Dwarfs, Large Scale Structure, and Satellites

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Dependence of galaxy growth on environment as a source of diversity for dwarfs

ICC

Durham University

- An intro to dwarf galaxies - why do we care about what they're up to in simulations?
- How do we get around the multi-scale problem of dwarf galaxies and the cosmic web?
- What do we see when we examine dwarf galaxies in the context of the cosmic web?

Why care about Dwarf Galaxies in Simulations?

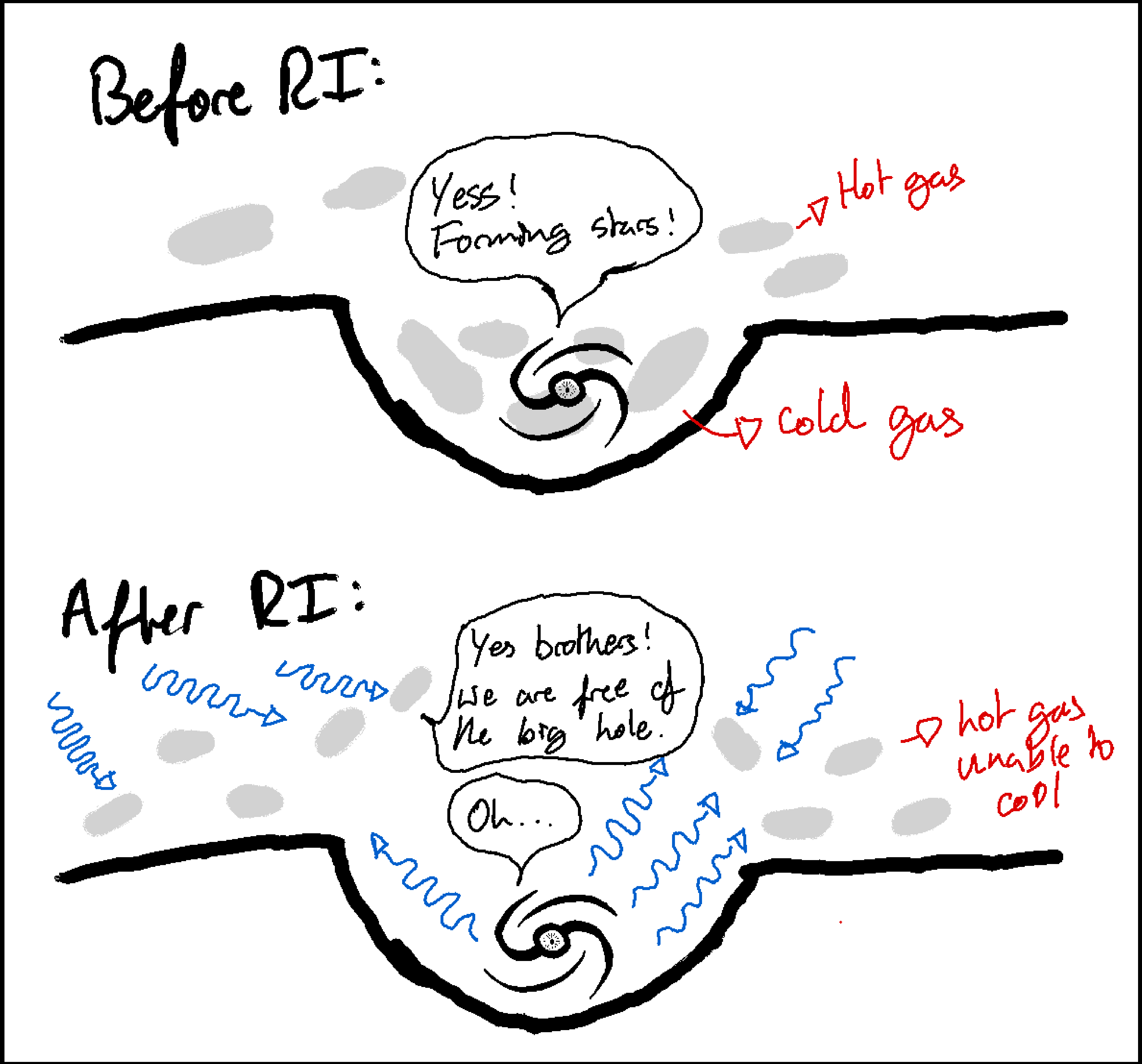
Dwarf galaxies have shallow potential wells

↓

More vulnerable to effects from the environment (eg. reionisation) and internal feedback (eg. supernova feedback)

↓

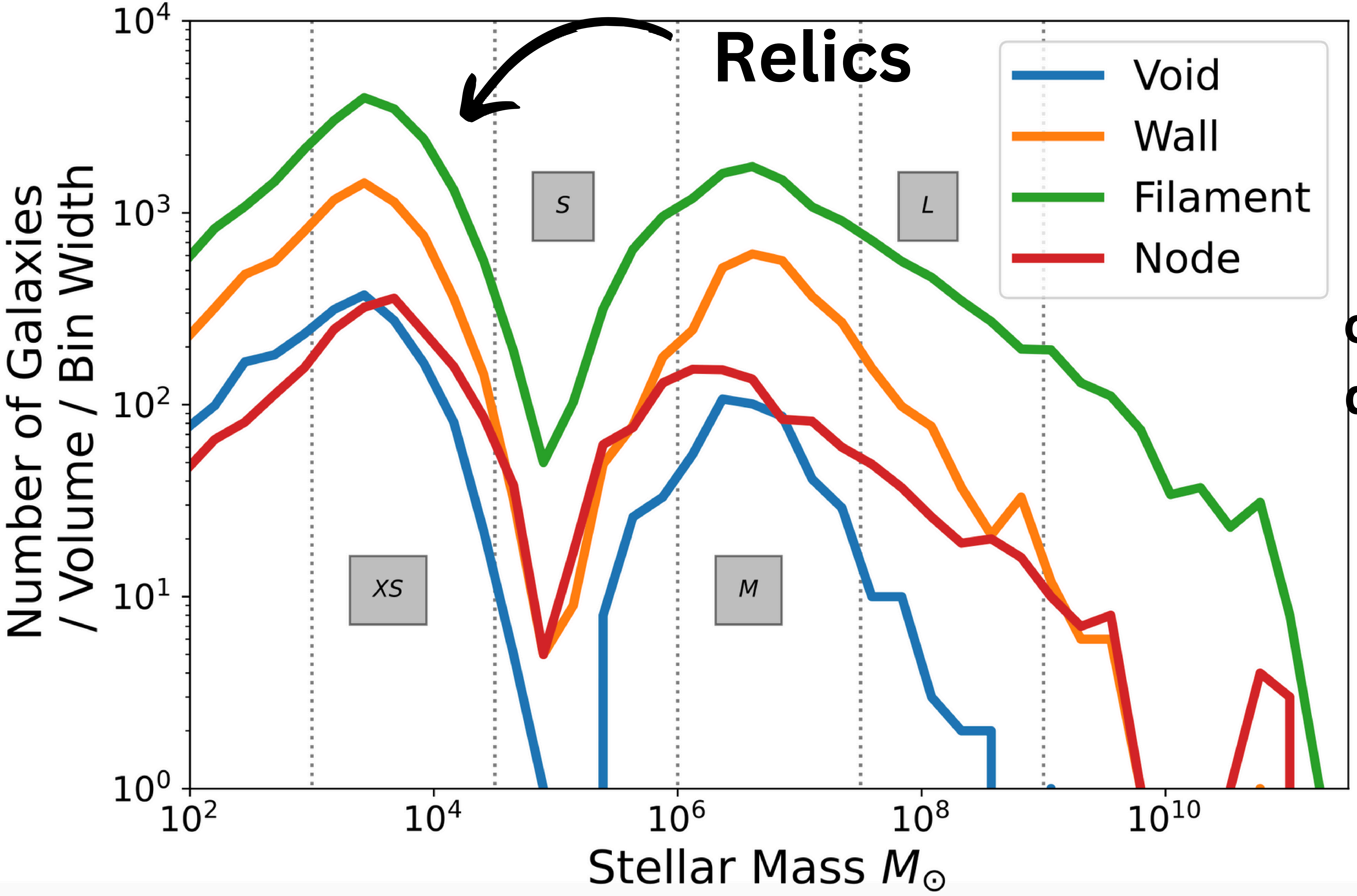
When can use dwarf galaxy simulations to constain the feedback mechanisms we use in all galaxies.



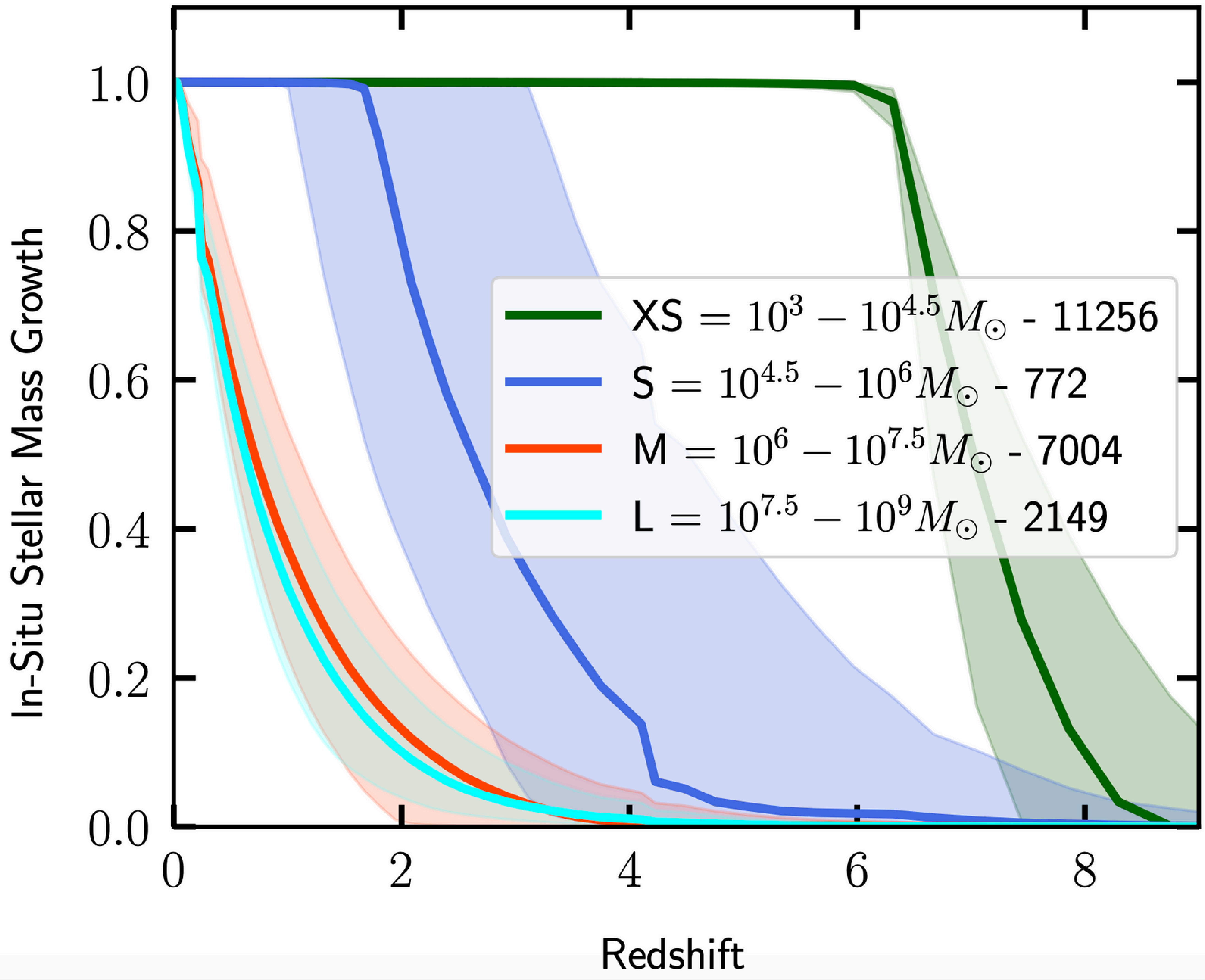
Why investigate the impact of the LSS on dwarf galaxies?

