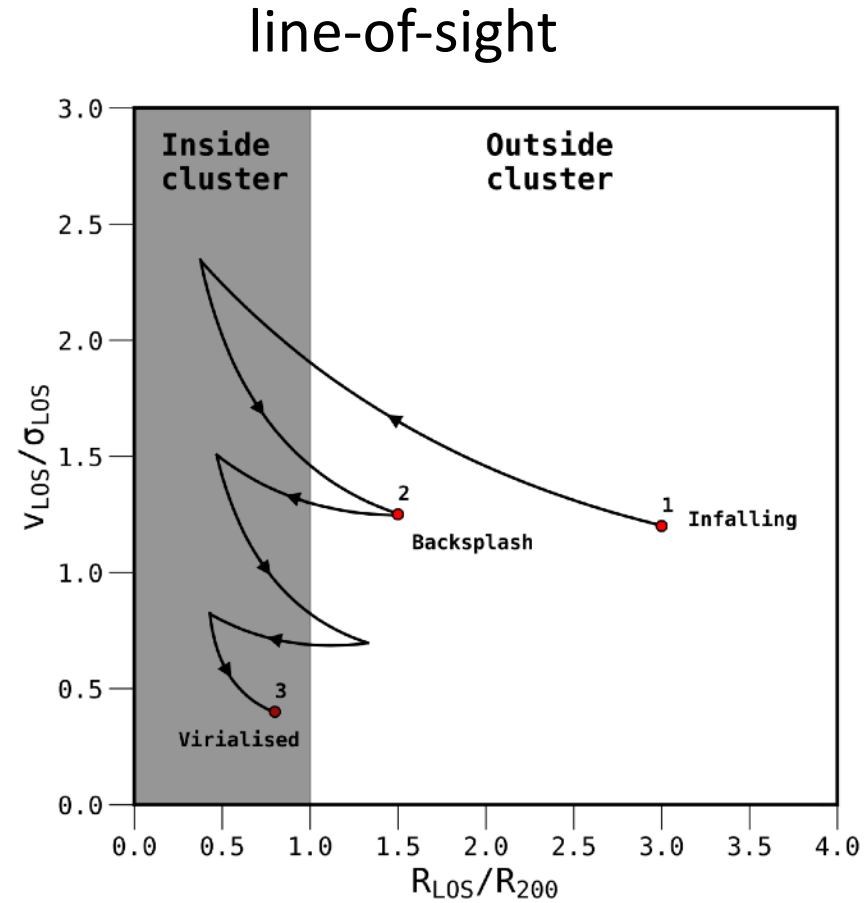
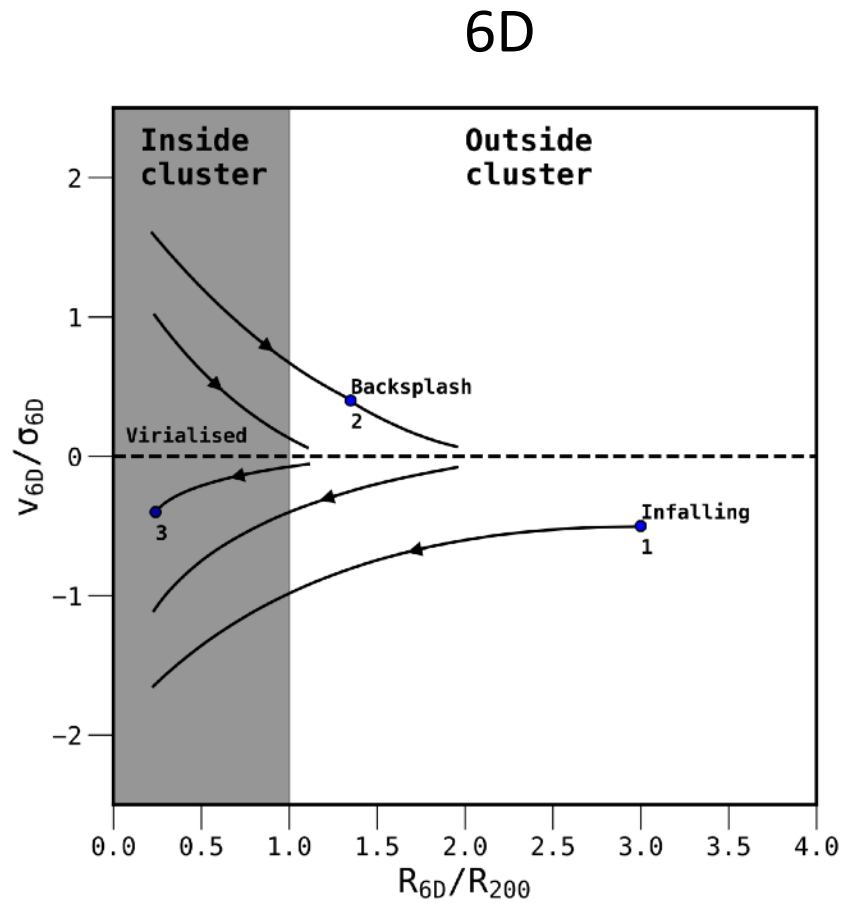
Gas loss outside R_{200} depends on time since infall*