1) We know that large scale structure affects more massive galaxies, but we don’t know how it would affect dwarf galaxies!

2) There is a lot of diversity in the stellar mass assemblies of dwarfs, we want to know why and what causes it!

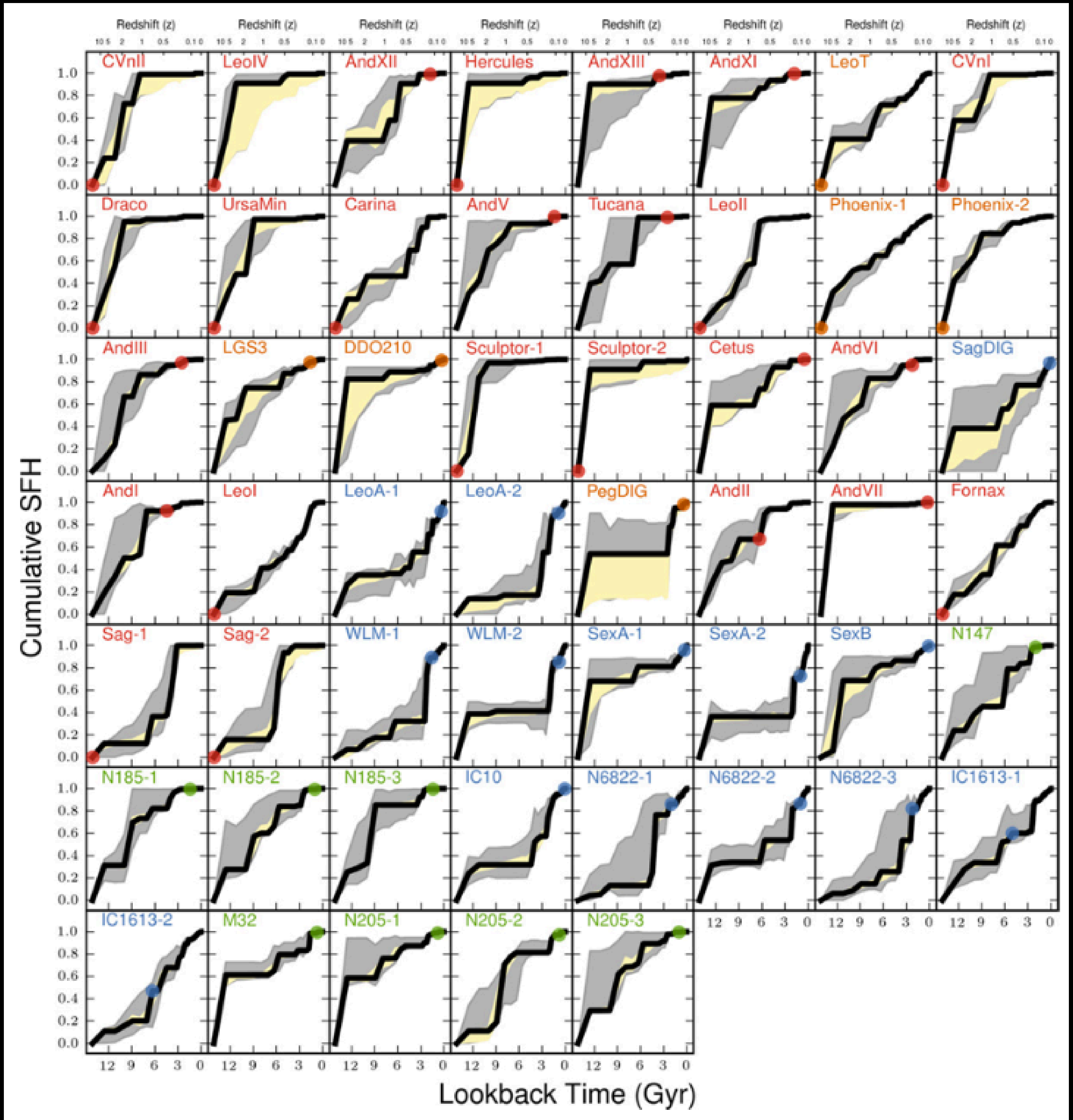


SMF has a characteristic dip caused by reionization (Bose et al. 2018)

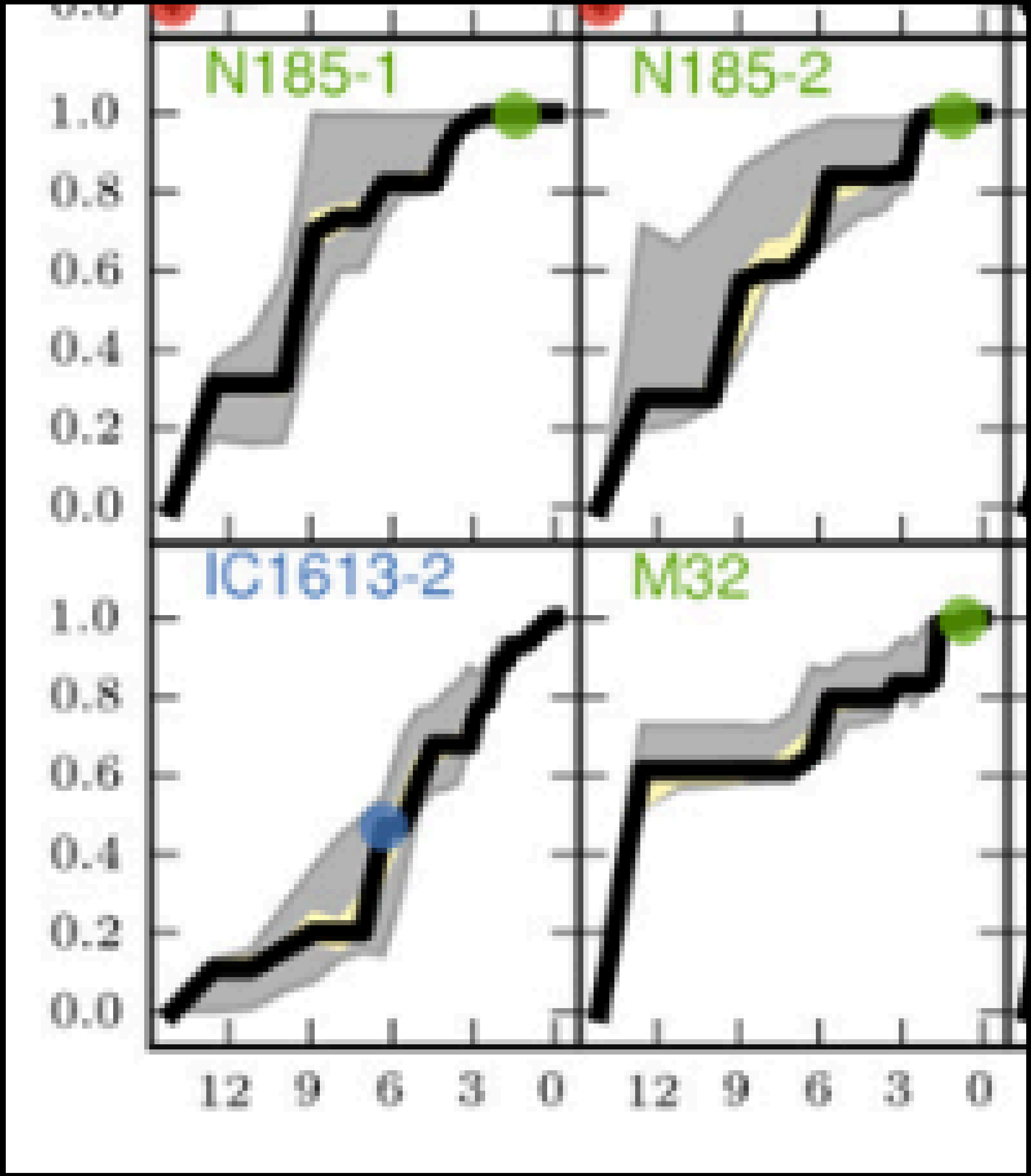


Final-day mass has a huge effect on the stellar mass assembly of galaxies.

2 Groups: relics and "normal" dwarfs.



Weisz et al. 2014



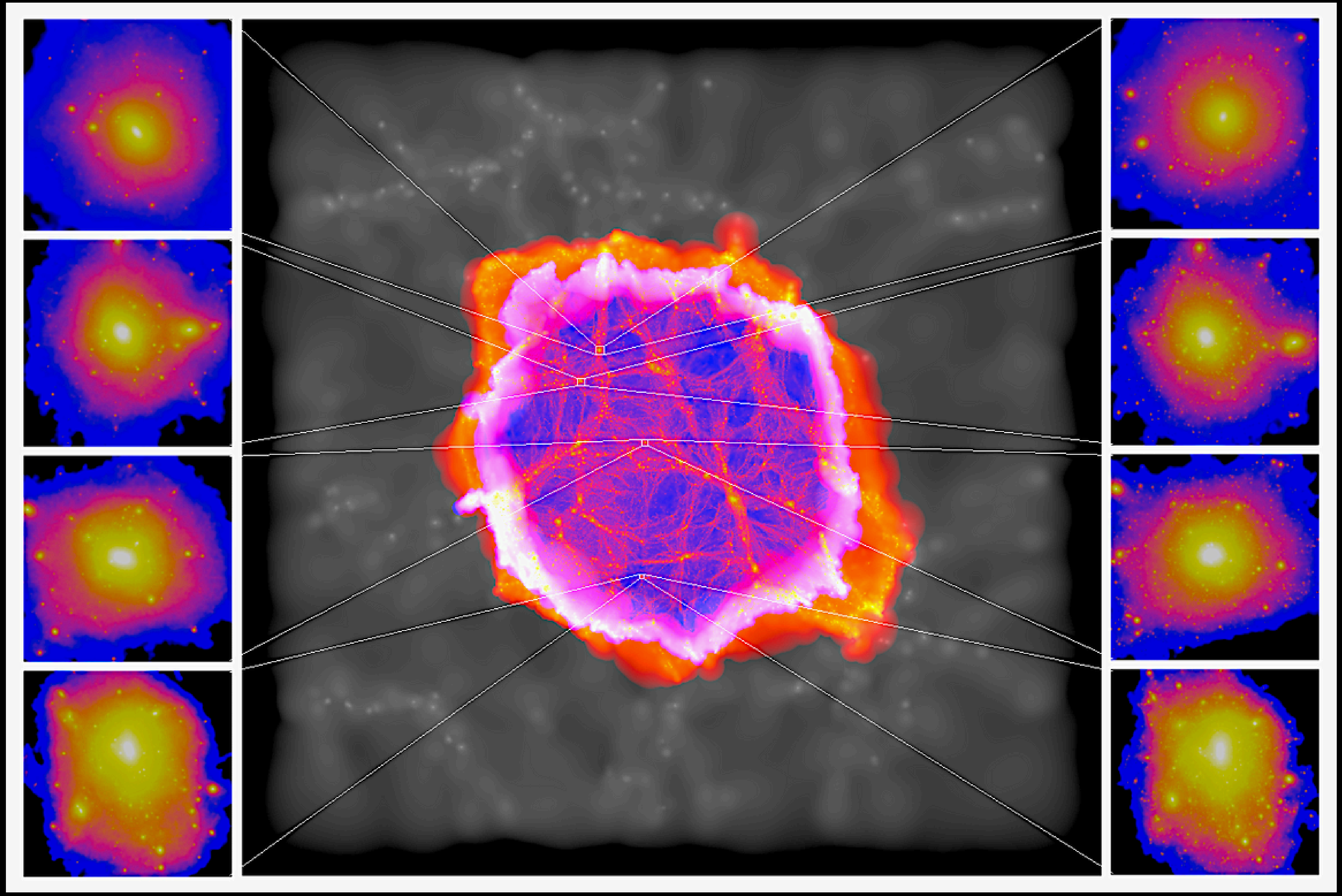
How do we get around the problem of simulating the smallest galaxies within the largest structures in the universe?

COCO + GALFORM + NEXUS!

Copernicus Complexio (COCO)

Wojciech Hellwing et al. 2016

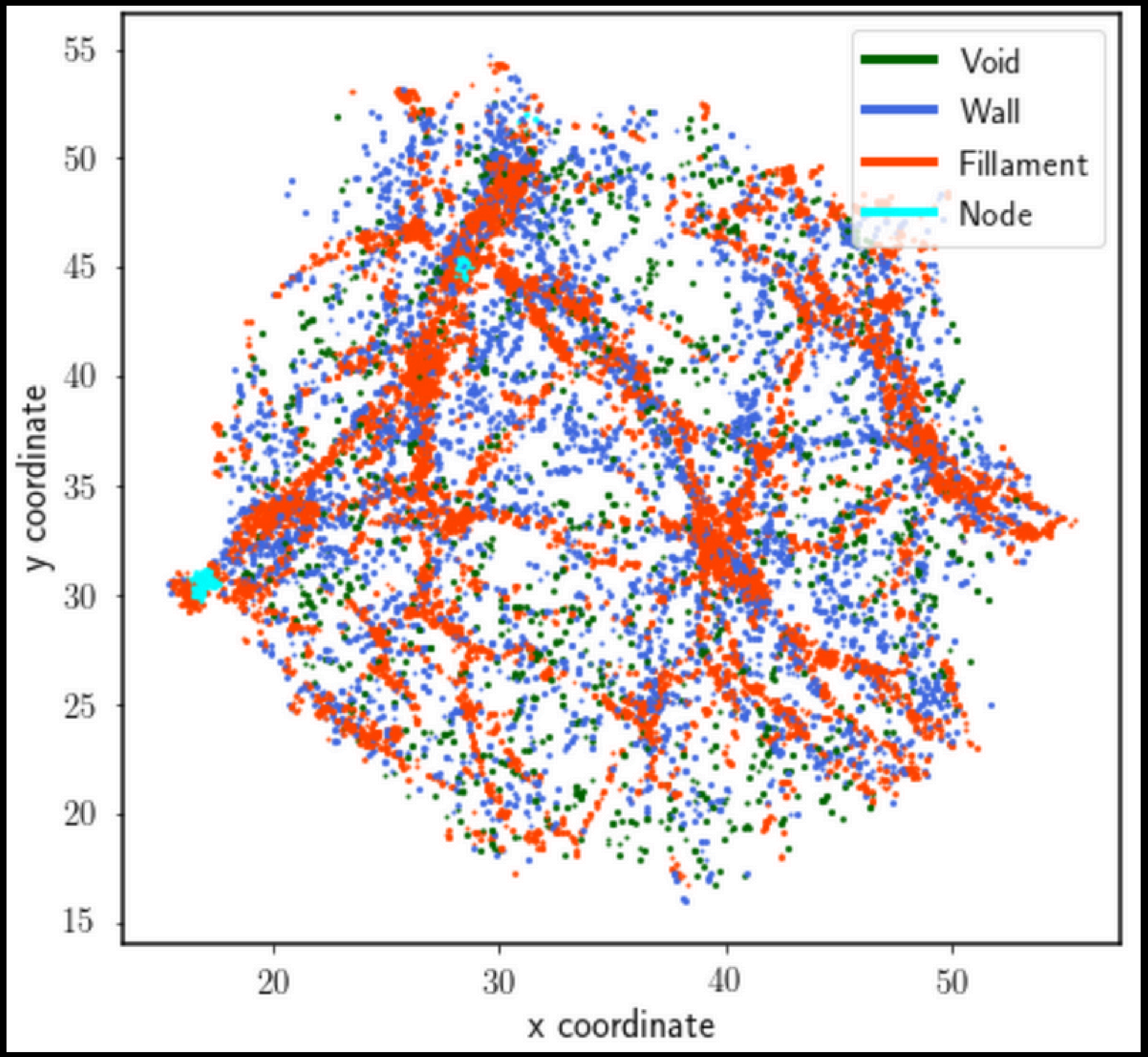
- Large region called COLOR with lower resolution (100 Mpc box)
- Central region (COCO) has higher resolution - DM ~ 1.6 x 10^5 Solar masses
- Minimum haloes are 10^6 Solar masses
- Simulation is dark matter only