* where "infall" = crossing $4 \times R_{200}$

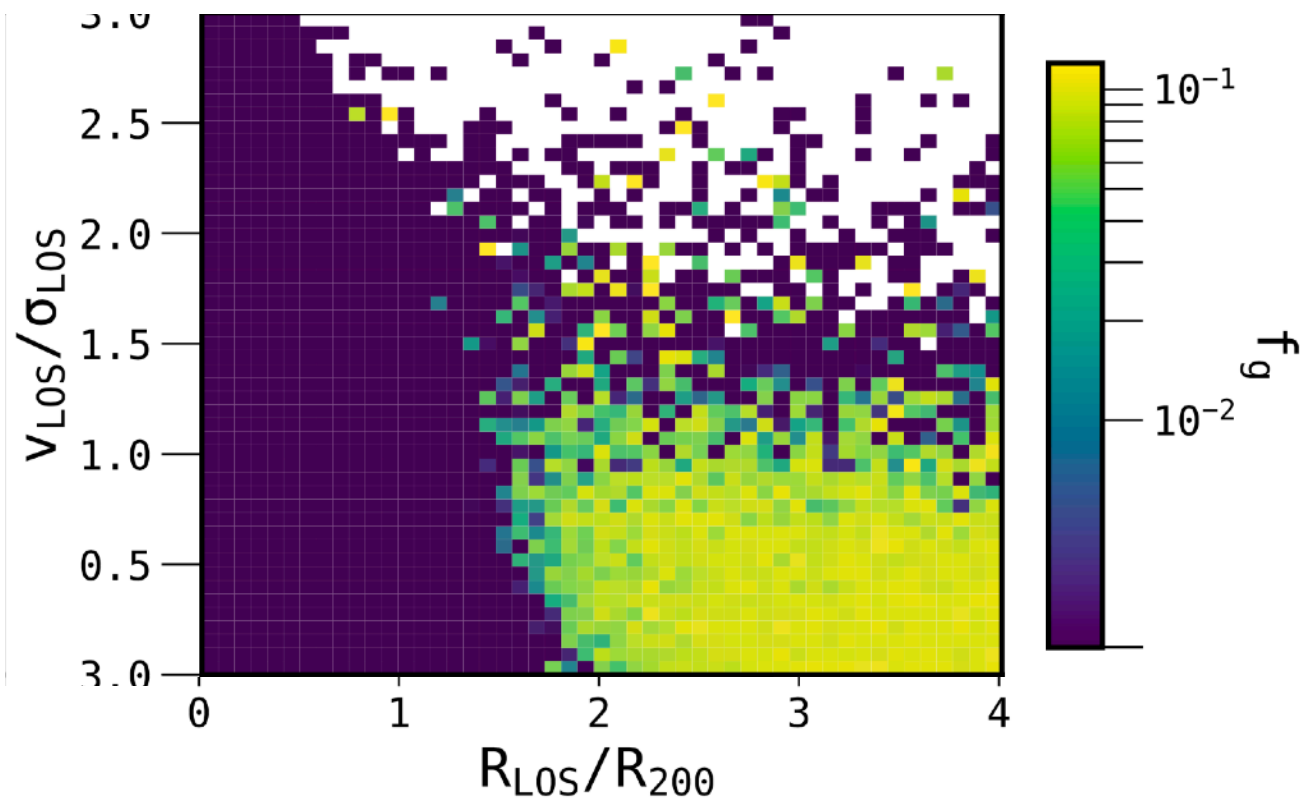


Robert Mostoghui (UAM)

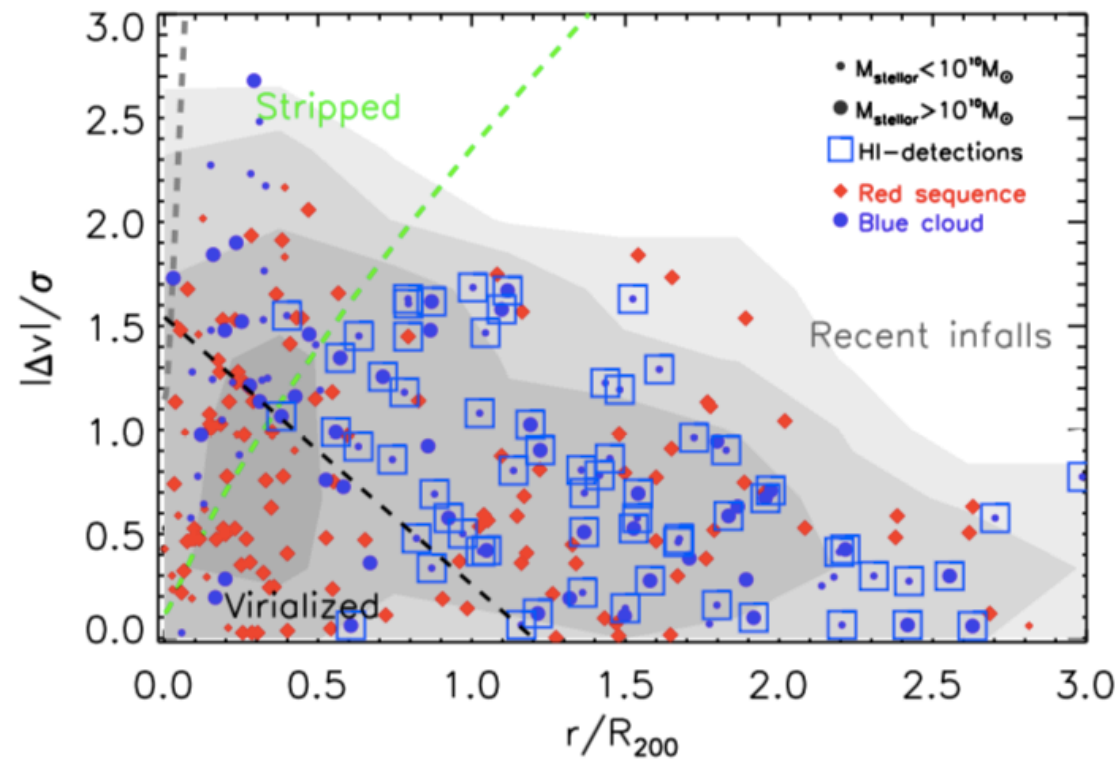
Towards observations: projection effects