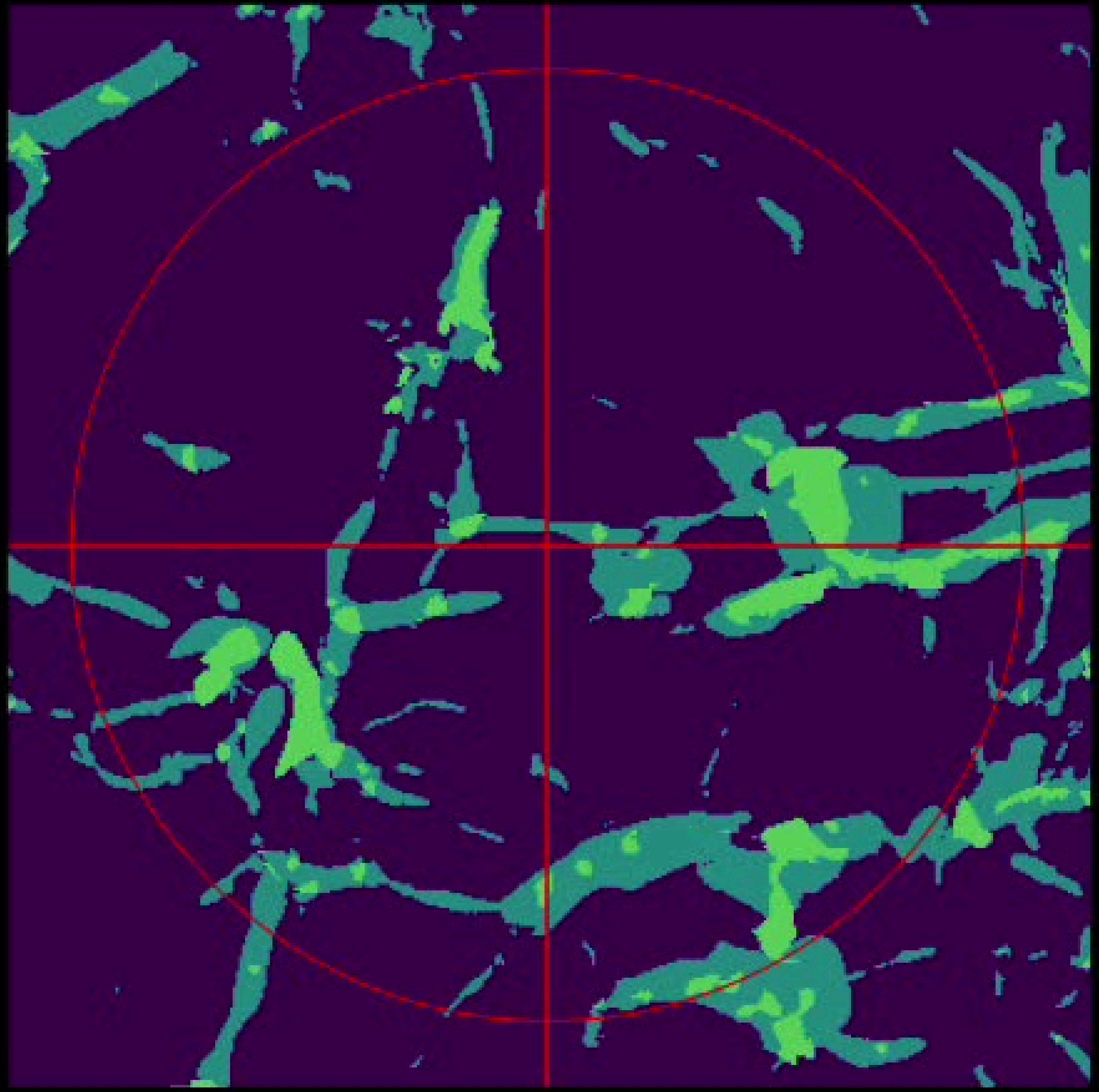


NEXUS

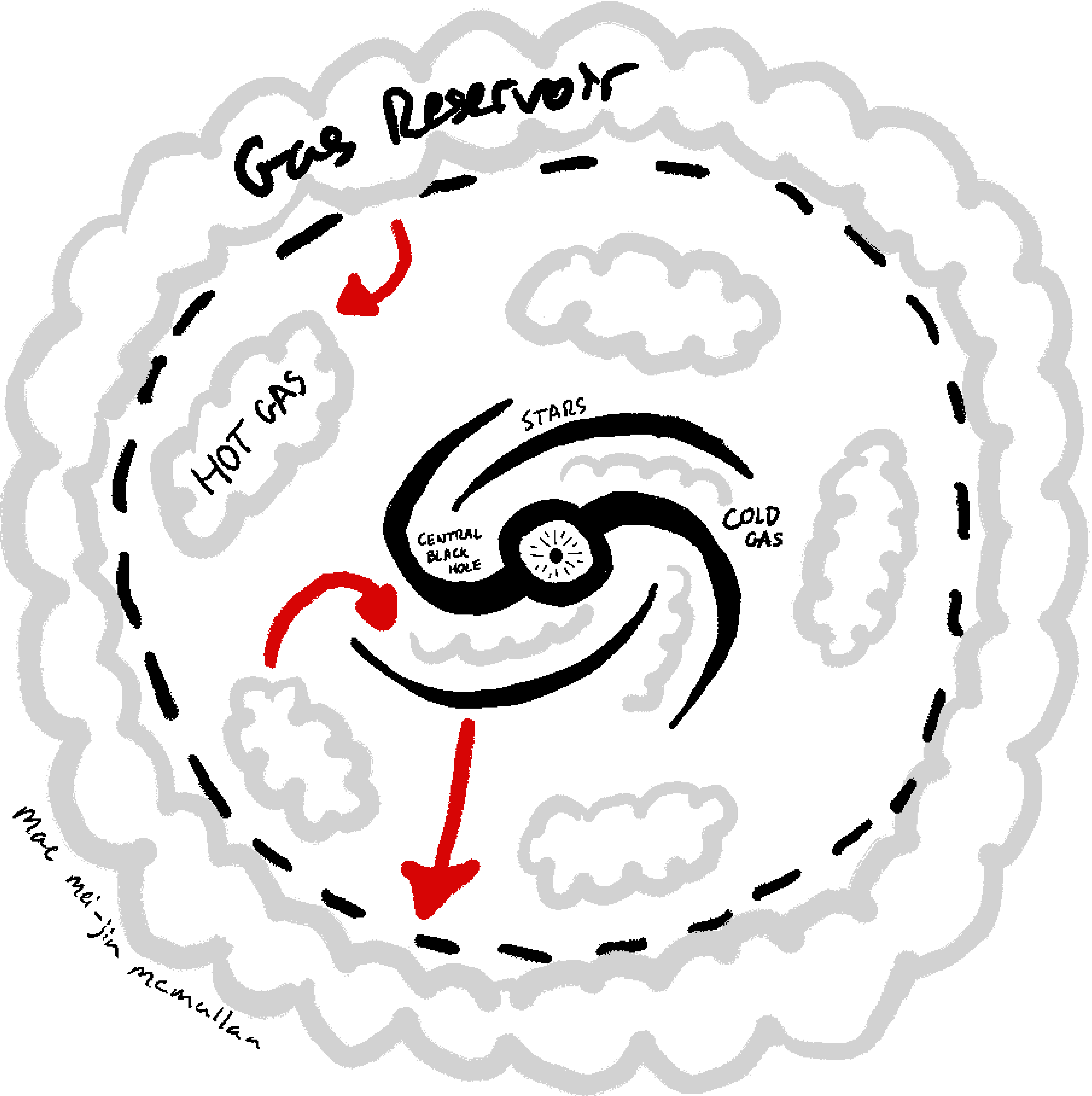
by Marius Cautun

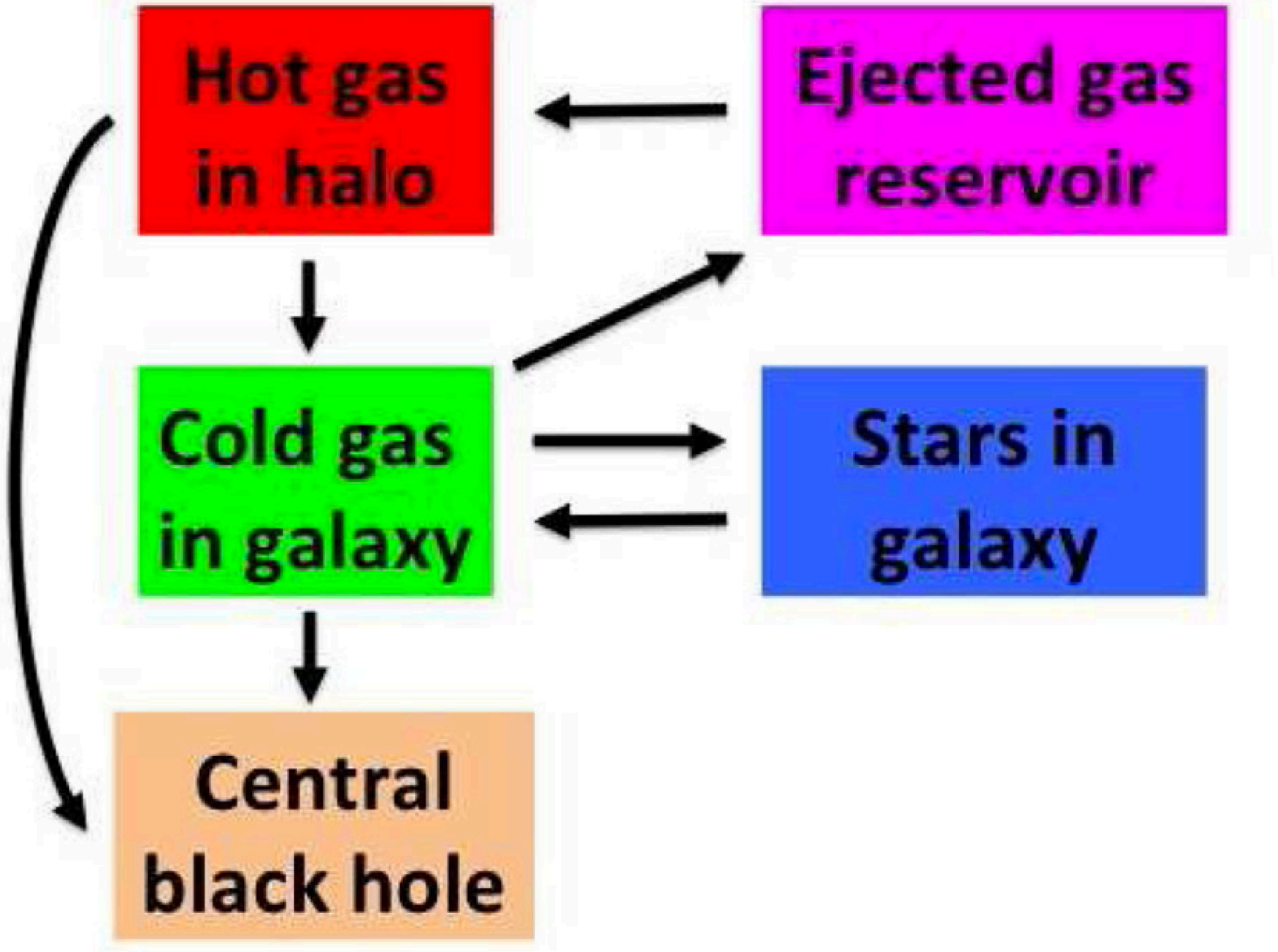
Solves Hessian matrix to find the large scale structure flags. Computationally expensive.





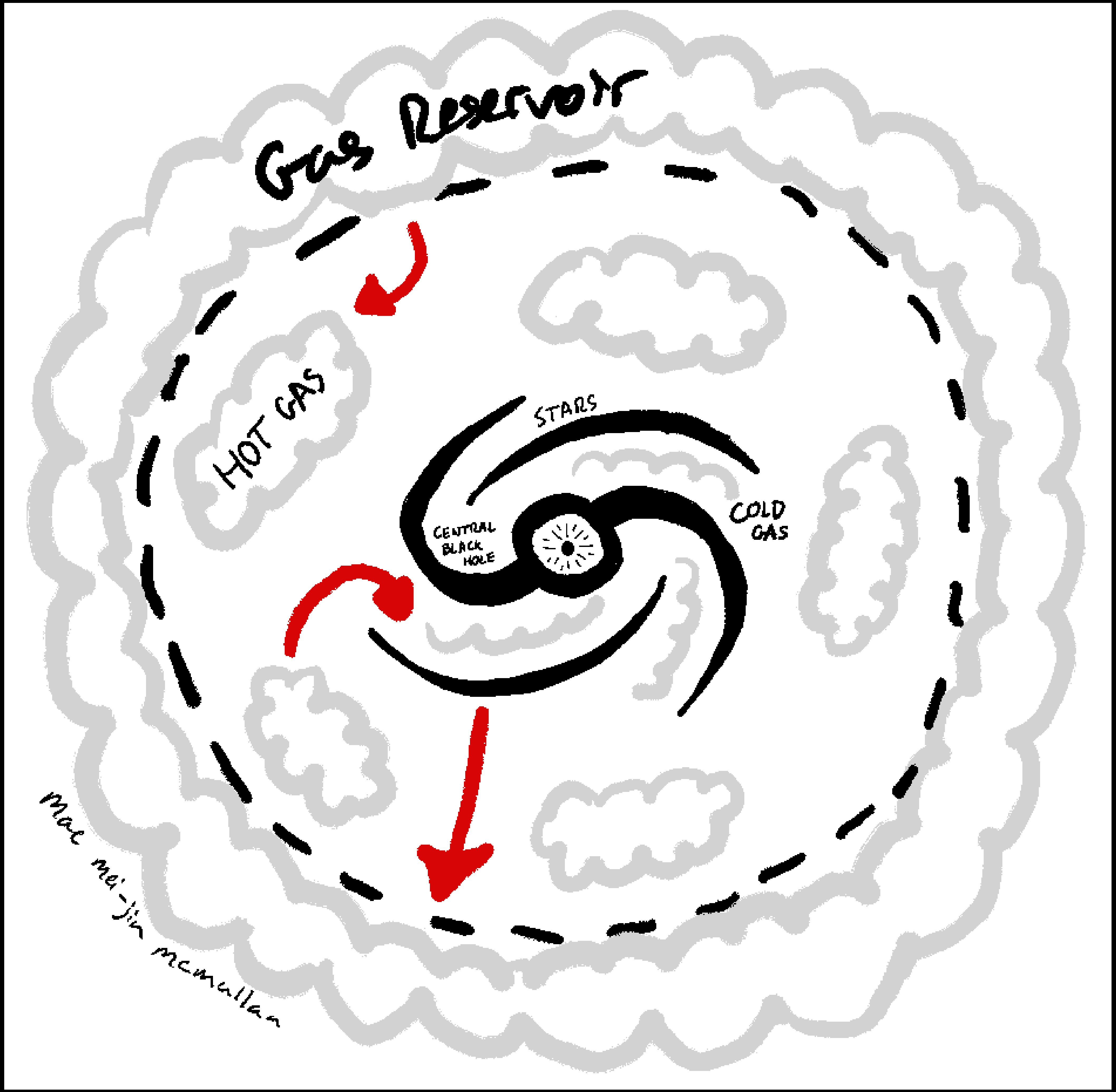
Credit: Tilly Evans-Hofmann





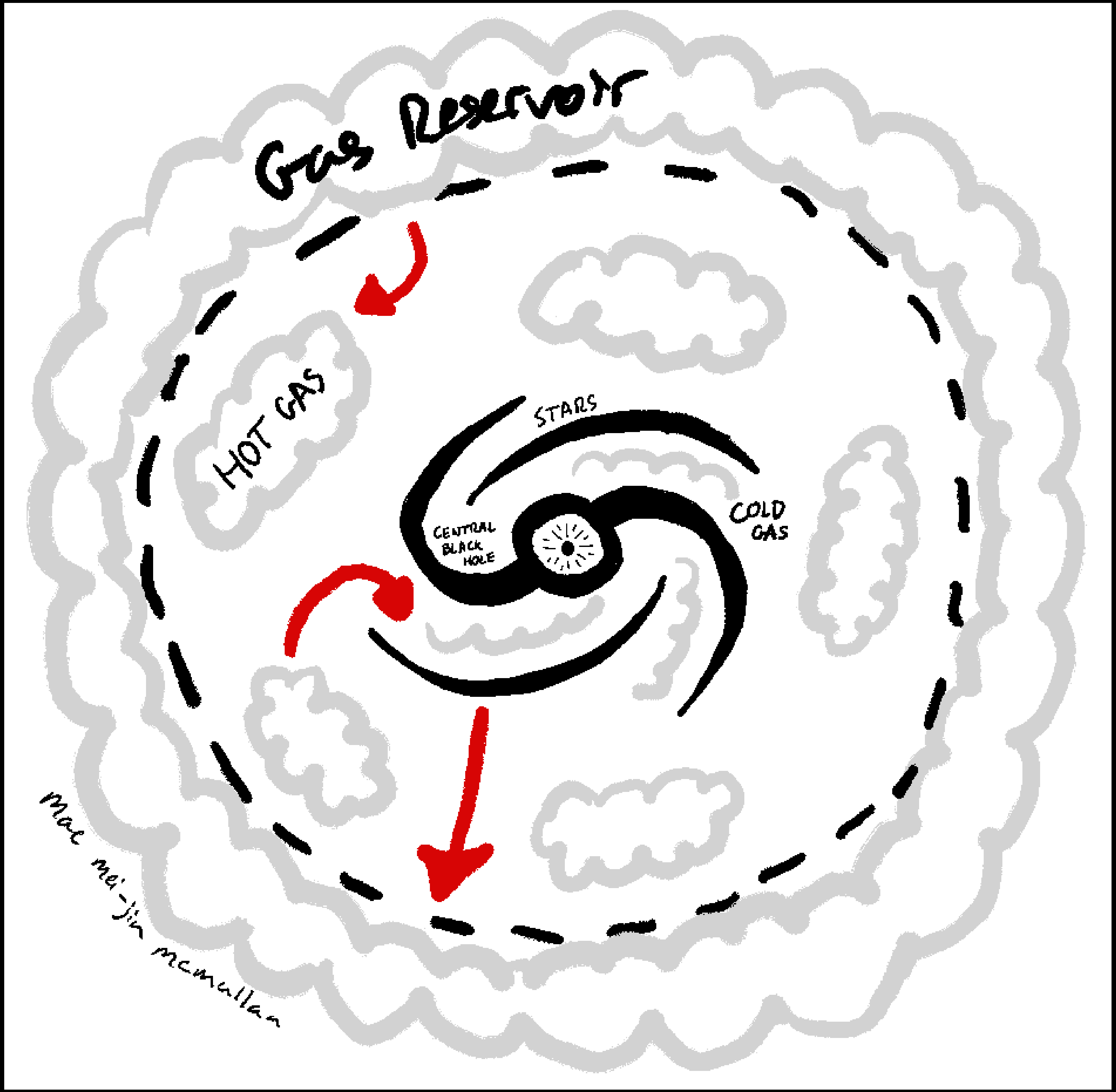
GALFORM!

Lacey et al. 2016



SAM Philosophy:

SAMs are a statistical model to understand the implications of our theories of galaxy evolution.



- Cold gas can be used to form stars or feed the central black hole.
- Remove cold gas or prevent gas cooling to stop star formation.

Gas prevented from cooling by:

- Reionization
- Atomic gas cooling limit
- Central galaxy becoming a satellite to larger host

REIONIZATION IN GALFORM

- RI happens at a given specific time, everywhere at once.
- zcut - this parameter controls when reionization happens in GALFORM.
- vcut - this parameter controls what haloes are affected by reionization after the zcut.

vs.

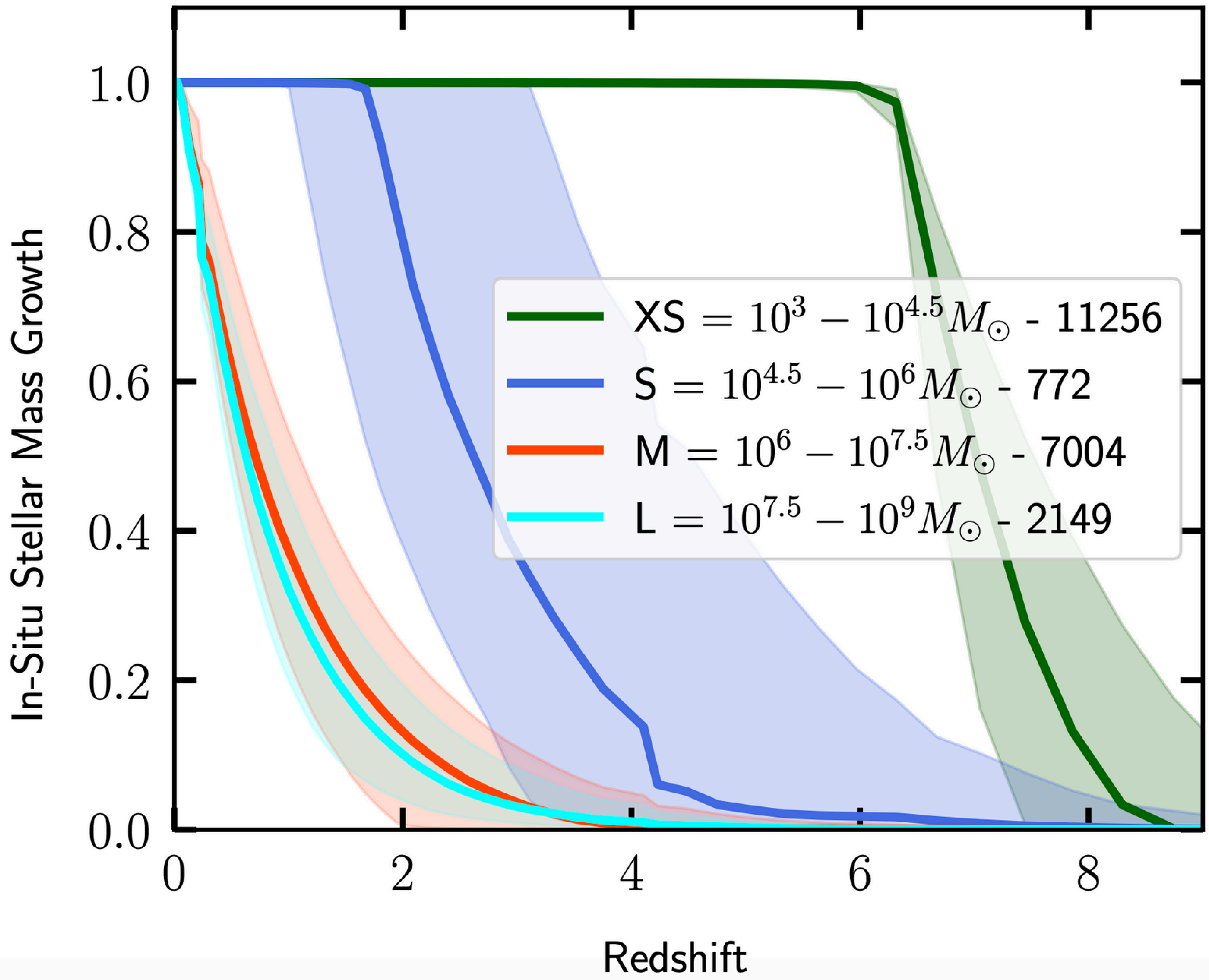
IRL, reionization doesn't happen everywhere at once...

There is no such thing as large-scale environment
there are individual central
galaxies, and there are satellites/orphans

— GALFORM —

AZ QUOTES

RESULTS



Final-day mass has a huge effect on the stellar mass assembly of galaxies.

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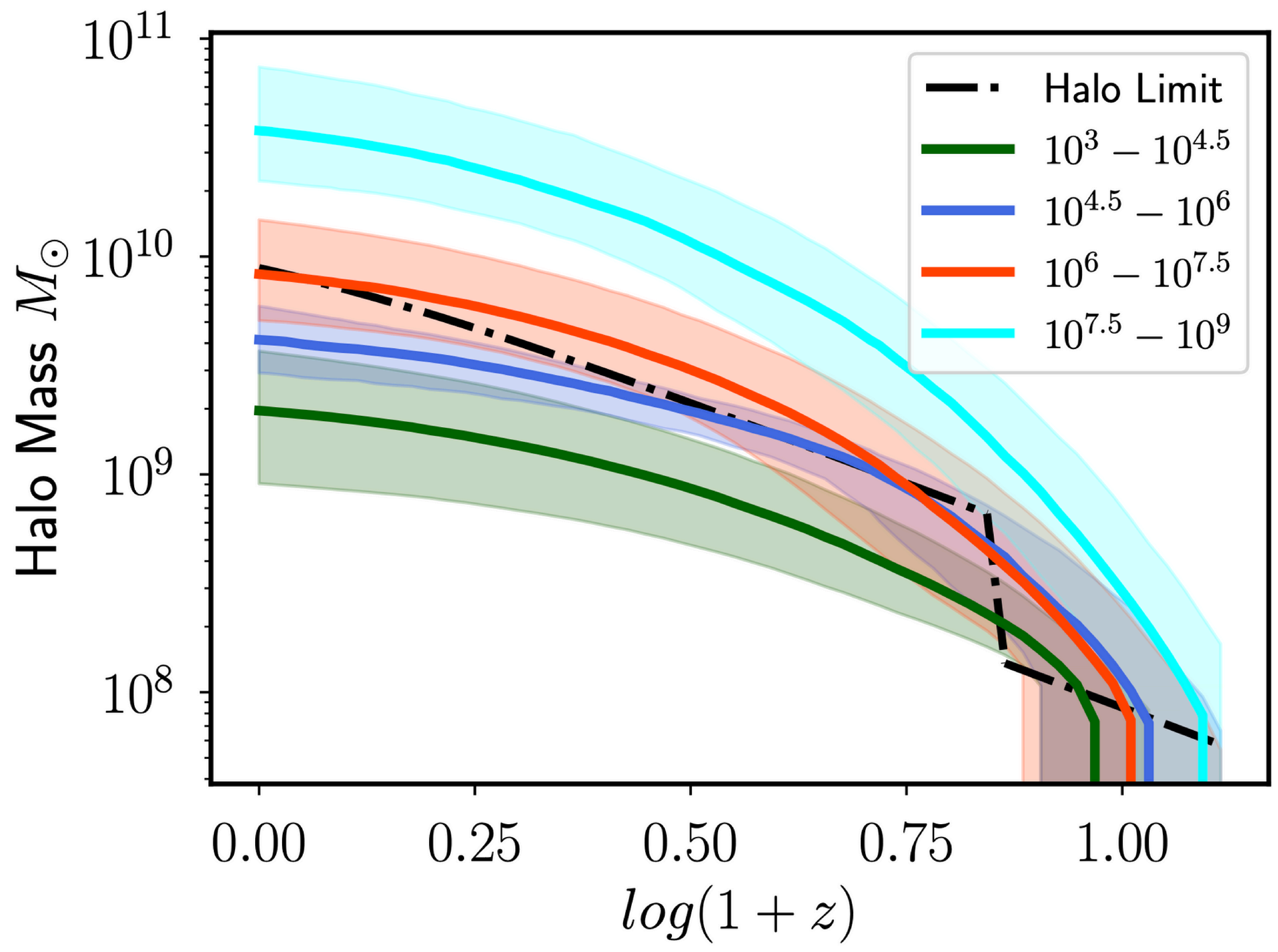
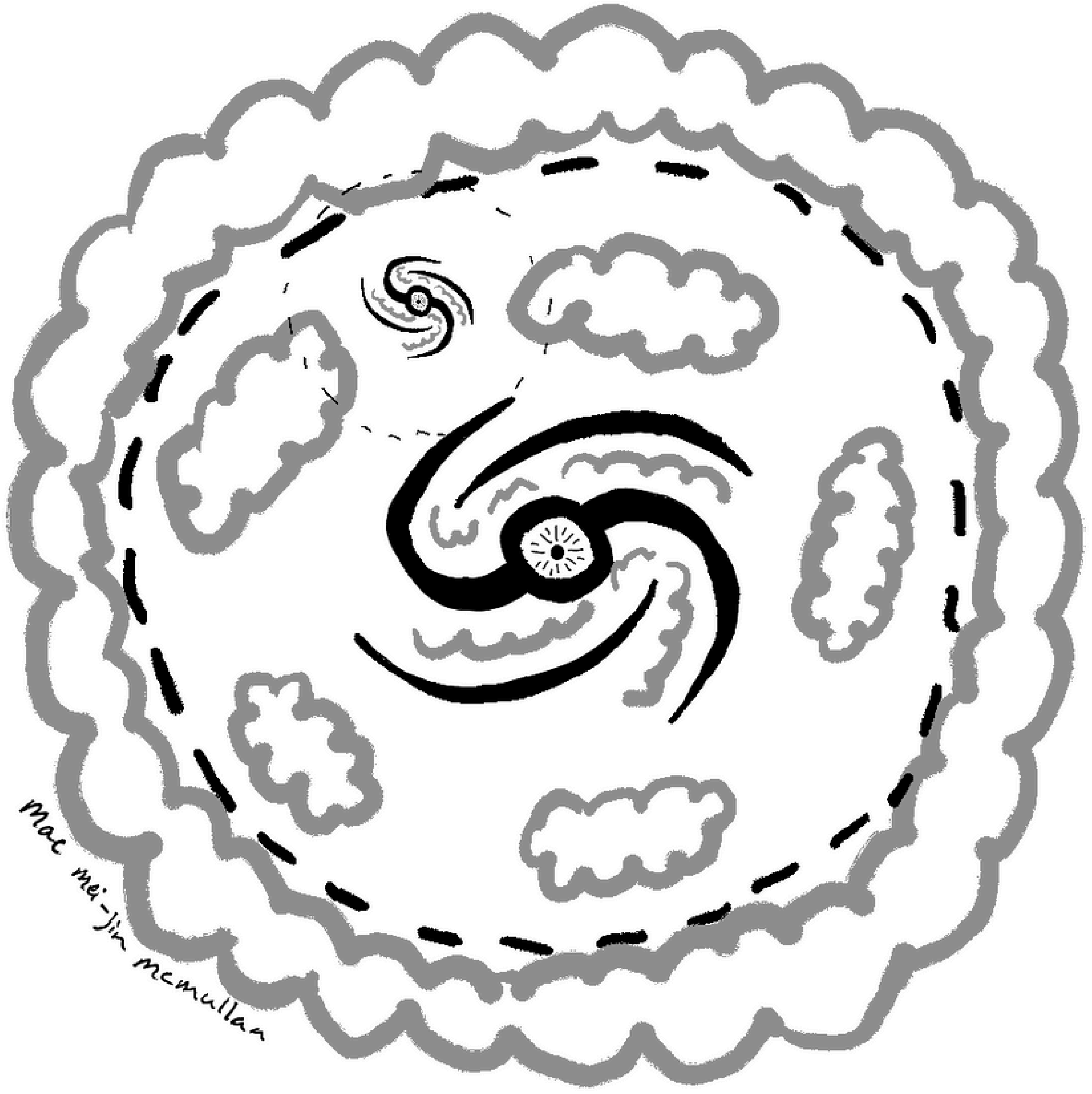