Comparison to observations of HI depletion

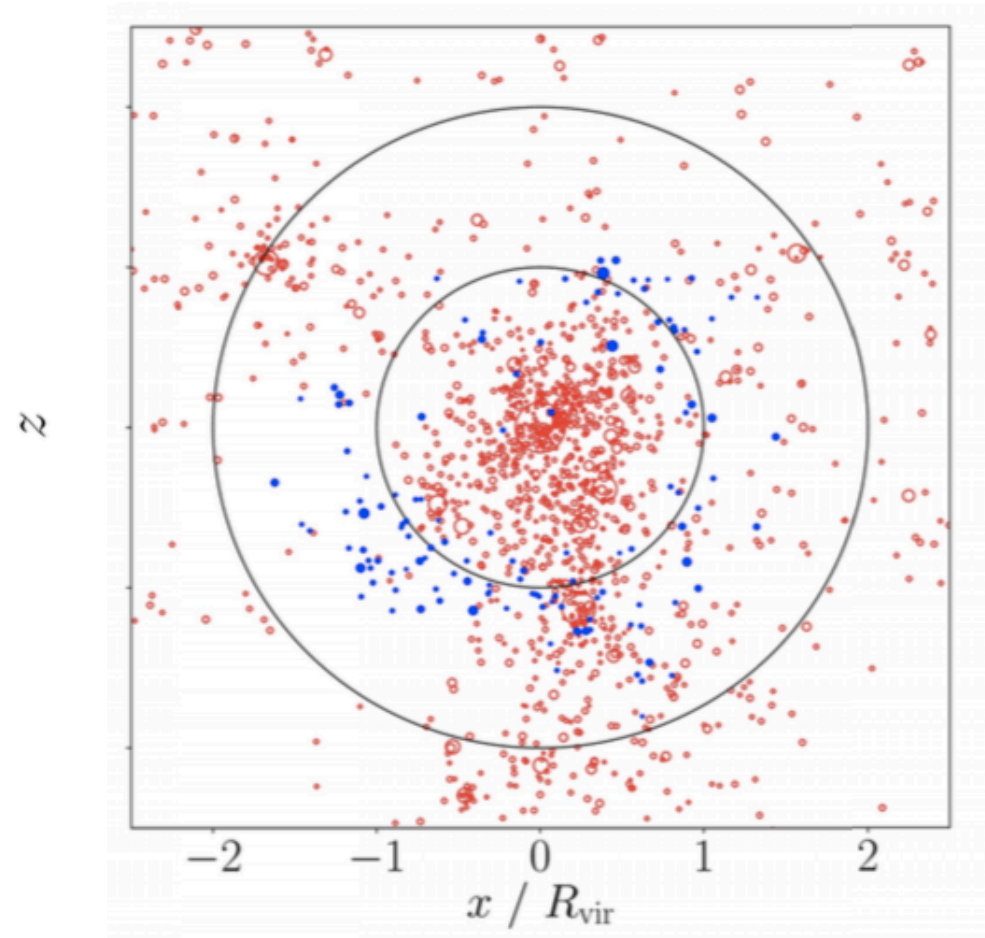
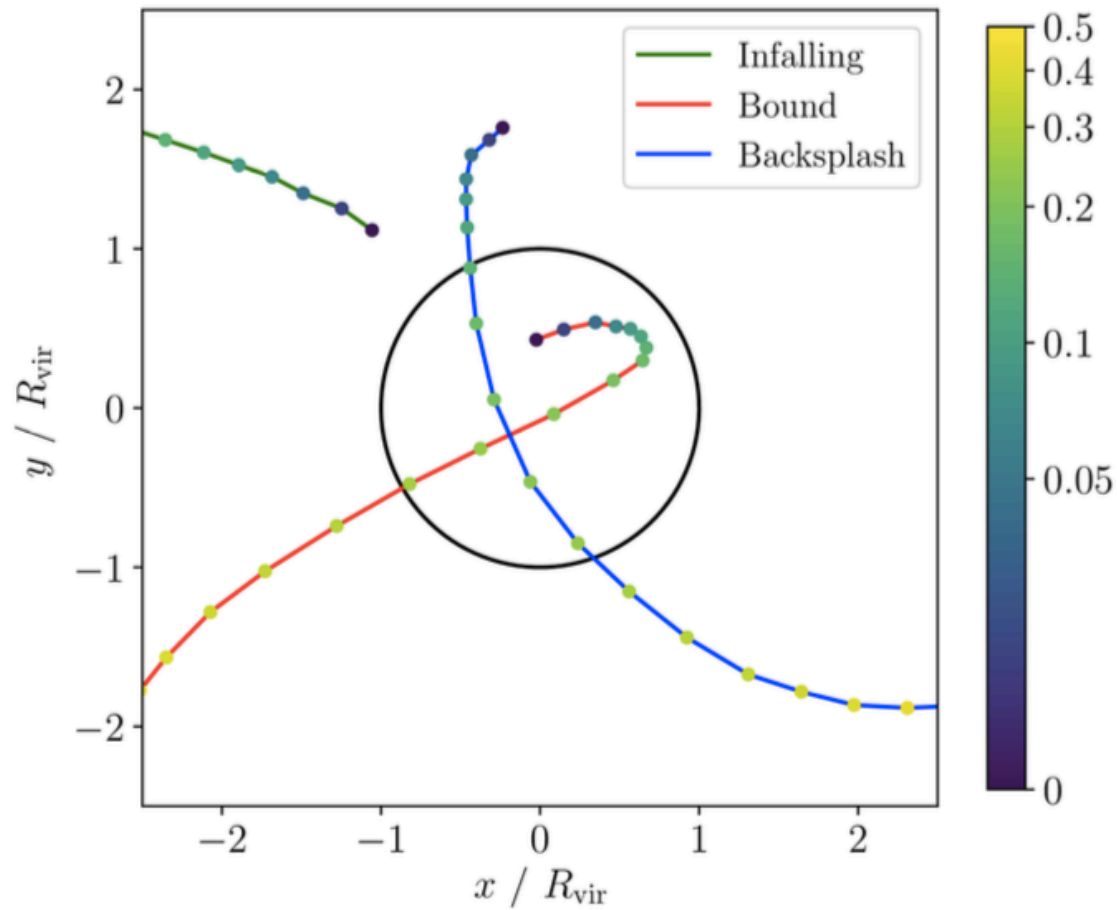


Arthur+ 2019



Jaffé+ 2015

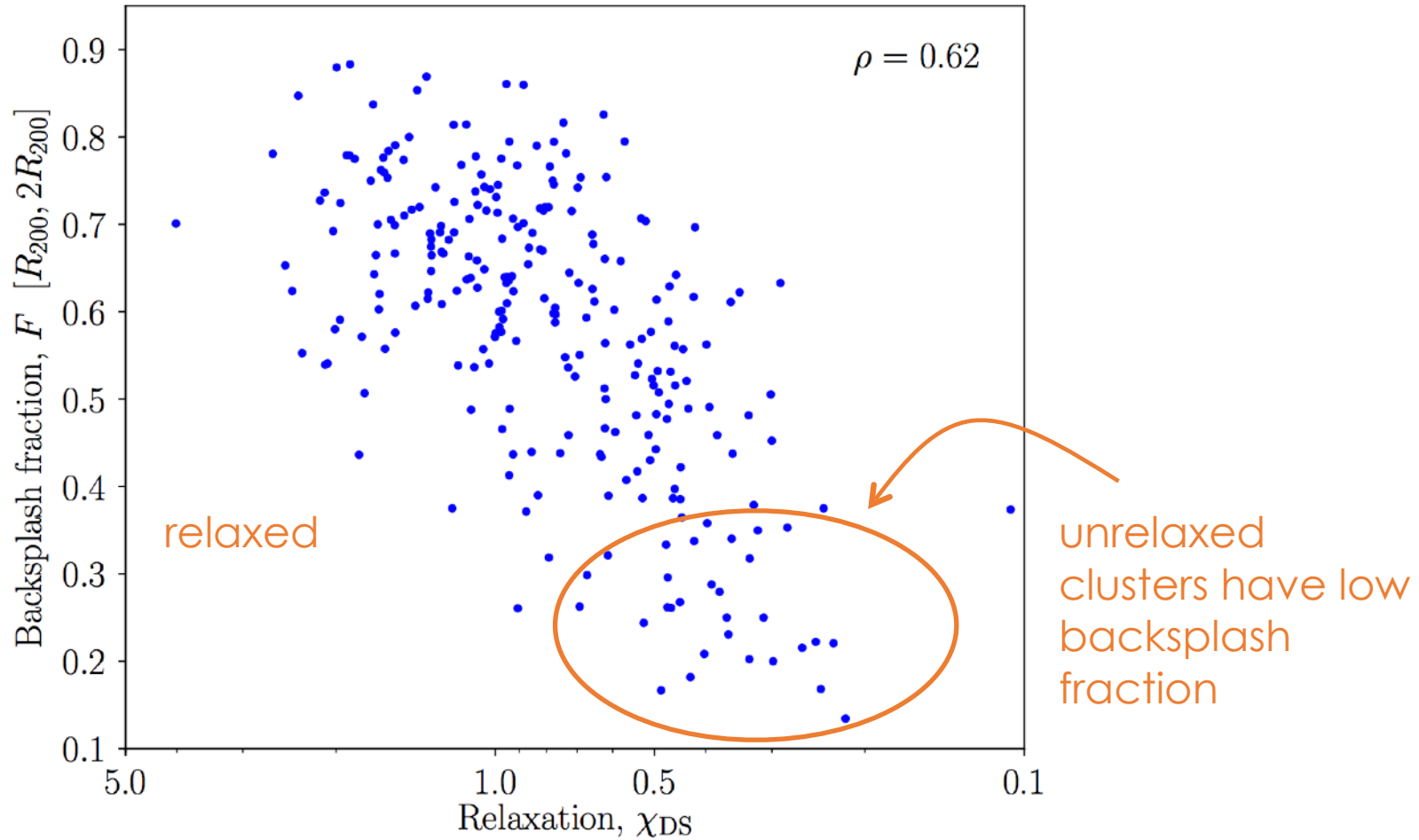
Backsplash galaxies



Roan Haggard
(Nottingham)

Haggard+ 2020

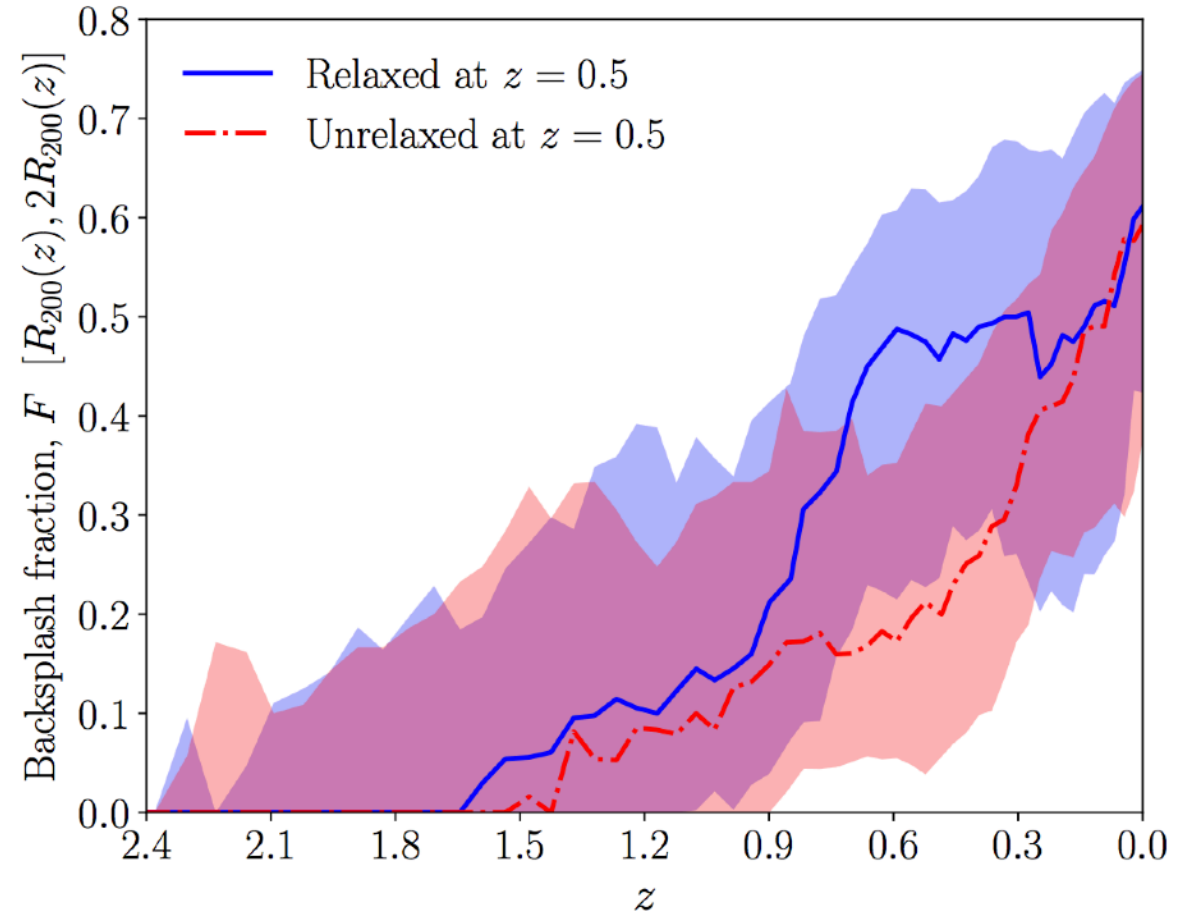
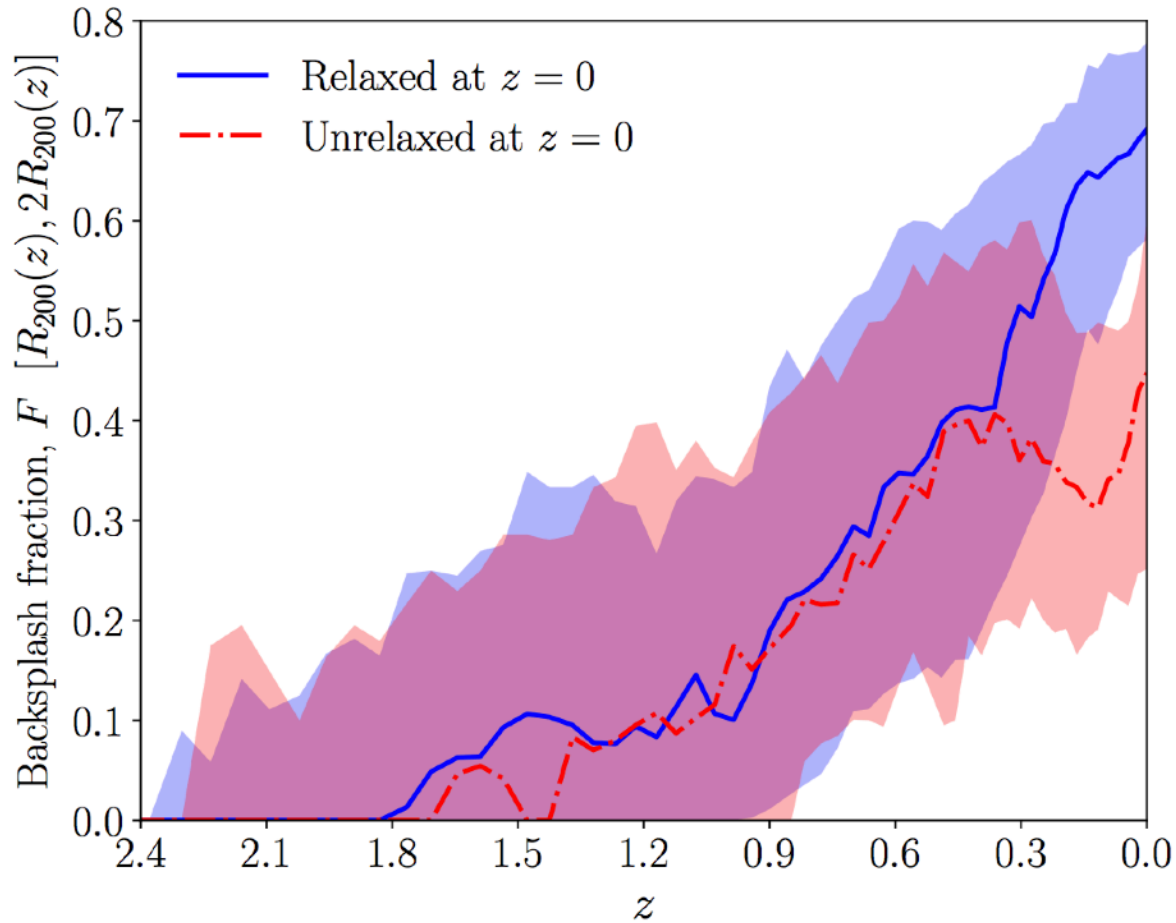
$f_{\text{backsplash}}$ depends on cluster dynamical state