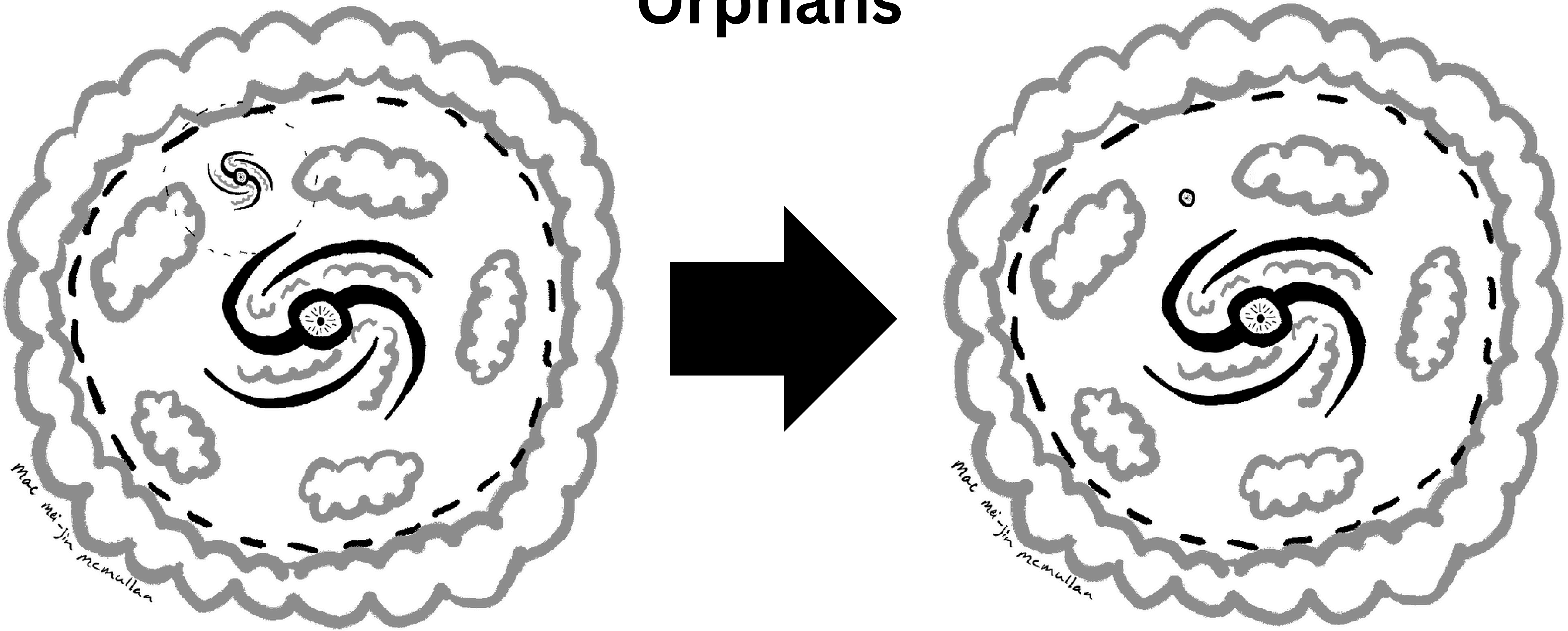
The gas cooling limit interacts with the haloes from each mass bins at different times.

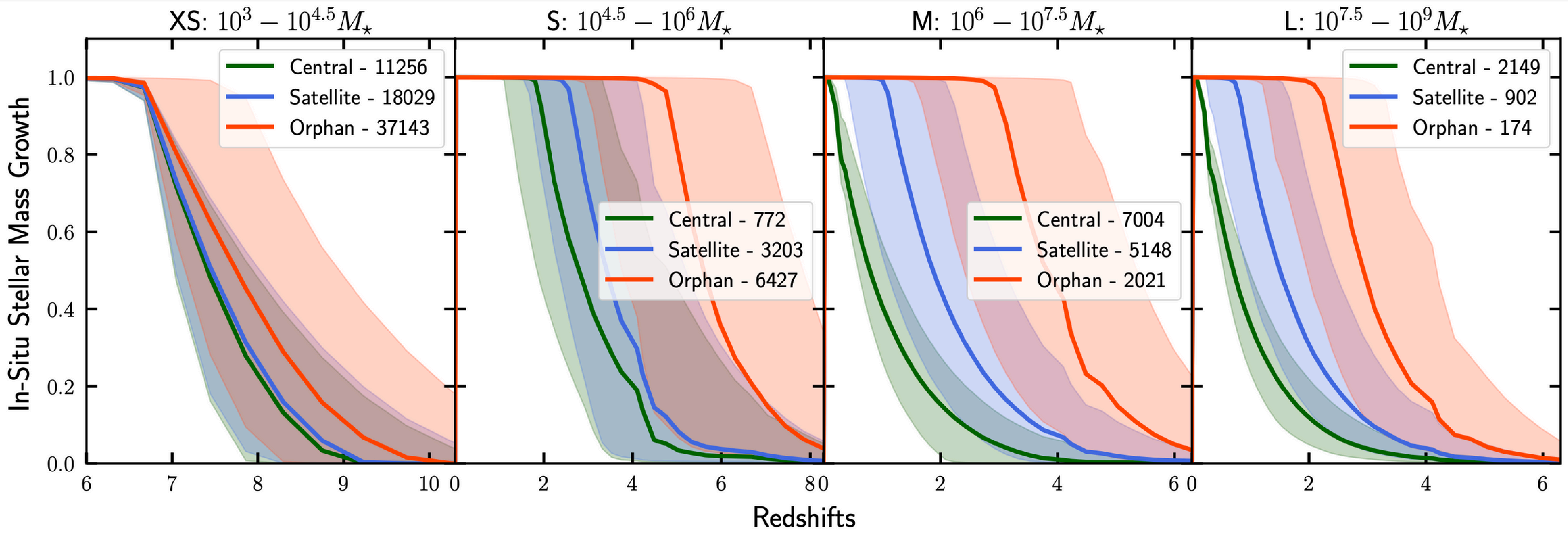


Satellites:

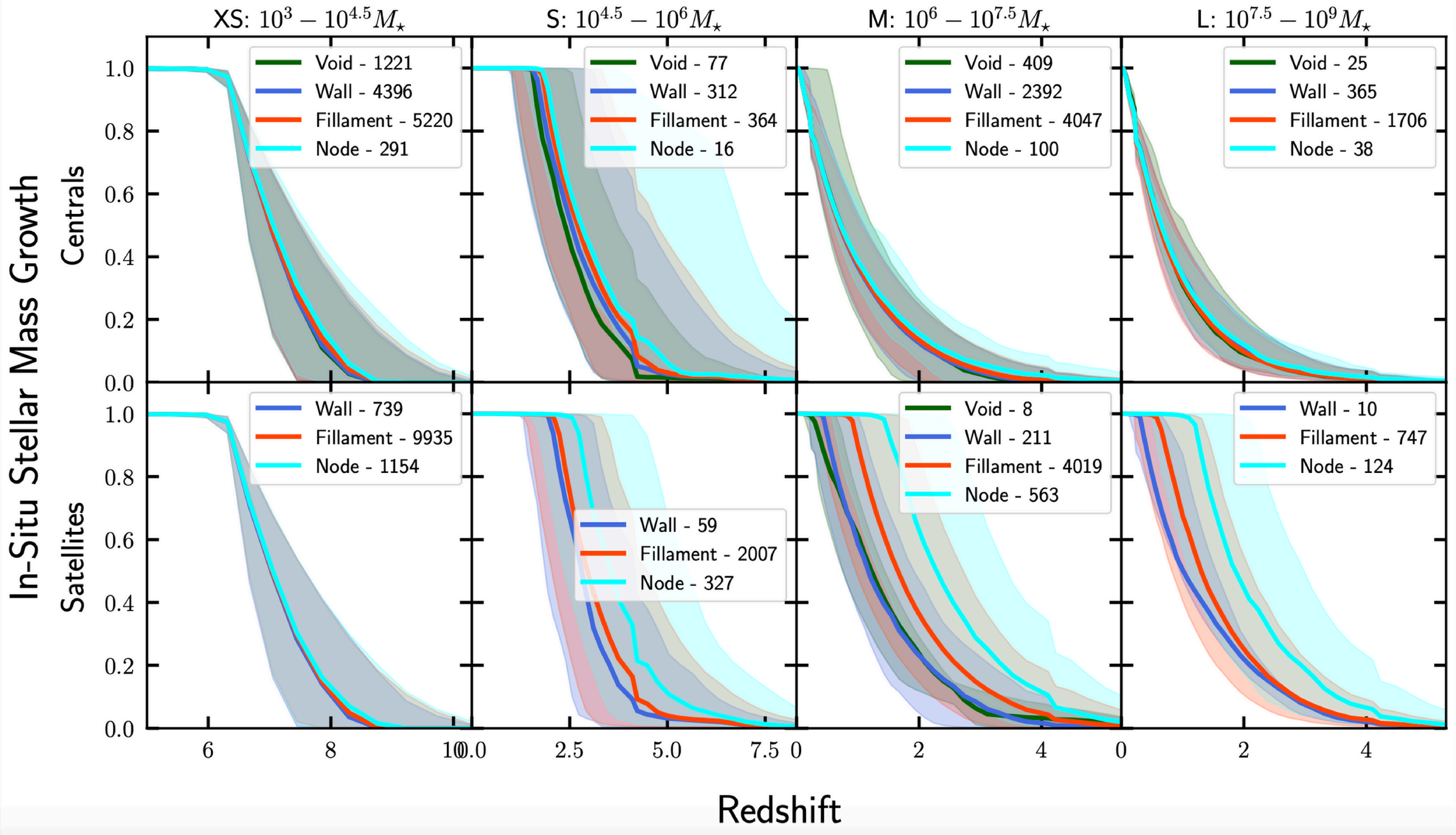
- Unable to cool cold gas in GALFORM
- Star formation dies out relatively soon after.