Haggar+ 2020

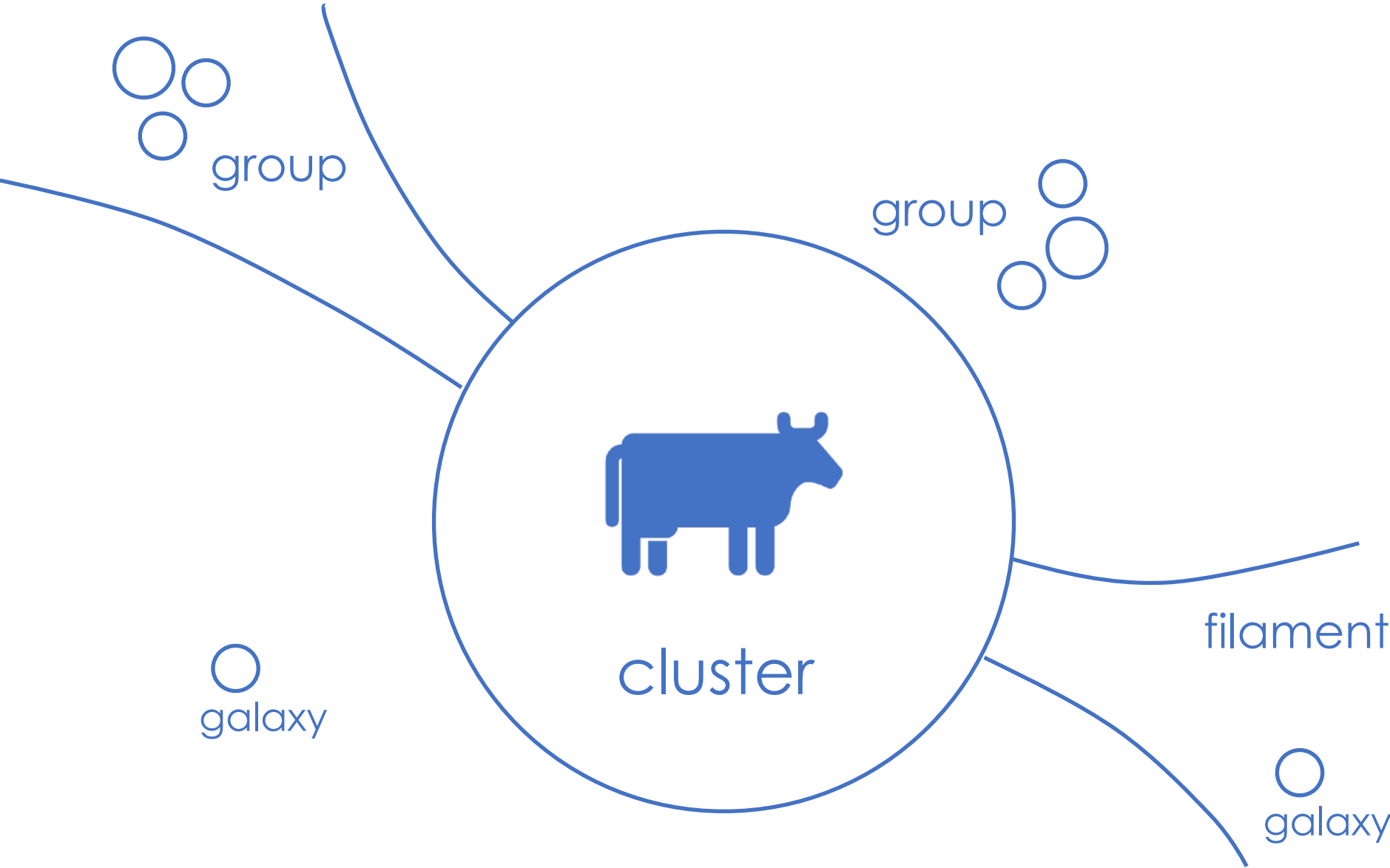
$f_{\text{backsplash}}$ becomes prominent at $z < 0.4$