Orphans

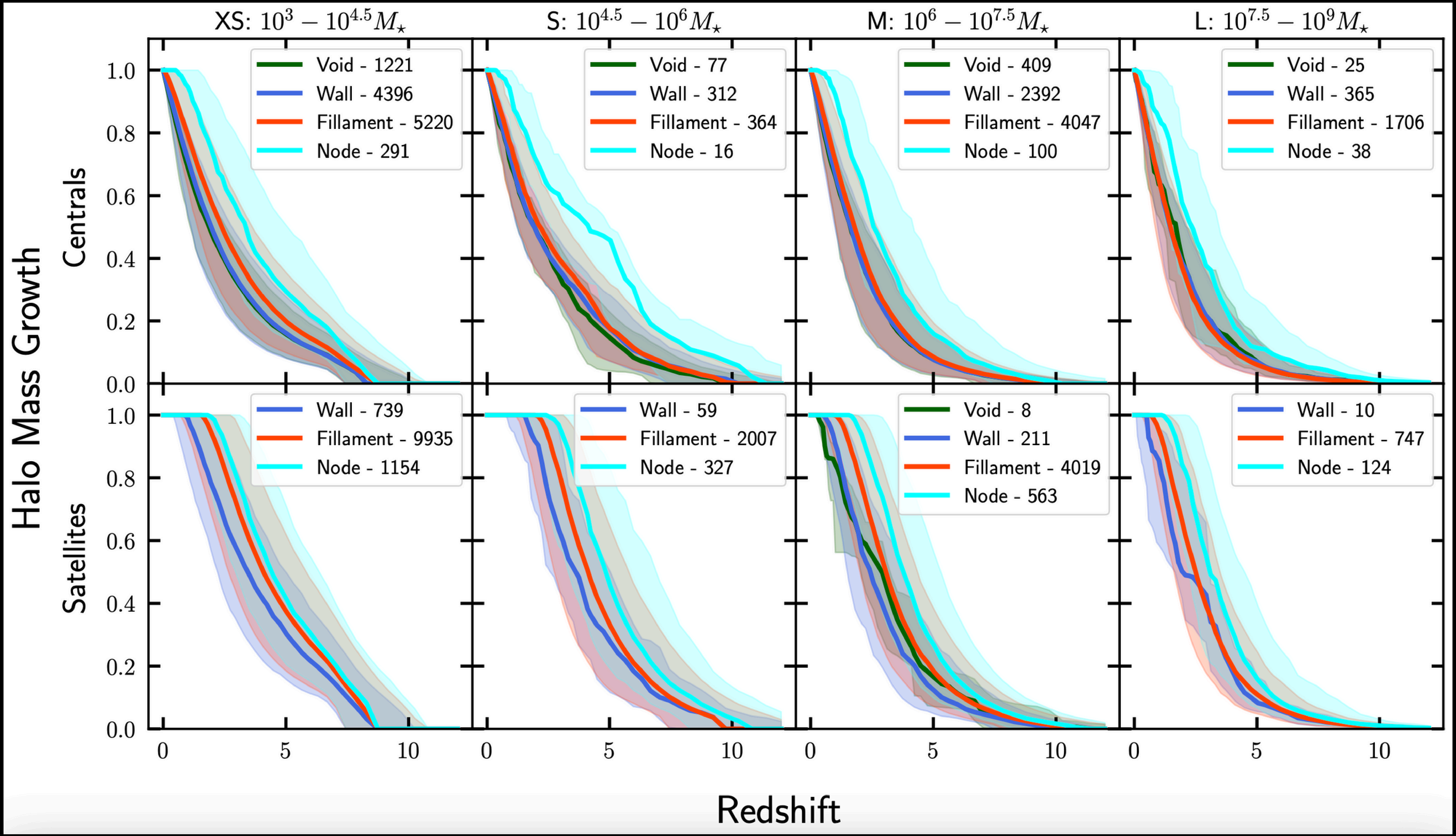




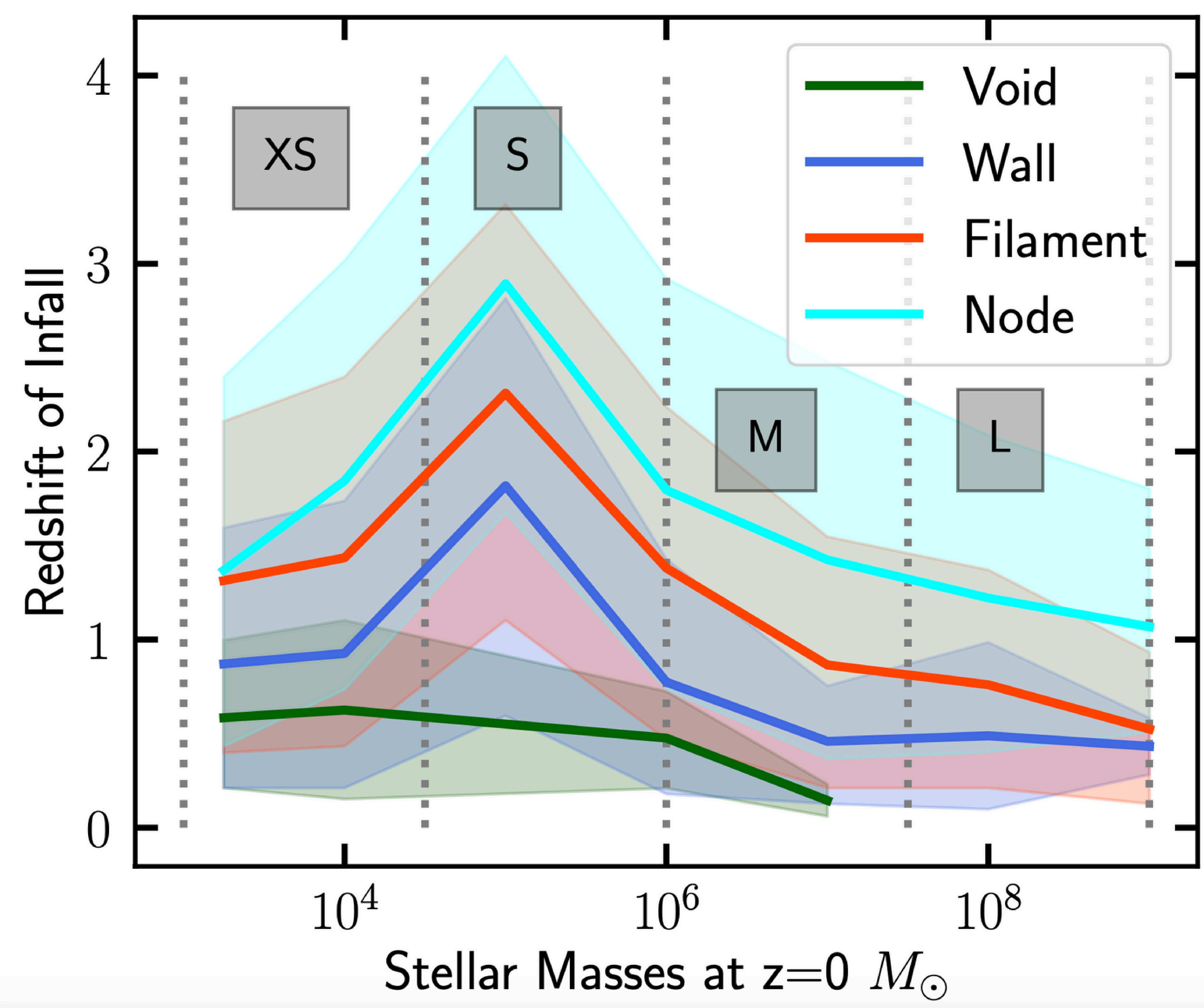
The type of galaxy (ie. satellite or central) has a measurable impact upon galaxy growth. Orphans finish their assembly first, then satellites, then centrals.



Greater trends in satellite galaxies than central galaxies. Satellite trends (1.78 Gyrs t50) > central trends (0.23 Gyrs t50)