...and depends on the recent dynamical history of the cluster

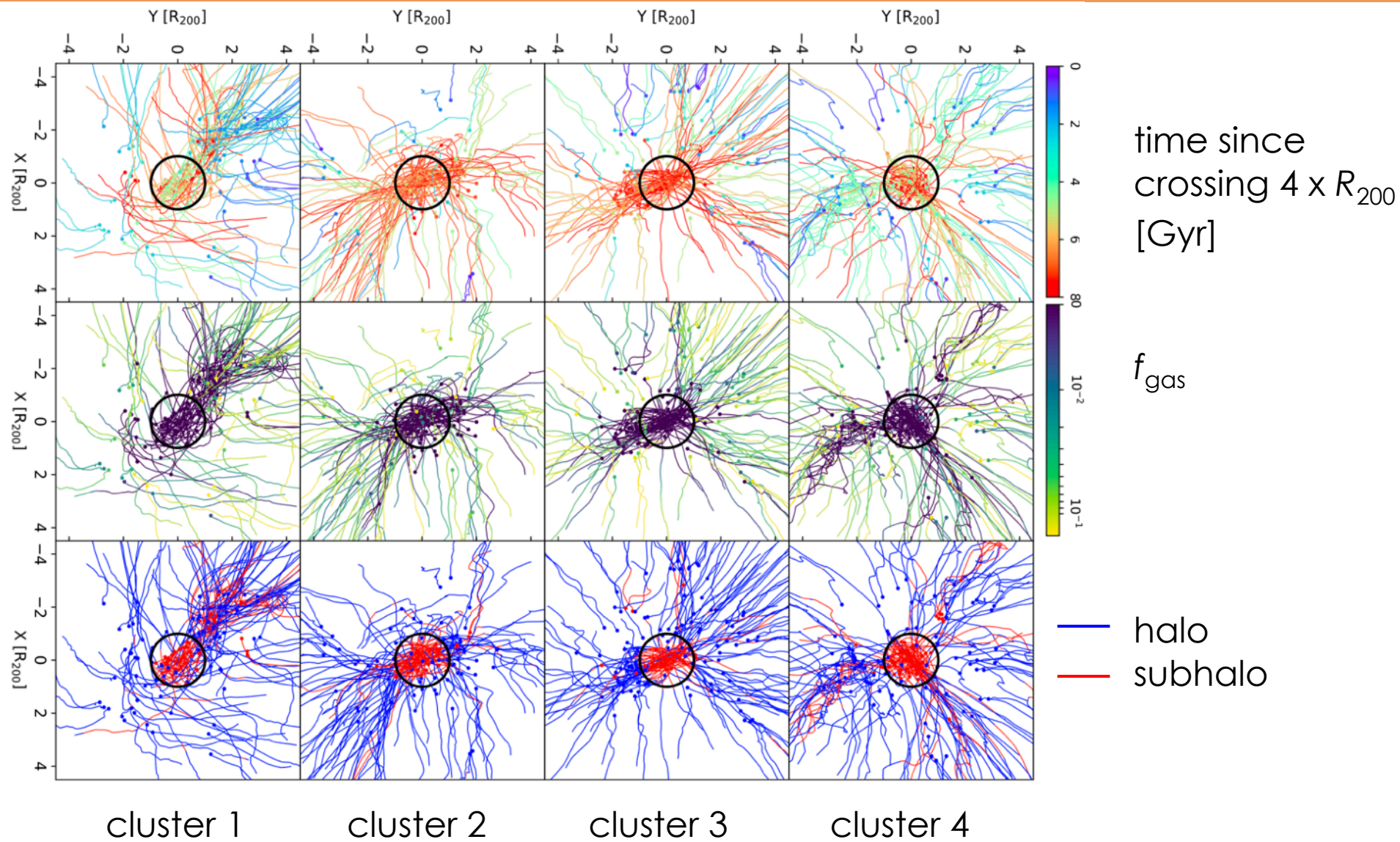


Haggar+ 2020

Beyond the spherical cow



Clusters have diverse assembly histories

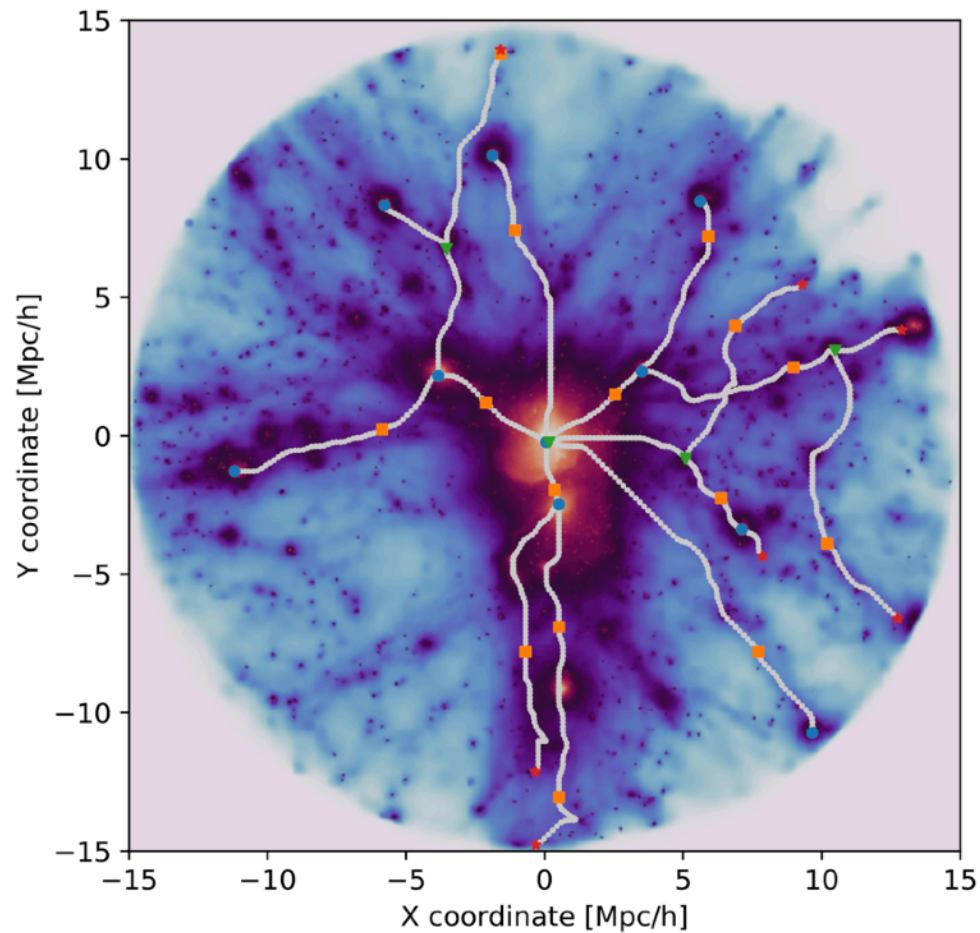


Filament detection in 3D with DisPerSE

Dr. Ulrike Kuchner,
Nottingham

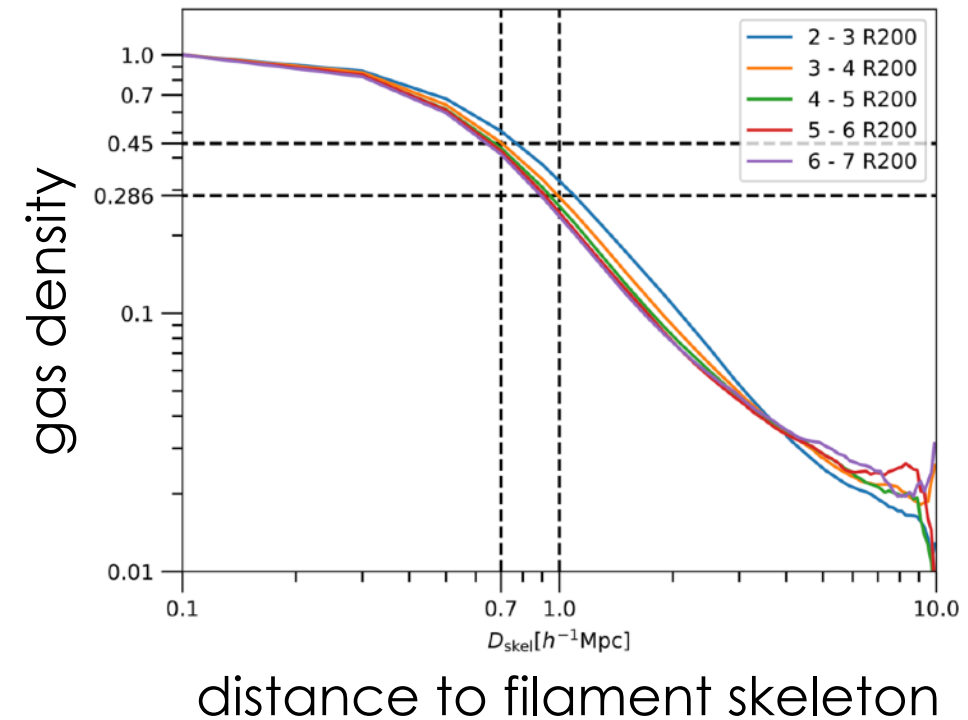


Agustín Rost
Nottingham/Cordoba

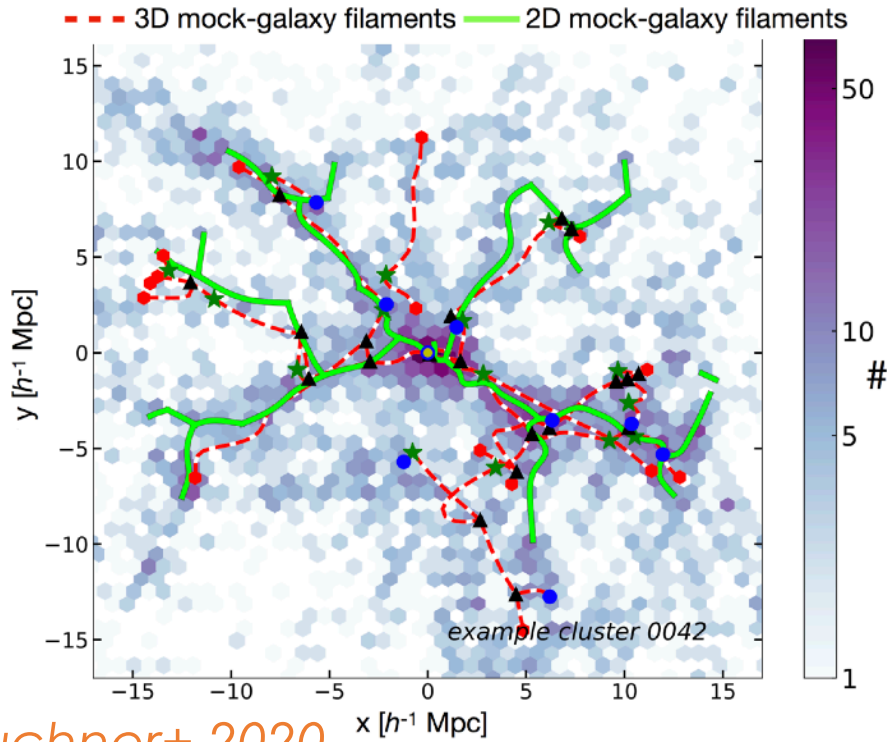


Rost+ in prep

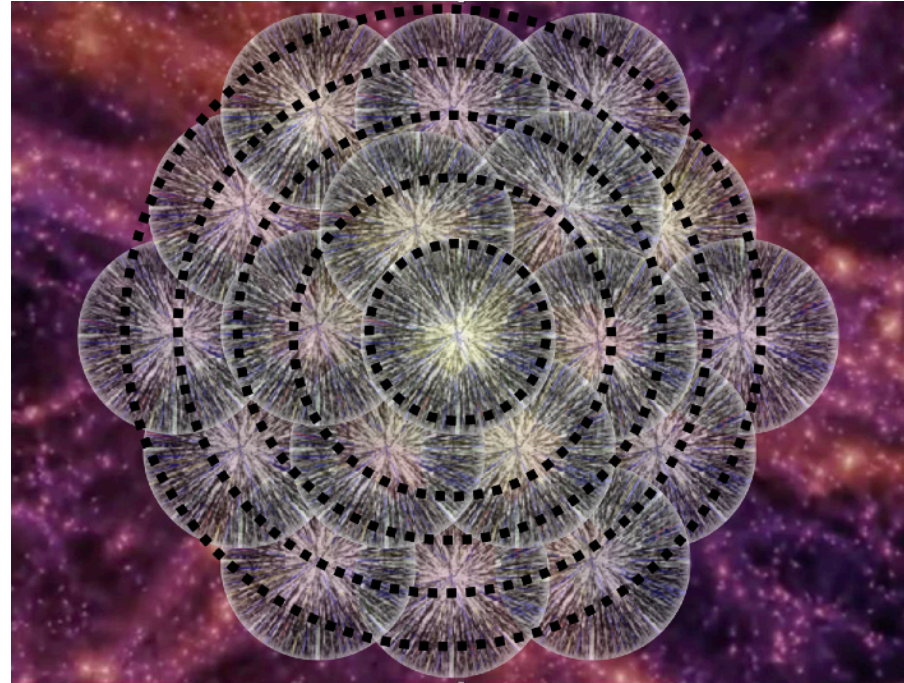
characteristic width:
Kuchner+ 2020



Preparing for WEAVE Wide-Field Cluster Survey



Kuchner+ 2020



16-20 clusters
 $0.04 < z < 0.07$

first light Dec 2020

4000 – 6000
spectra/cluster
to $5 \times R_{200}$

See S2b Tues 14:55 (Talk 281)
Ulrike Kuchner

fraction of galaxies in filaments
preferential feeding (and backplash)
strategies for filament detection

Summary: How well do we know where we are in the cosmic web?

simulations

full knowledge of environment
using full 6D info
+
orbital tracking

“truth table”

The 300

quantifying halo environment
+
environmental histories

ram pressure,
gas fractions,
quenching timescales

difference between full 6D measurements and LOS projections

backsplash, filaments, galaxies as tracers

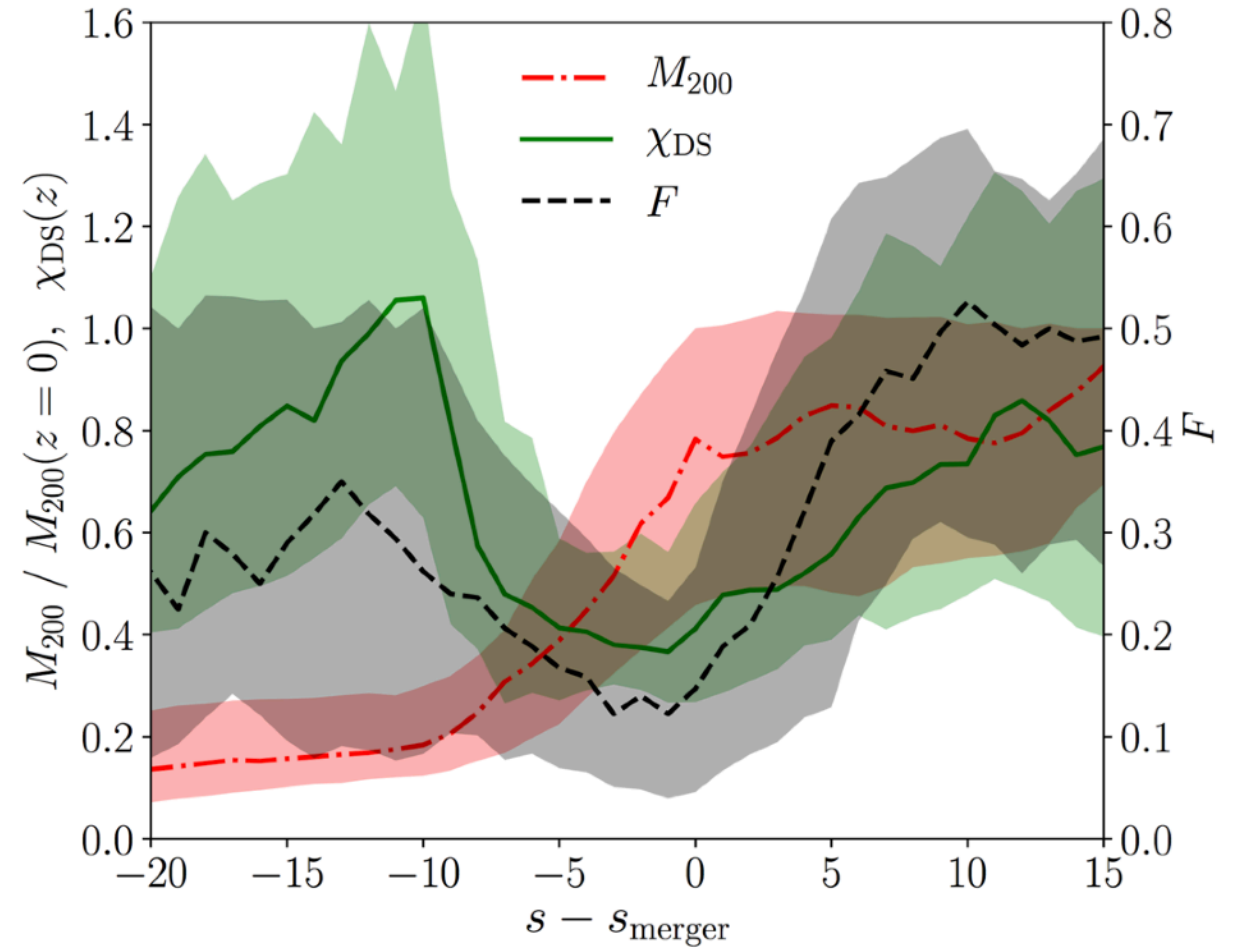
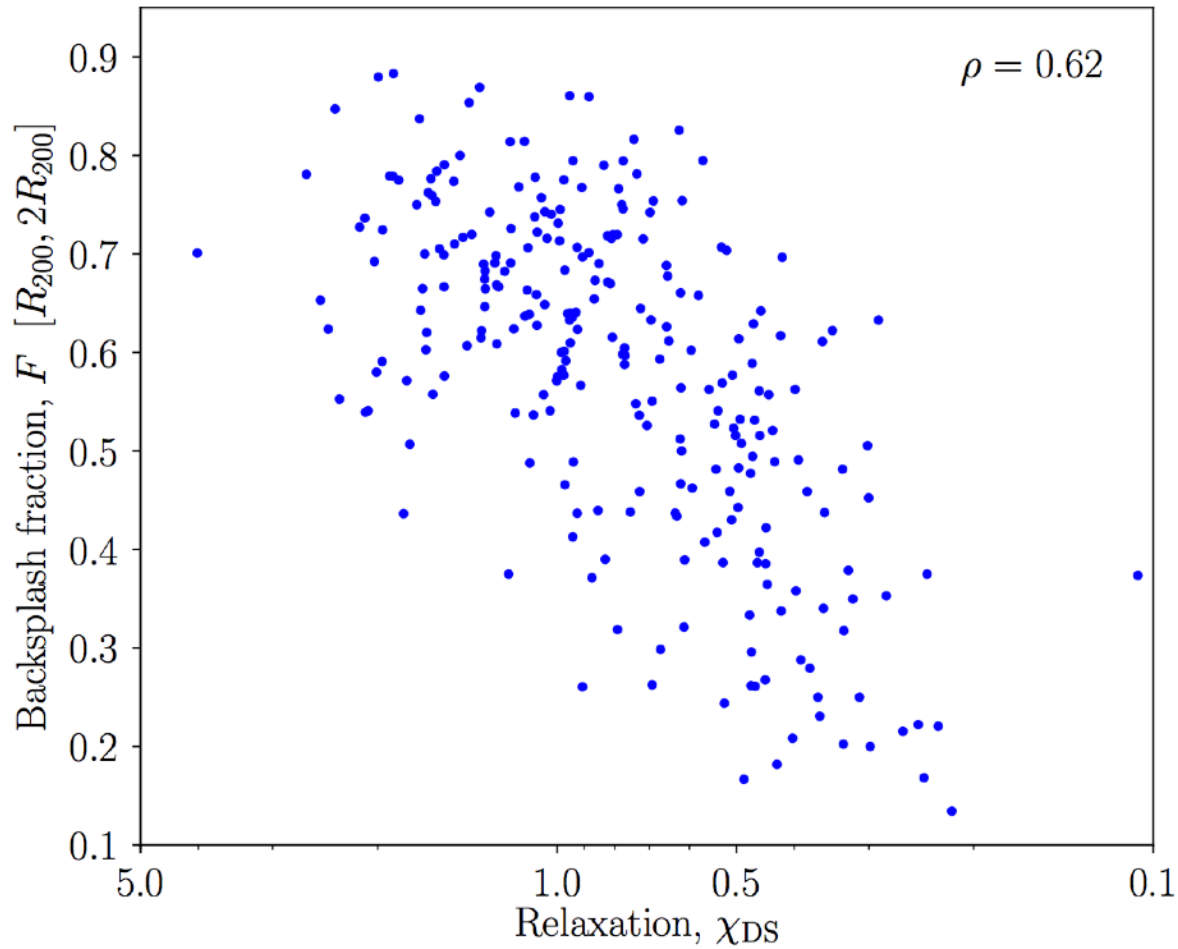
observations

observations using only (x,y) positions plus LOS velocity (at best)

star formation, morphologies

WEAVE

$f_{\text{backsplash}}$ depends on cluster dynamical state



Towards observations: projection effects