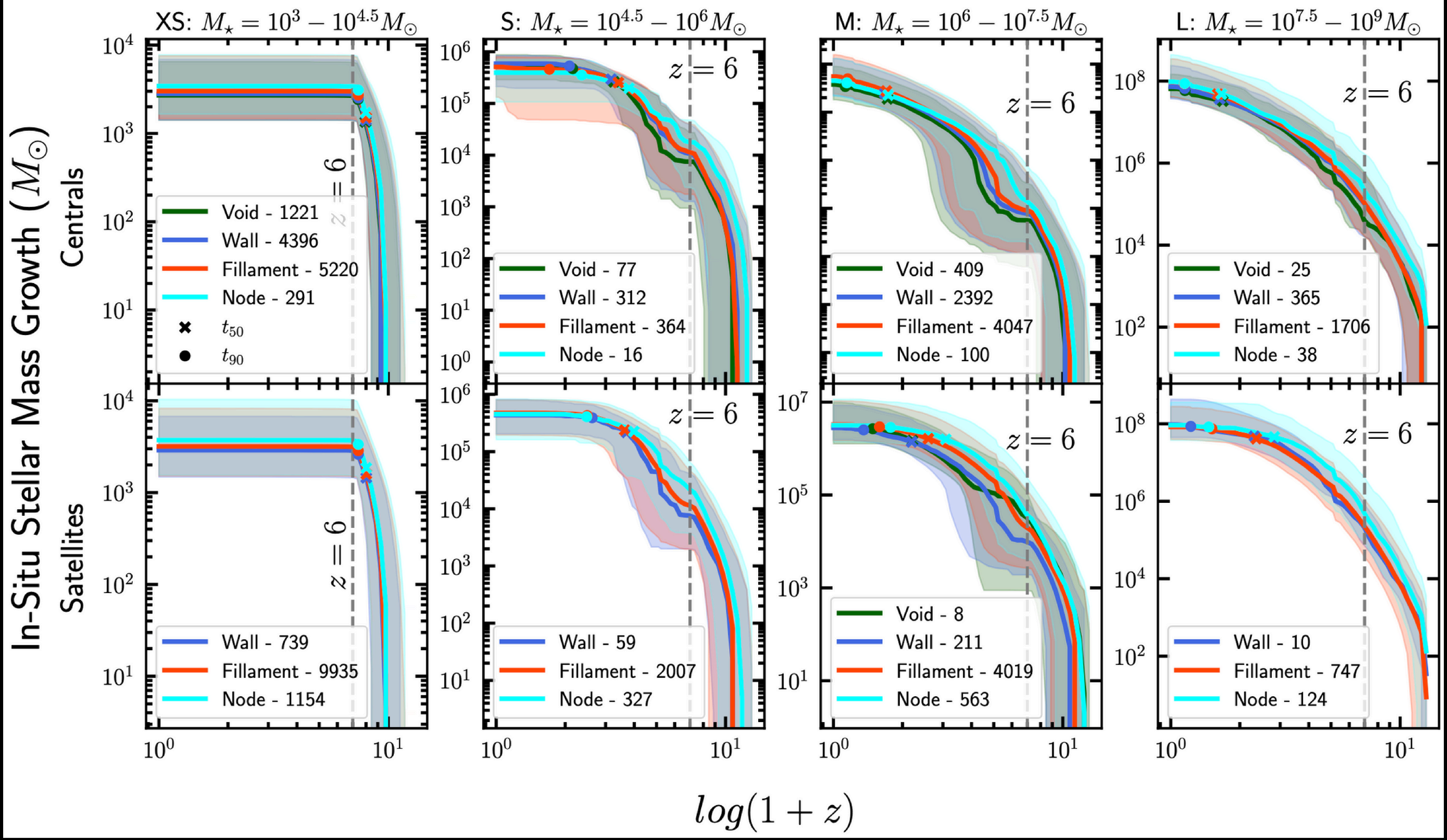
Central trends = 2.1 Gyrs t50, satellite trends = 0.85 Gyrs t50. Central trends in haloes > satellite trends in haloes, halo growth trends in satellites < stellar mass growth trends in satellites



Denser environments produce satellites earlier.

Node satellites (on average) infall at redshift 1.95, void satellites infall at redshift 0.56

Difference of about 5 Gyrs!



Trends in central galaxies are actually driven by average final mass differences.

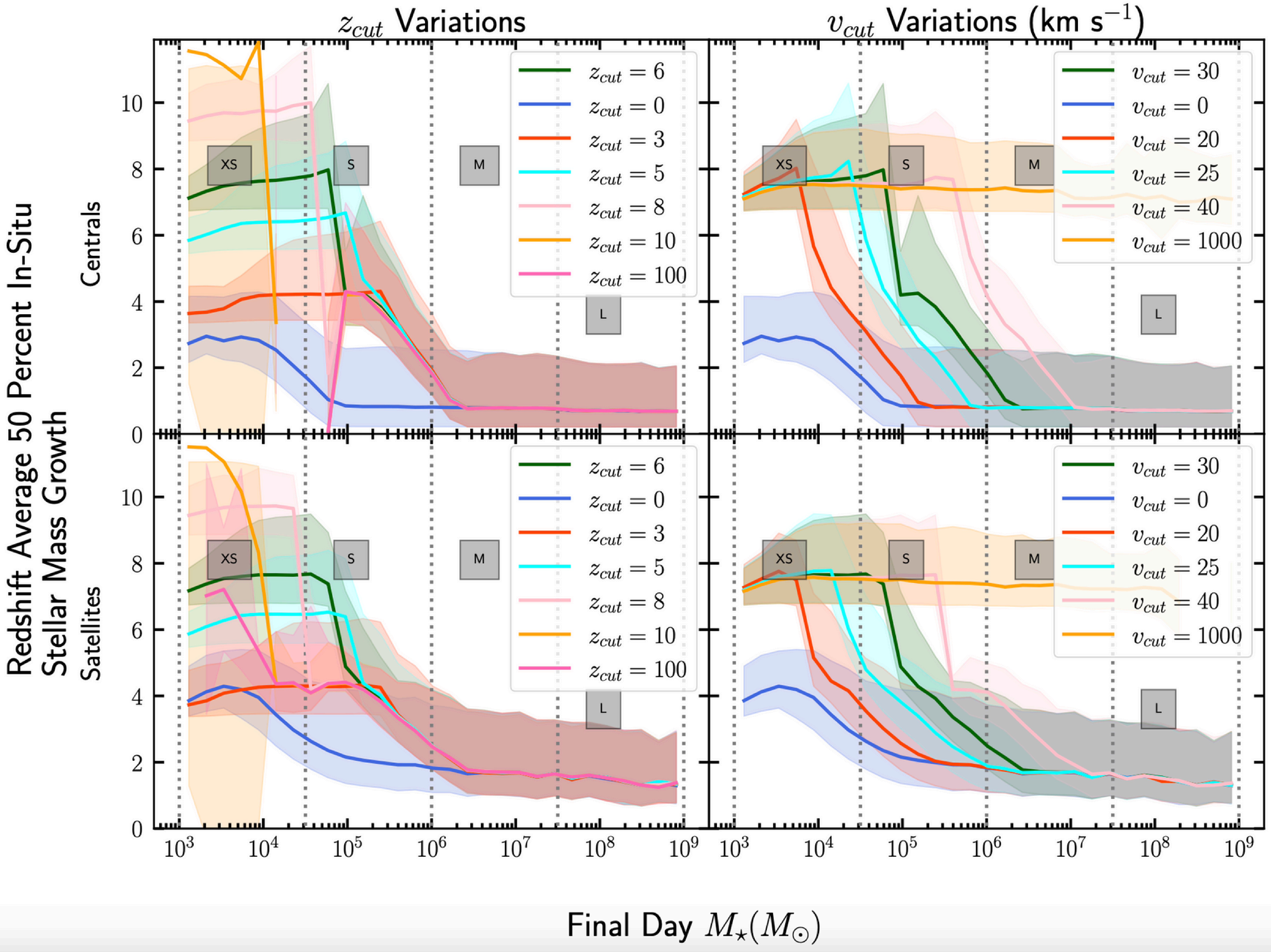
Results summary:

- The large scale structure trends are caused by galaxies becoming satellites at different times depending on their location in the cosmic web. (earlier in denser environments, later in void environments)
- The trends in central galaxies are caused by differences in halo mass assembly.
- Paper coming to Arxiv very very soon!

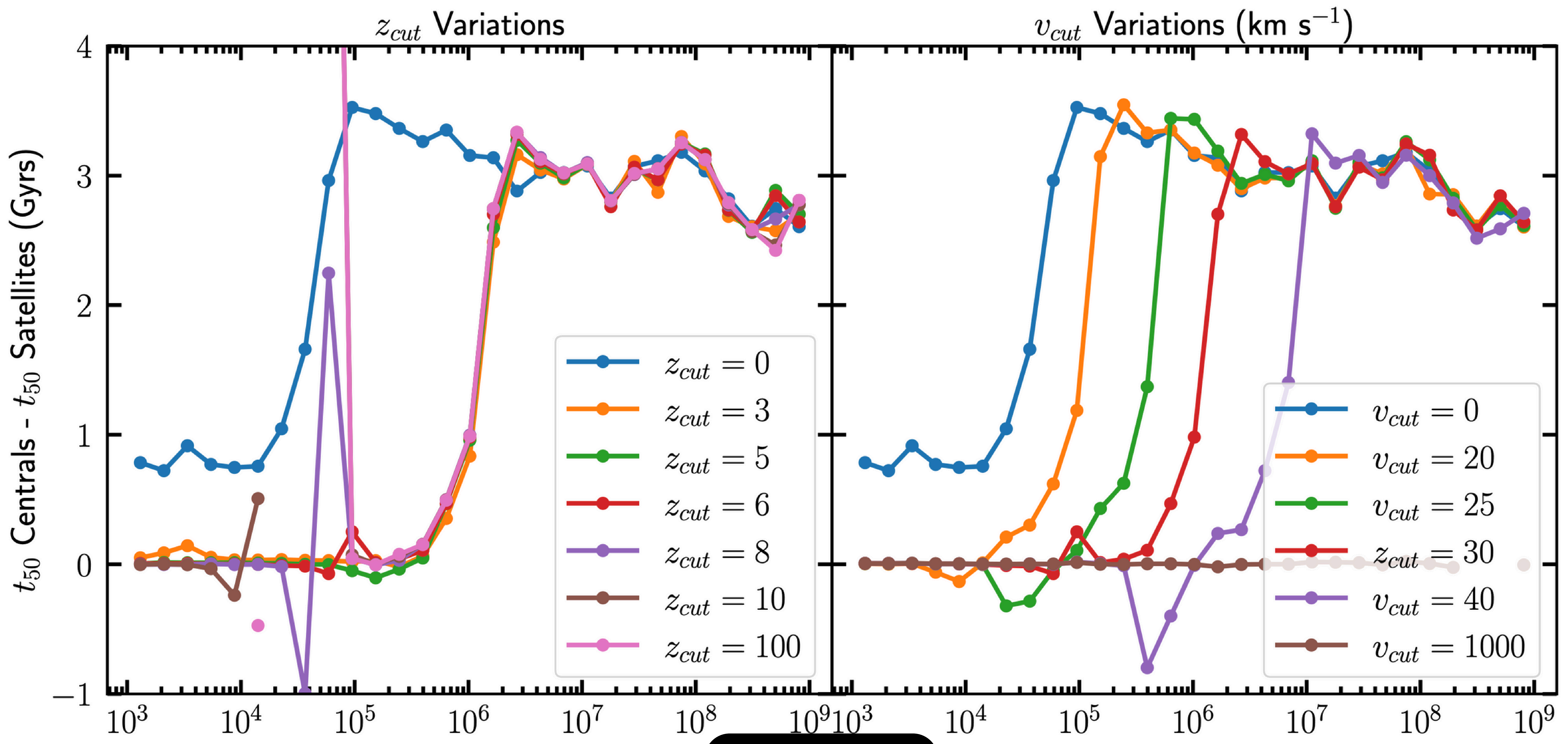
Current Work:

- Looking at the black holes in GALFORM dwarf galaxies.
- Conclusions so far: the black holes in GALFORM dwarf indicate that we are not modelling the growth of black holes in high-mass galaxies correctly, and this is most apparent to the dwarf regime. Growth is too dependent on mergers, and then on hot halo growth, to match observations.

MORE PLOTS



Earlier zcut makes the dip deeper and longer. Higher vcut makes the location of the turnover region change to higher masses.



z_{cut} Variations
v_{cut} Variations (km s^{-1})
t_{50} Centrals - t_{50} Satellites (Gyrs)
4
3
2
1
0
−1
10^3
10^4
10^5
10^6
10^7
10^8
10^9
$z_{cut} = 0$
$z_{cut} = 3$
$z_{cut} = 5$
$z_{cut} = 6$
$z_{cut} = 8$
$z_{cut} = 10$
$z_{cut} = 100$
$v_{cut} = 0$
$v_{cut} = 20$
$v_{cut} = 25$
$z_{cut} = 30$
$v_{cut} = 40$
$v_{cut} = 1000$

Mstars

“so this is just mass assembly bias?”

Yes. Kinda. For satellite infall.

Come see my poster to do with Dwarf Galaxy Black Holes in GALFORM!!!